Measurement of RF Interference from a PL161 Bluetooth Low Energy Transceiver

For	Caterpillar, Inc. Rt. 29 Bldg. AC Dock 29 AC 6132 Mossville, IL 61552
P.O. Number	JBJ 18384 and JBL 23785
Date Received	September 23, 2016
Date Tested	September 23, 2016 through January 19, 2017
Test Personnel	Mark Longinotti
Specification	FCC "Code of Federal Regulations" Title 47, Part 15, Subpart C, Sections 15.207 and 15.247 for Digital Modulation Intentional Radiators Operating within the band 2400-2483.5MHz FCC “Code of Federal Regulations” Title 47, Part15, Subpart 15B, Section 15.107 and 15.109 for Receivers Innovation, Science, and Economic Development Canada RSS-247 Innovation, Science, and Economic Development Canada RSS-GEN
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REVISION HISTORY

Revision	Date	Description
—	25 Jan 2017	Initial release

Measurement of RF Emissions from a Bluetooth Low Energy Transceiver, Part No. PL161

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. PL161 (hereinafter referred to as the EUT). Serial No. AK0W00F02 was assigned to the EUT used for all case spurious radiated emissions tests. Serial No. DJOW009302 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 8, 2016

- Innovation, Science, and Economic Development Canada RSS-247, Issue 1, May 2015, "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. PL161. 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 20dB 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 713.4kHz which is greater than minimum allowable 6dB bandwidth requirement of 500kHz for systems using digital modulation techniques. The 99% bandwidth was measured to be 1.1MHz.

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 20dB 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 0.0016W (2.05dBm) 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 the 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 5.0dBm or 0.0032 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 closet to the limit (worst case) occurred at 7326MHz. The emissions level at this frequency was 3.8dB 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 EUT was set up inside the test chamber on a non-conductive stand.
2) A broadband measuring antenna was placed at a test distance of 3 meters from the EUT.
3) The EUT was set to transmit continuously at the channel closest to the low band-edge.
4) The EUT was maximized for worst case emissions at the measuring antenna. The maximum meter reading was recorded.
5) 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) ≥ 1% of the span.
    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

Pages 63 through 65 show the radiated band-edge compliance results. As can be seen from these plots, the radiated 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 20dB 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): 3kHz ≤ RBW ≤ 100kHz
    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. PL161, 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. PL161, 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	3/2/2016	3/2/2017
APW3	PREAMPLIFIER	PLANAR ELECTRONICS	PE2-35-120-5R0-10-12	PL2924	1GHZ-20GHZ	9/28/2016	9/28/2017
CDU3	LAPTOP COMPUTER						
CDY0	WORKSTATION	ELITE	WORKSTATION		WINDOWS 7	N/A	
CPS1	COMPUTER		8470P	CNU3119YTX			
GSE0	SIGNAL GENERATOR (40GHZ)	ROHDE & SCHWARZ	SMB100A	175137	100KHZ-40GHZ	3/17/2016	3/17/2017
NHG0	STANDARD GAIN HORN ANTENNA	NARDA	638	---	18-26.5GHZ	NOTE 1	
NTA3	BILOG ANTENNA	TESEQ	6112D	32853	25-1000MHz	3/23/2016	3/23/2017
NWI0	RIDGED WAVE GUIDE	AEL	H1498	153	2-18GHZ	1/31/2015	1/31/2017
NWQ1	DOUBLE RIDGED WAVEGUIDE ANTENNA	ETS-LINDGREN	3117	66655	1GHZ-18GHZ	4/4/2016	4/4/2018
RBA1	EMI TEST RECEIVER	ROHDE & SCHWARZ	ESIB26	100146	20HZ-26.5GHZ	2/12/2016	2/12/2017
RBB0	EMI TEST RECEIVER 20HZ TO 40 GHZ.	ROHDE & SCHWARZ	ESIB40	100250	20 HZ TO 40GHZ	2/16/2016	2/16/2017
RBG0	EMI ANALYZER	ROHDE & SCHWARZ	ESW500	101533	10HZ-44GHZ	11/10/2016	11/10/2017
T2SE	20DB 25W ATTENUATOR	WEINSCHEL	46-20-34	CD5019	DC-18GHZ	7/7/2016	7/7/2018
XOB2	ADAPTER	HEWLETT PACKARD	K281C,012	09407	18-26.5GHZ	NOTE 1	
XPR0	HIGH PASS FILTER	K&L MICROWAVE	11SH10-4800/X20000	001	4.8-20GHZ	9/14/2016	9/14/2017

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.

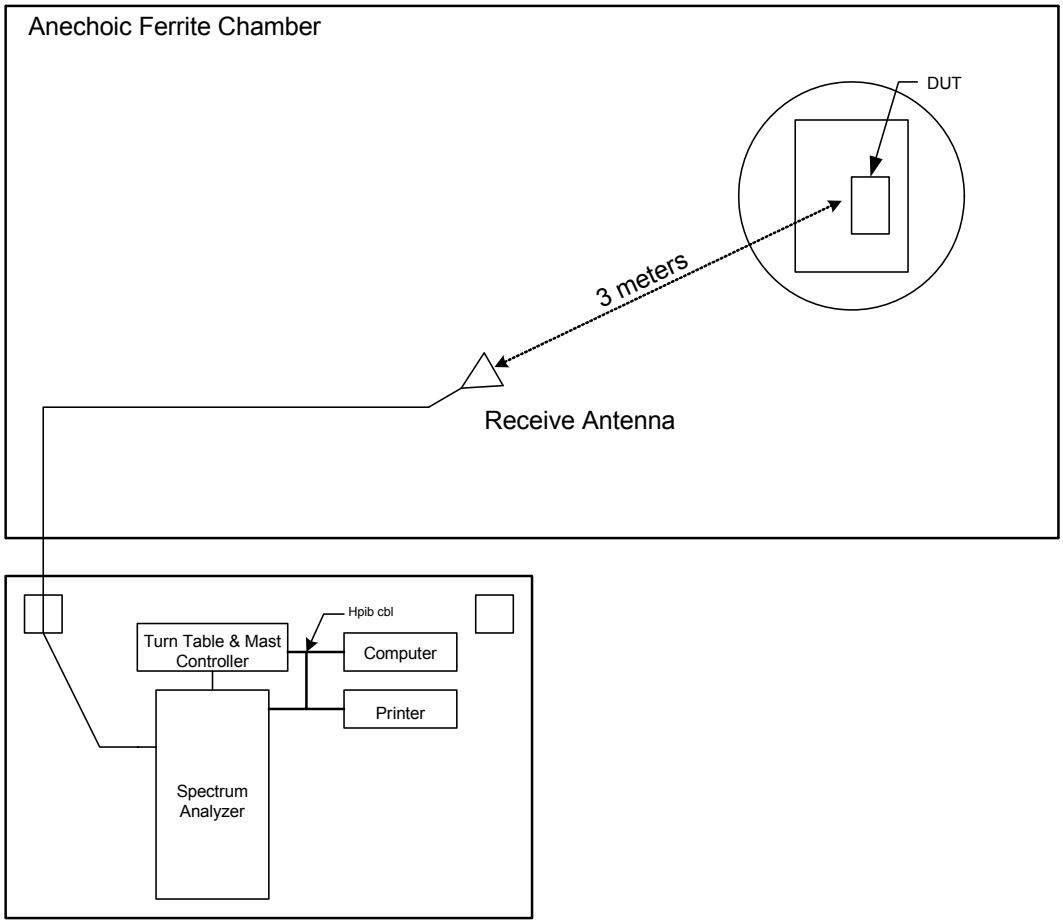


FIGURE 1 BLOCKDIAGRAM OF TEST SETUP

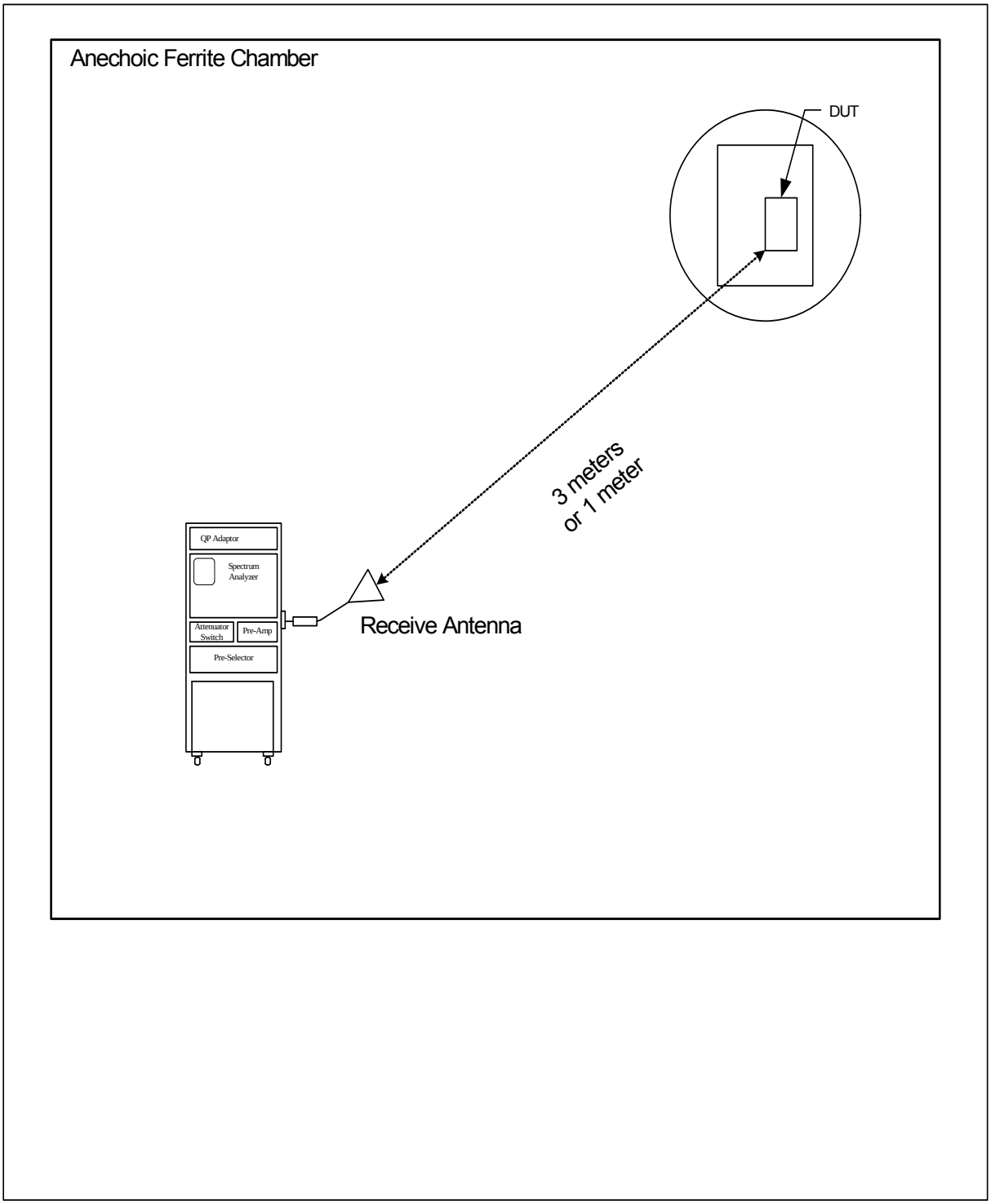


Figure 2: BLOCK DIAGRAM OF TEST SETUP FOR RADIATED EMISSIONS ABOVE 18GHZ

Figure 3

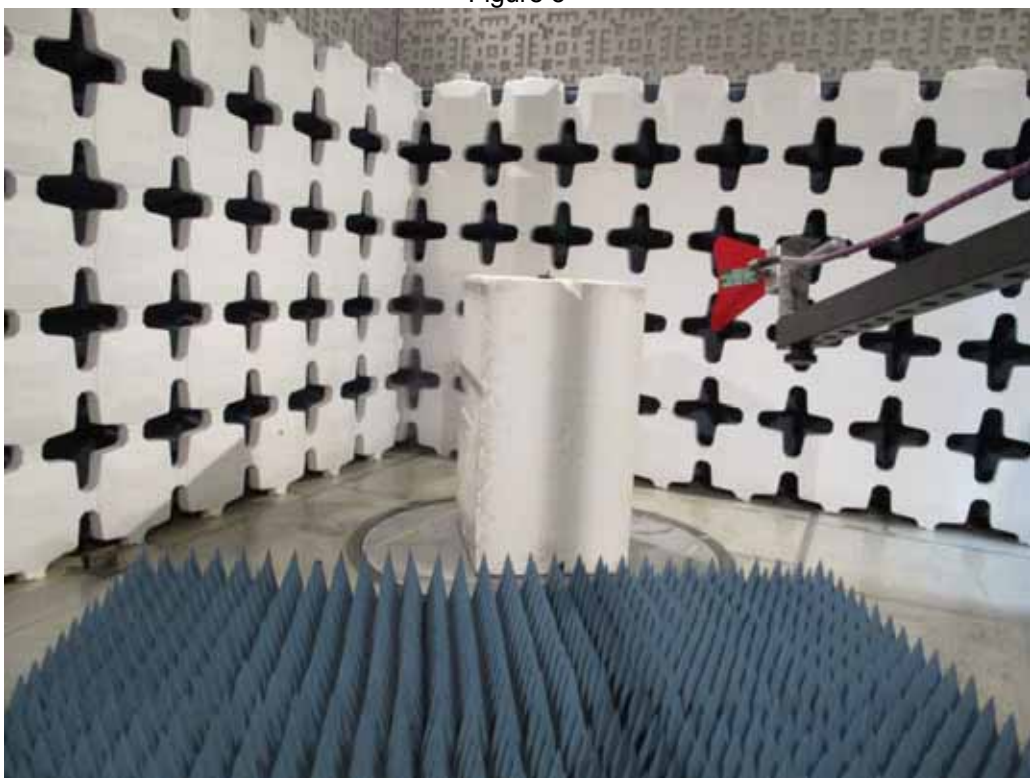
Photograph of EUT

Figure 4

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

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

Figure 5



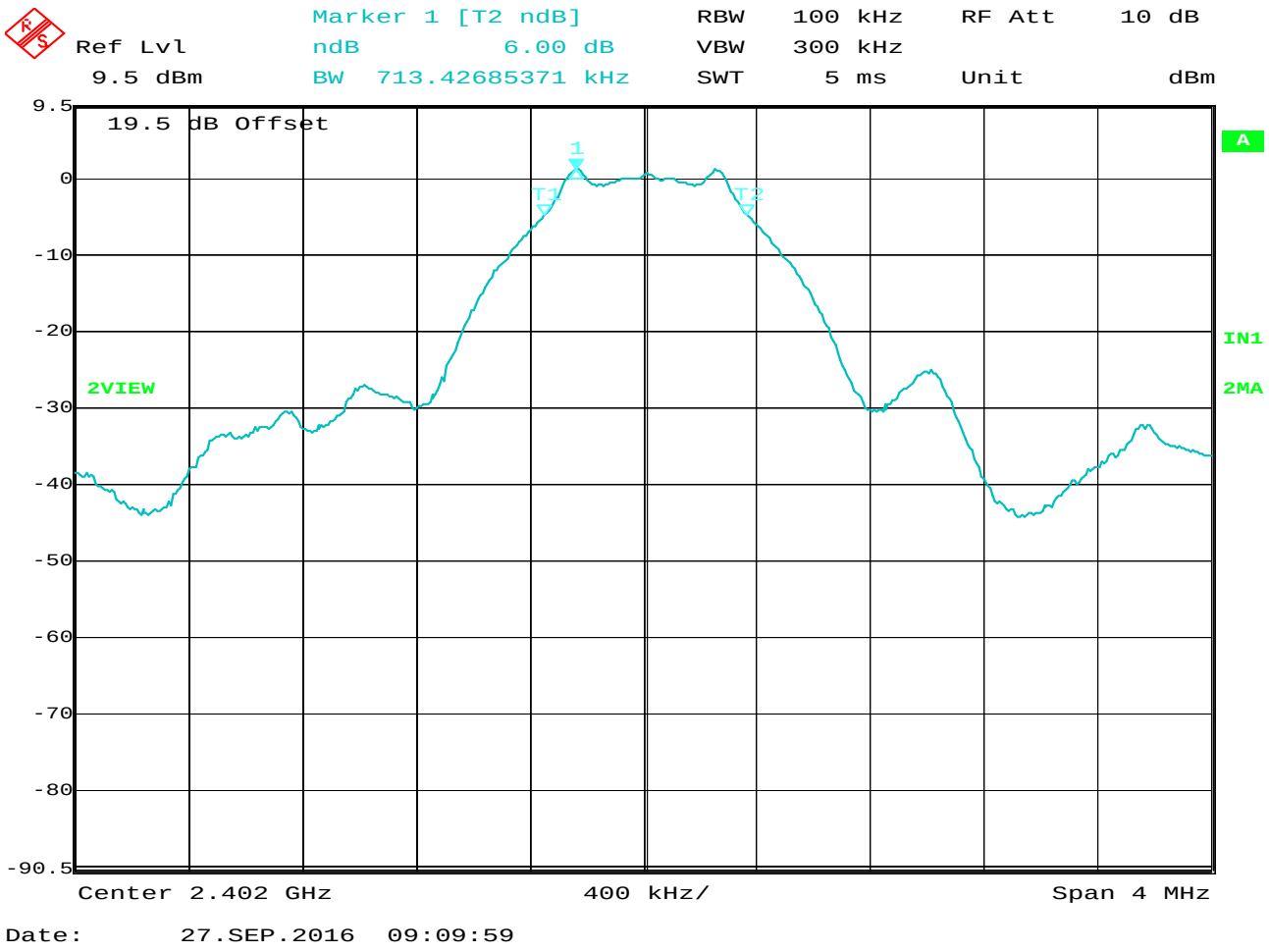
Test Setup for Radiated Emissions – 1GHz to 18GHz, Horizontal Polarization

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

Figure 6

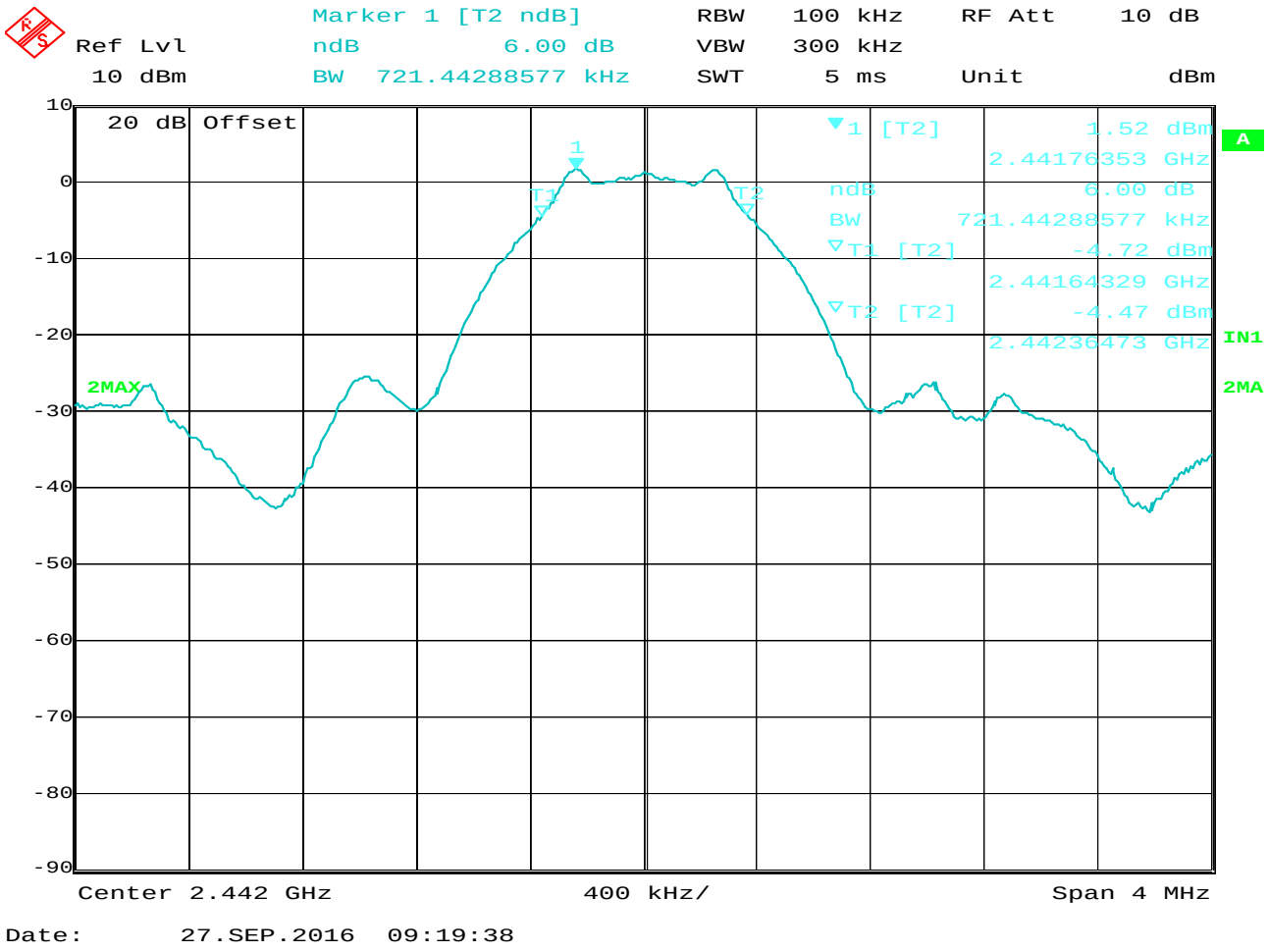
Test Setup for Radiated Emissions – 18GHz to 25GHz, Horizontal Polarization

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



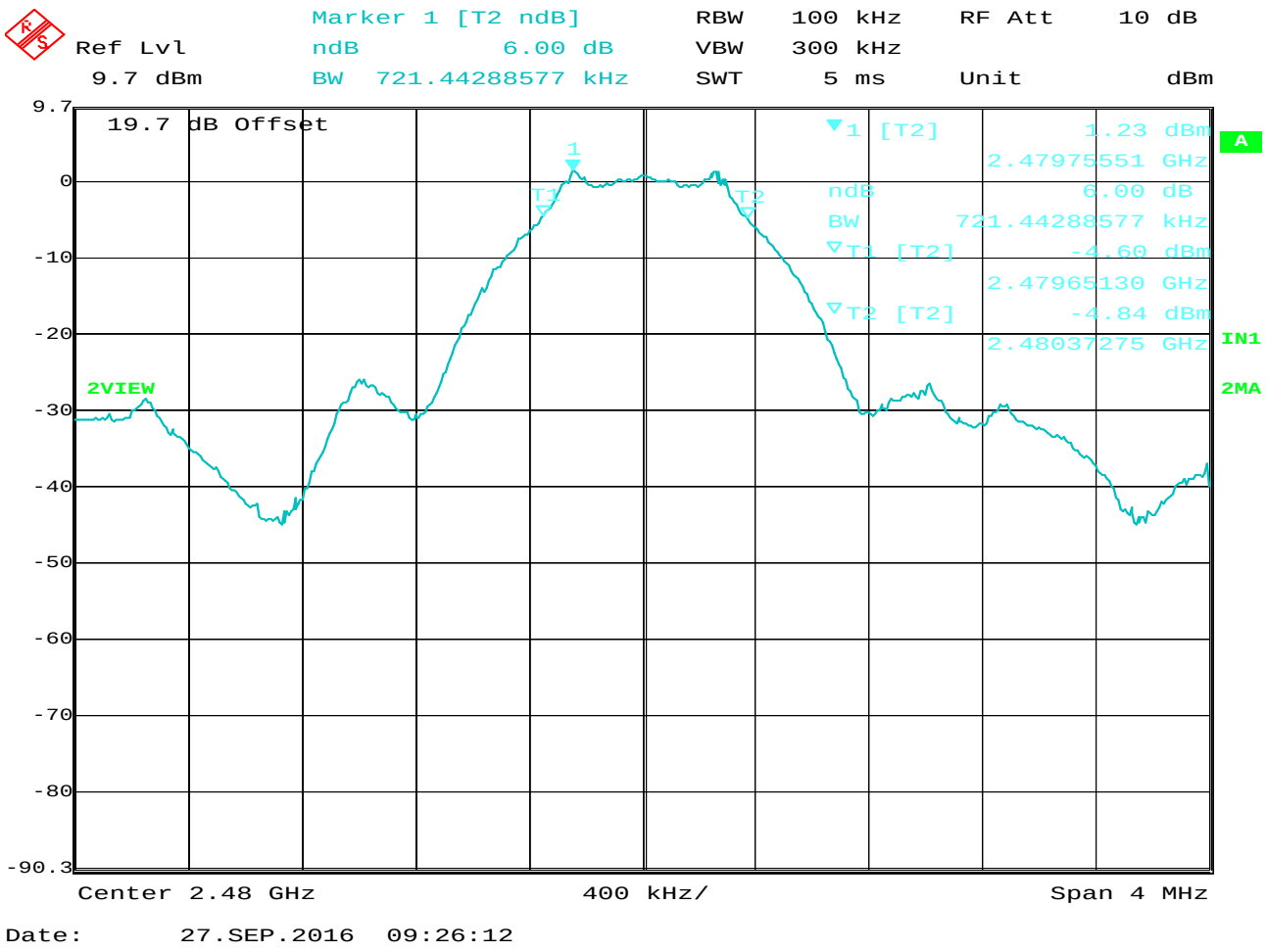
FCC 15.247 6dB Bandwidth

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
NOTES	:	6dB bandwidth = 713.43kHz
EQUIPMENT USED	:	RBA1, T2SE



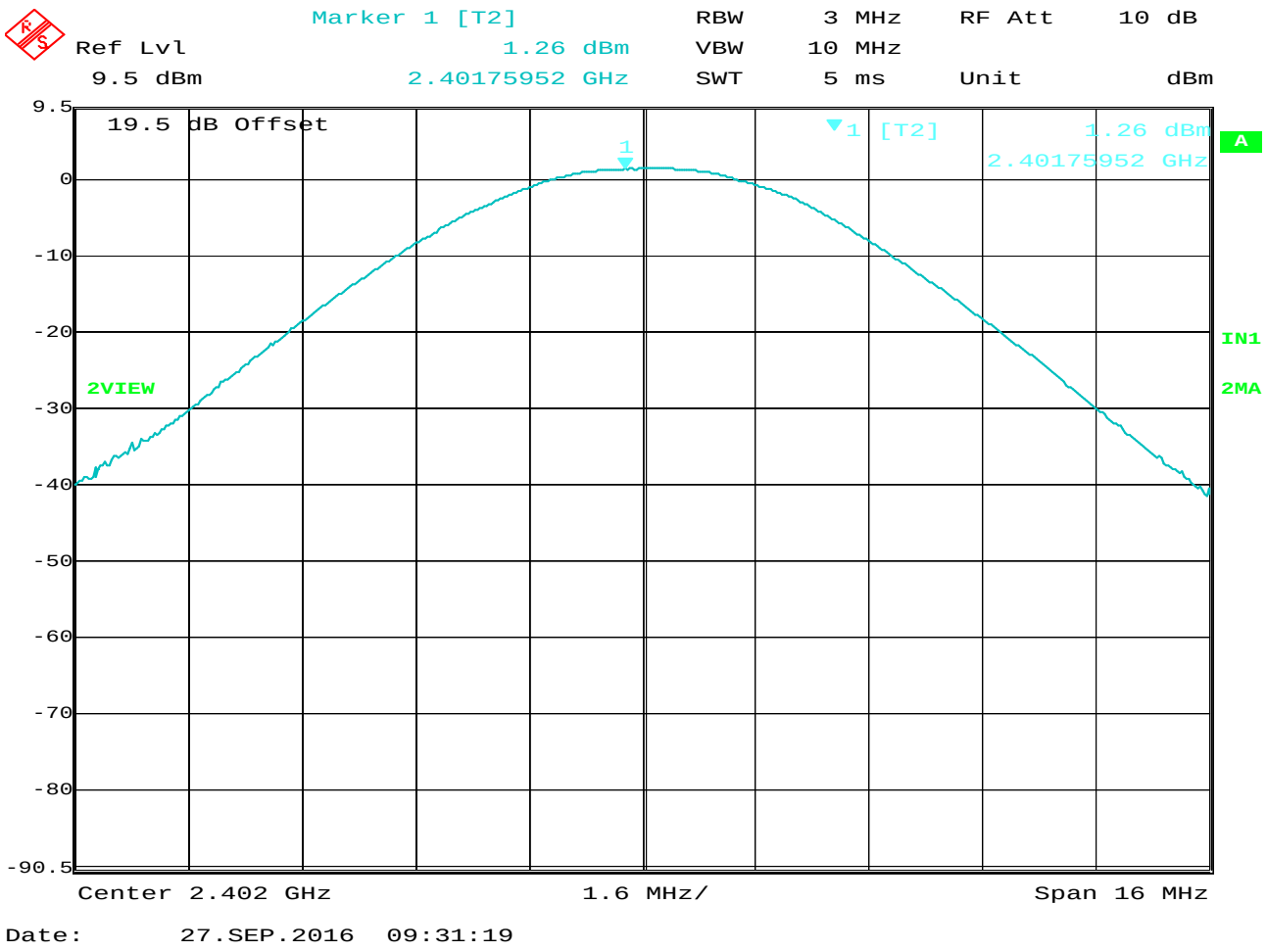
FCC 15.247 6dB Bandwidth

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
NOTES	:	6dB bandwidth = 713.4kHz
EQUIPMENT USED	:	RBA1, T2SE



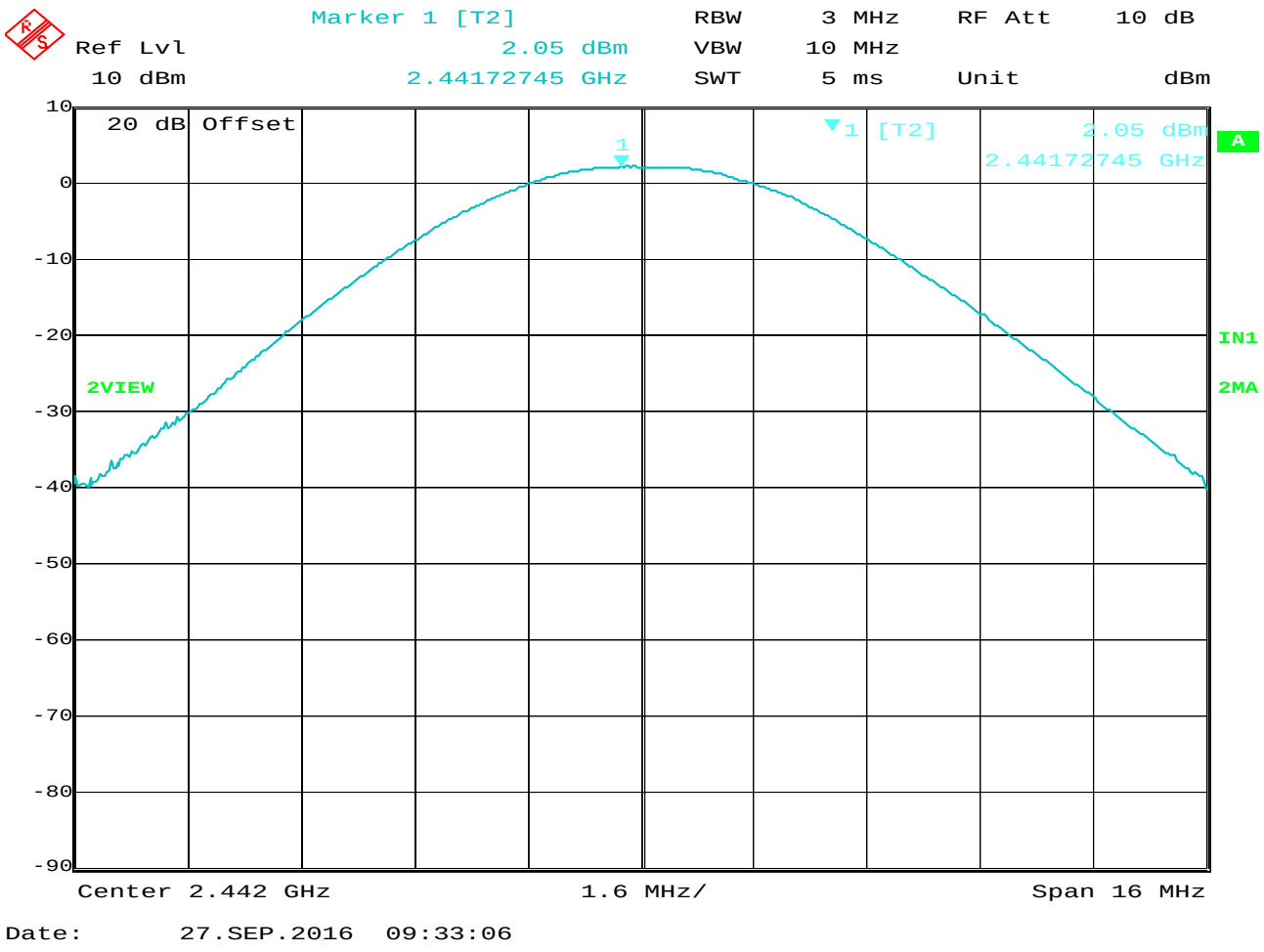
FCC 15.247 6dB Bandwidth

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
NOTES	:	6dB bandwidth = 721.4kHz
EQUIPMENT USED	:	RBA1, T2SE



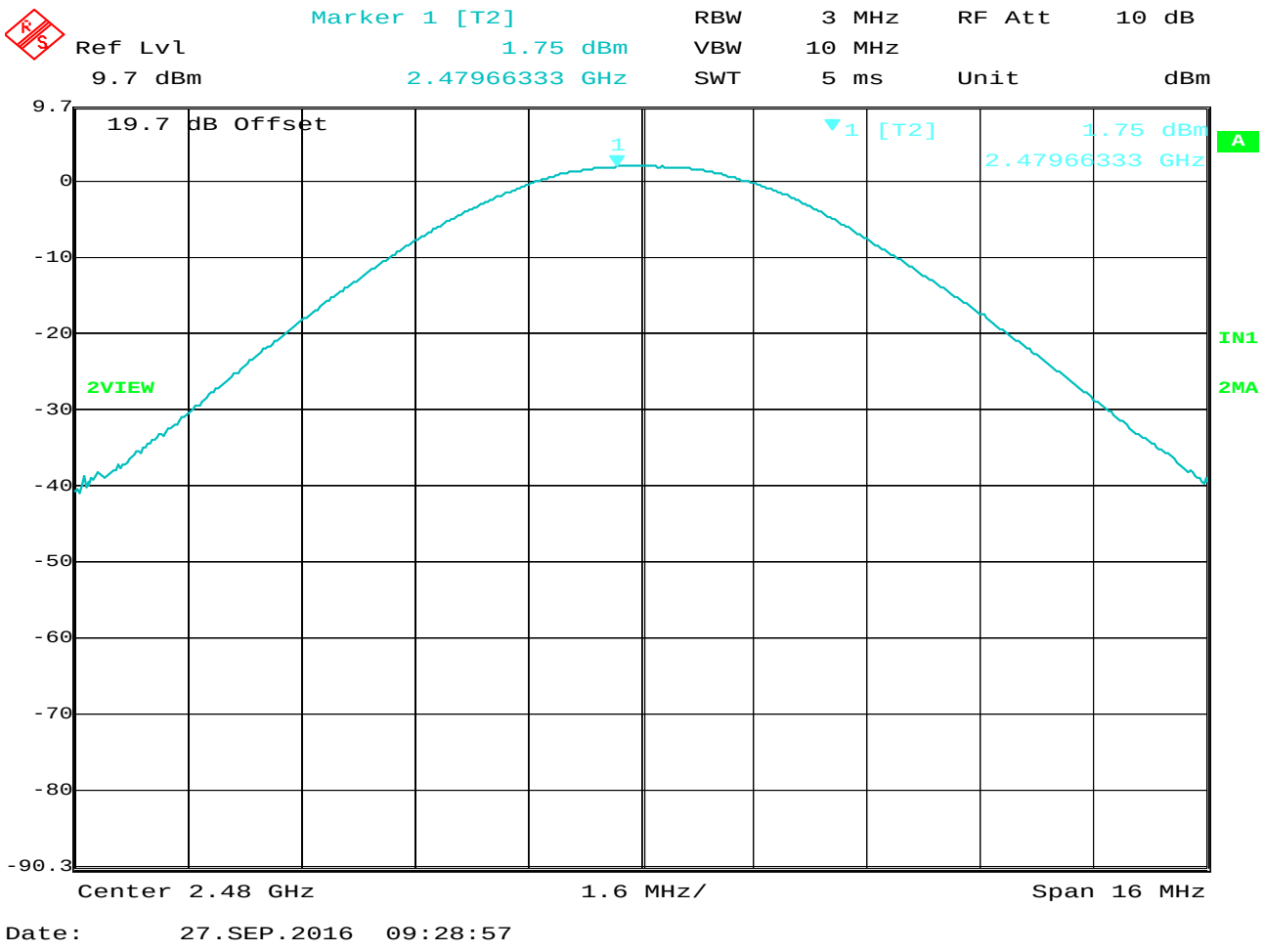
FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
NOTES	:	Antenna Conducted Output Power = 1.26dBm
EQUIPMENT USED	:	RBA1, T2SE



FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
NOTES	:	Antenna Conducted Output Power = 2.05dBm
EQUIPMENT USED	:	RBA1, T2SE



FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
NOTES	:	Antenna Conducted Output Power = 1.75dBm
EQUIPMENT USED	:	RBA1, T2SE

Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : January 17, 2017 and January 18, 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	64.3	-2.0	6.4	2.7	1.6	36.0	-34.4
2402.00	V	63.2	1.4	6.4	2.7	5.0	36.0	-31.0

EIRP = Sig. Gen. Reading (dBm) + Antenna Gain (dB) – Cable Loss (dB)

Checked By: MARK E. LONGINOTTI

Mark E. Longinotti

Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : January 17, 2017 and January 18, 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	59.7	-2.2	6.5	2.8	1.5	36.0	-34.5
2442.00	V	57.9	-3.4	6.5	2.8	0.3	36.0	-35.7

EIRP = Sig. Gen. Reading (dBm) + Antenna Gain (dB) – Cable Loss (dB)

MARK E. LONGINOTTI

Mark E. Longinotti

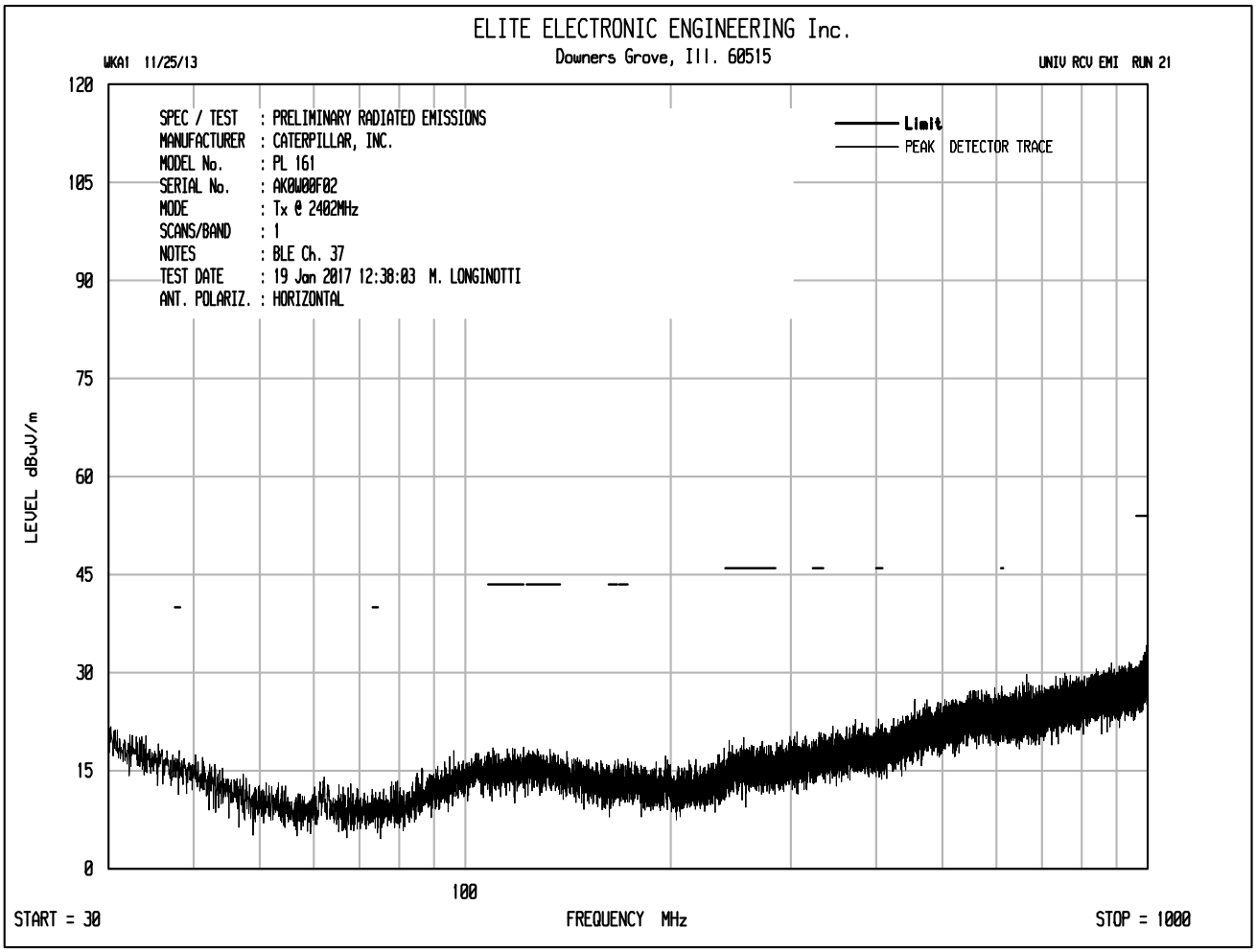
Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : January 17, 2017 and January 18, 2017
Test Distance :3 meters
Notes :

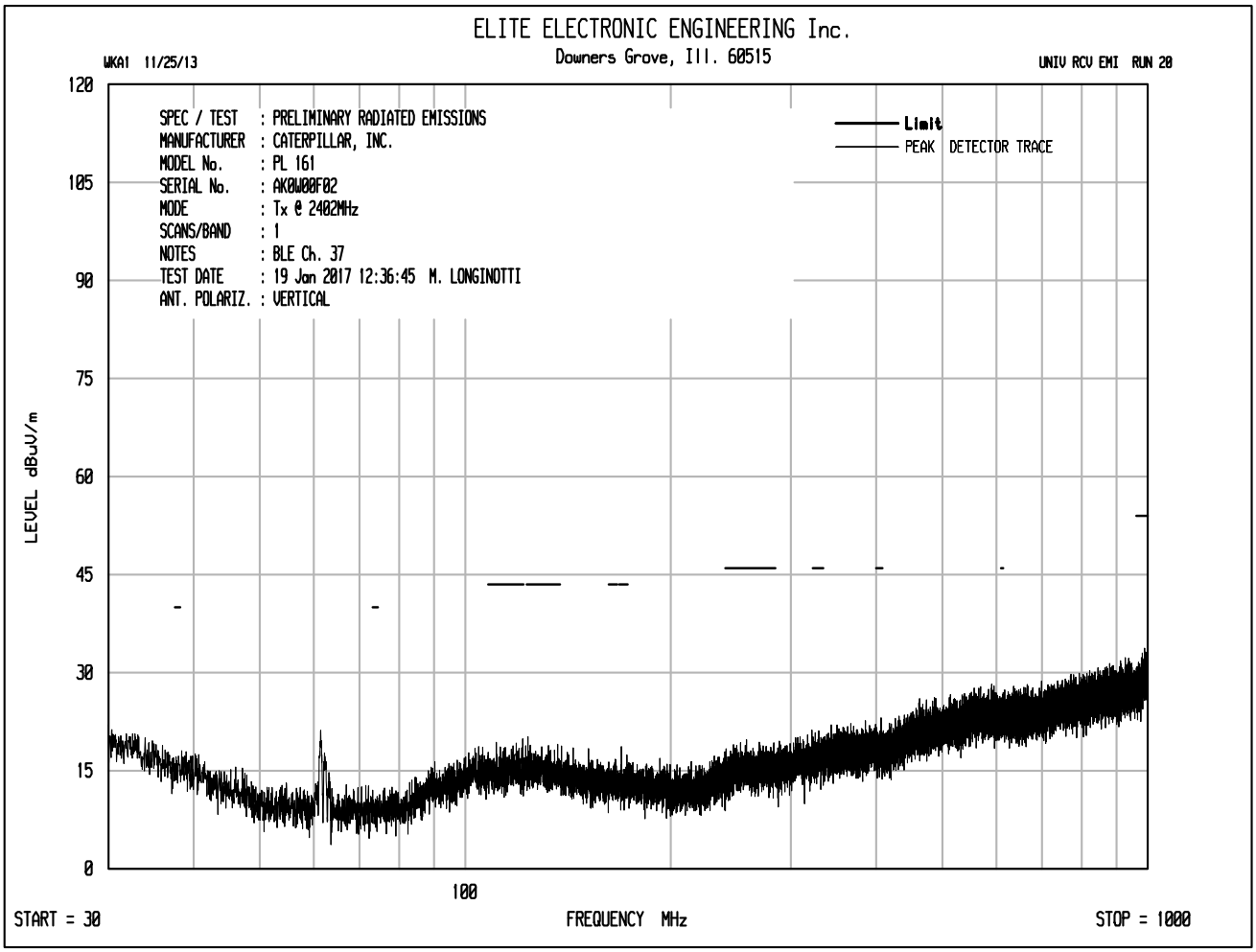
Freq. (MHz)	Ant Pol	Wide BW Meter Reading (dBuV)	Matched Sig. Gen. Reading (dBm)	Equivalent Antenna Gain (dB)	Cable Loss (dB)	EIRP (dBm)	Limit (dBm)	Margin (dB)
2480.00	H	55.7	-6.2	6.6	2.8	-2.4	36.0	-38.4
2480.00	V	54.3	-7.8	6.6	2.8	-4.0	36.0	-40.0

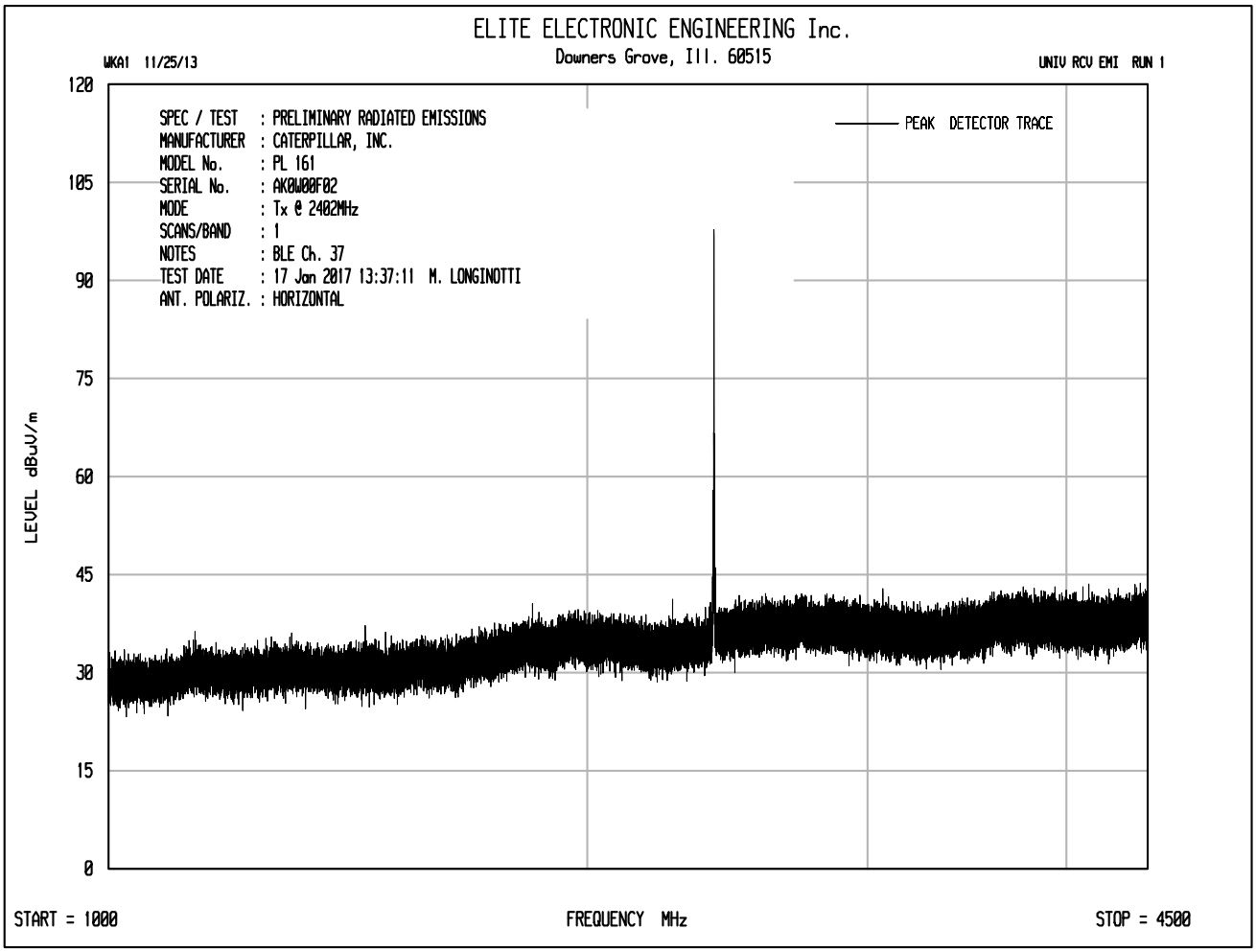
EIRP = Sig. Gen. Reading (dBm) + Antenna Gain (dB) – Cable Loss (dB)

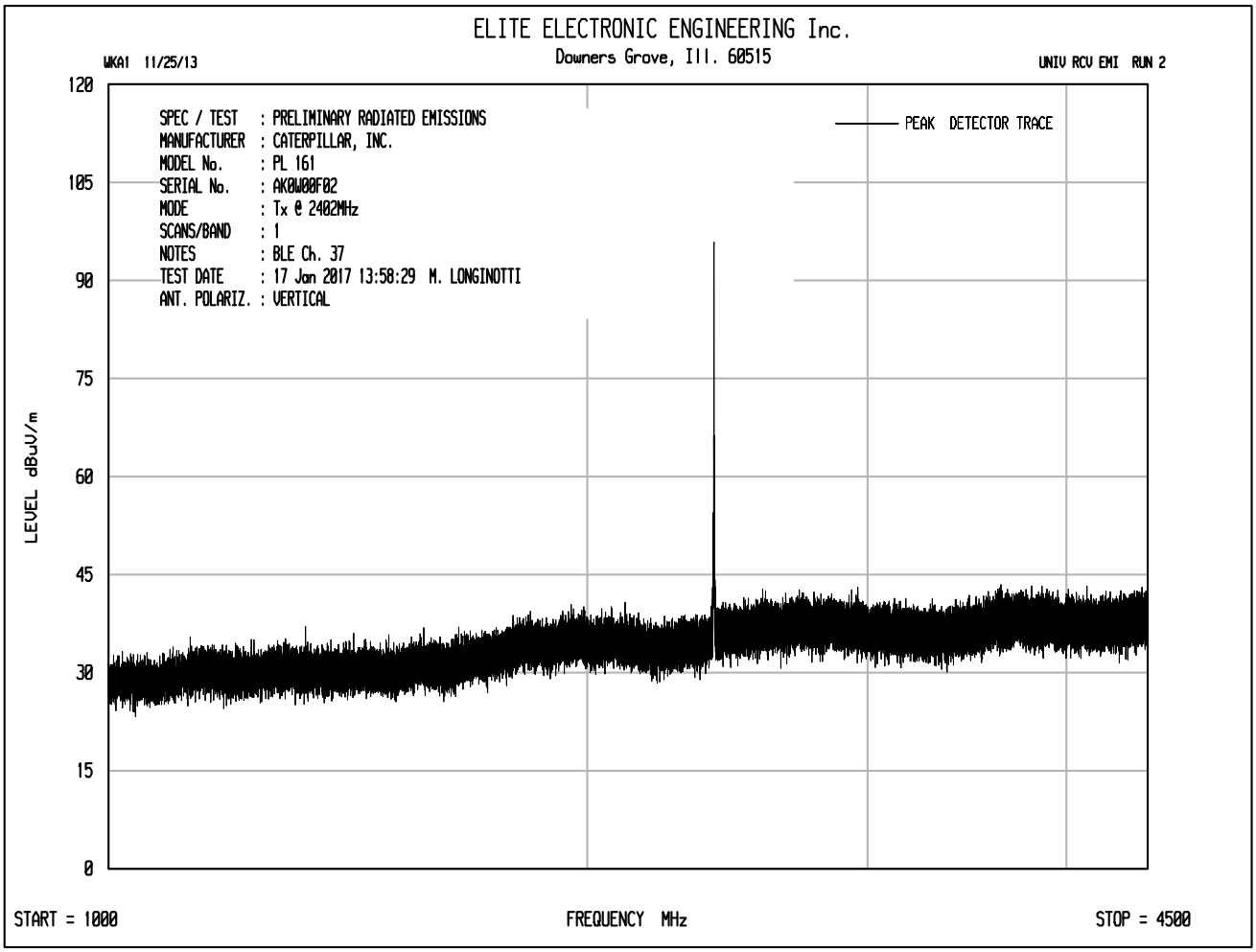
Checked By: MARK E. LONGINOTTI

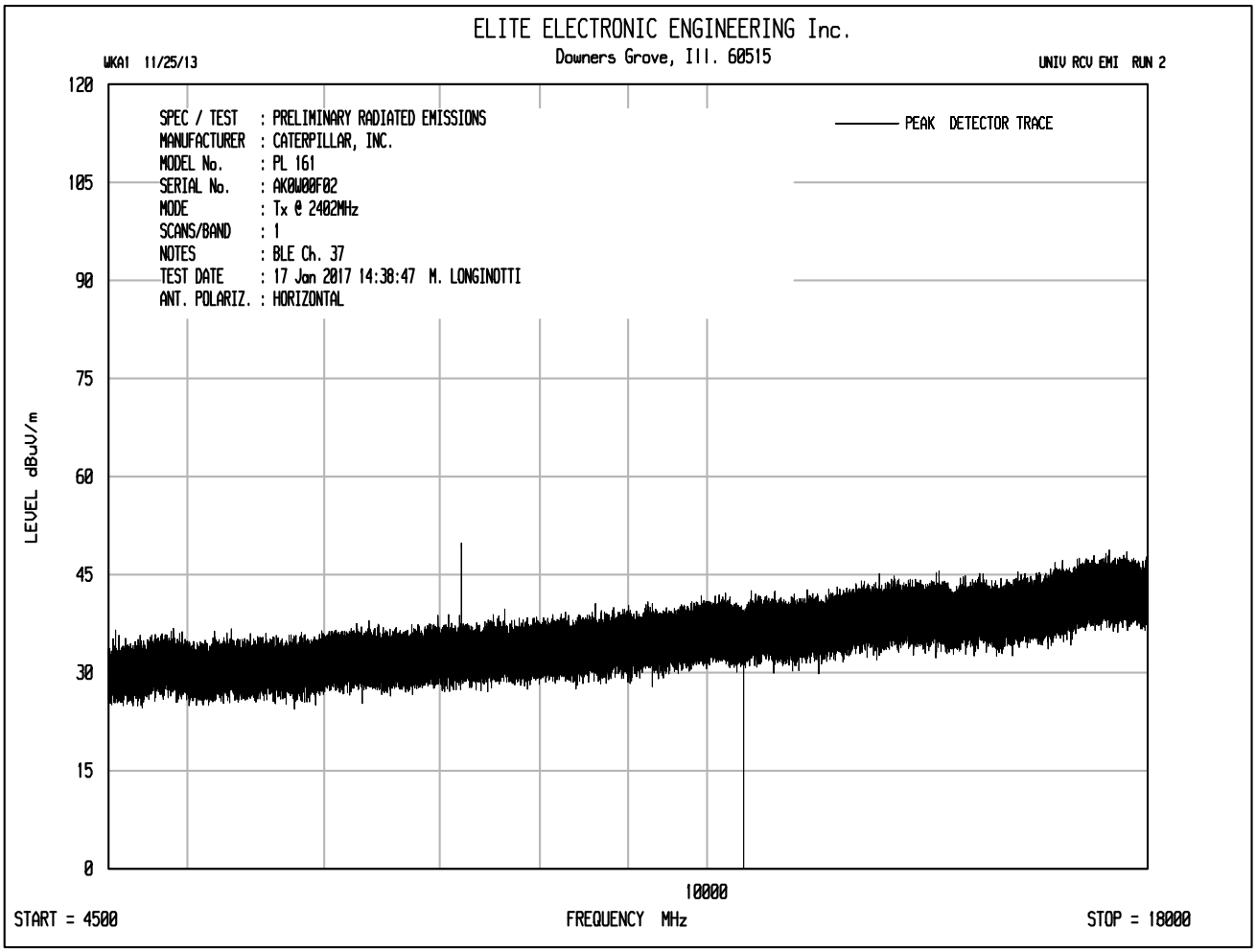
Mark E. Longinotti

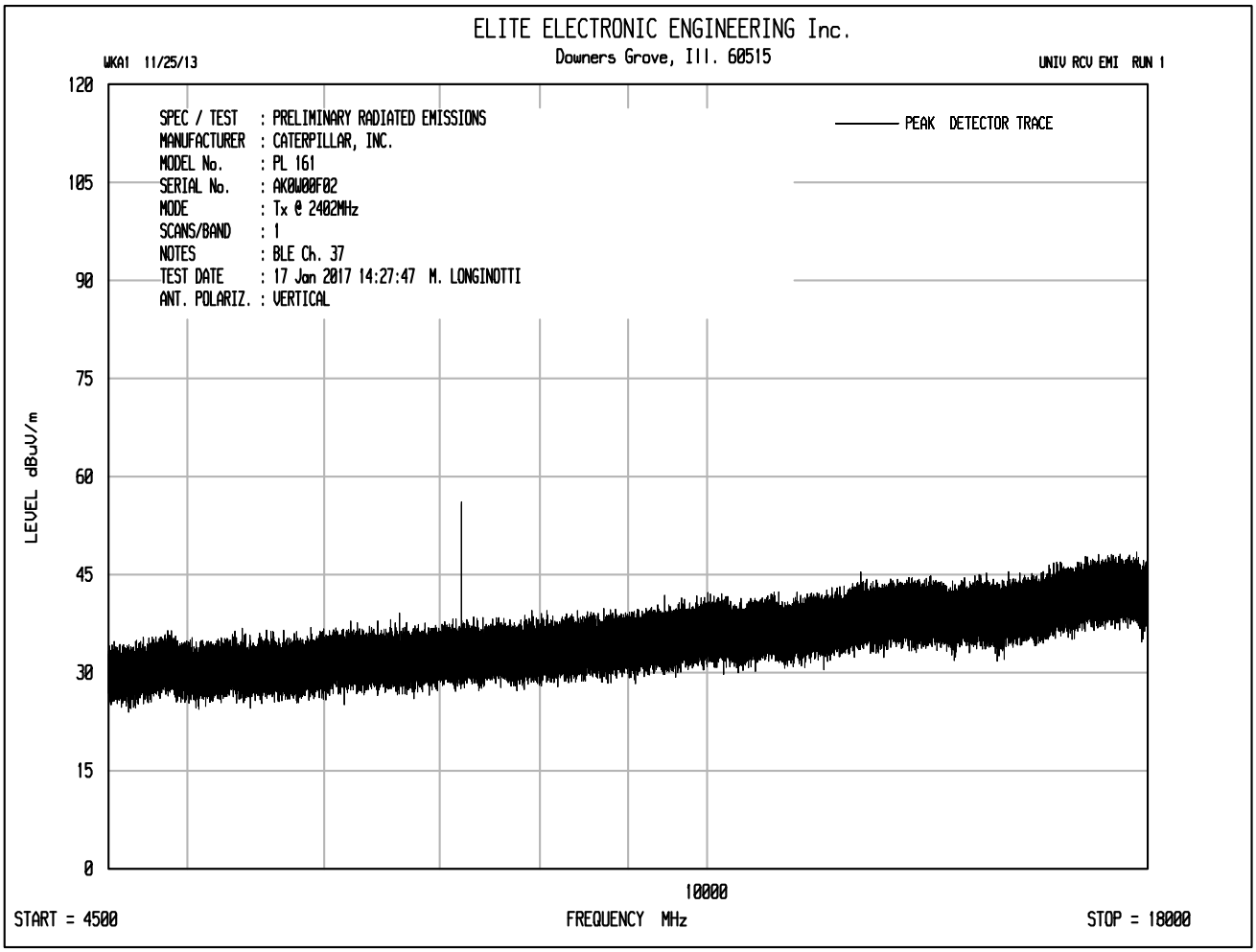

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 21
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 19 Jan 2017 12:38:03 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

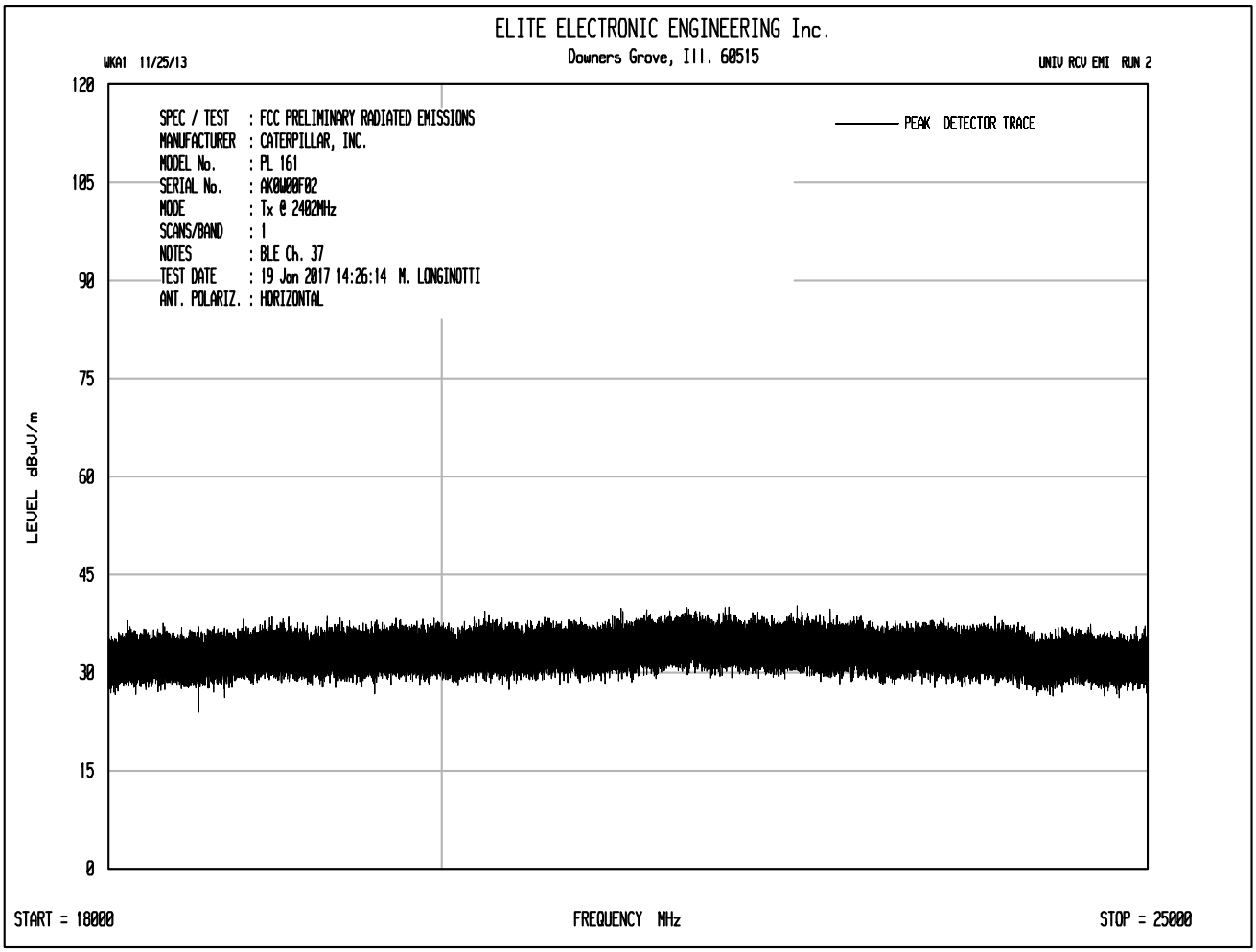

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 20
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 19 Jan 2017 12:36:45 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

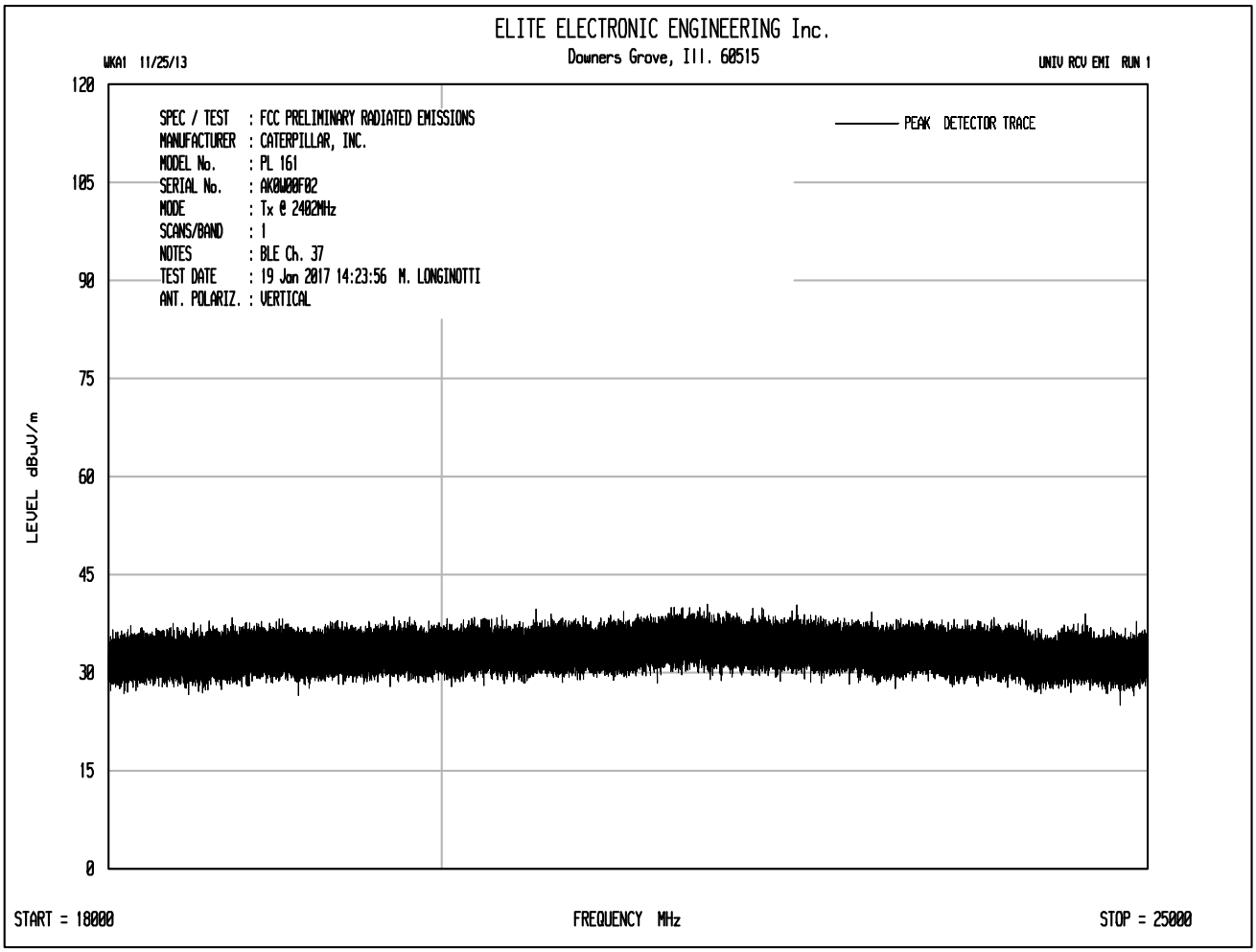

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 1
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 17 Jan 2017 13:37:11 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500

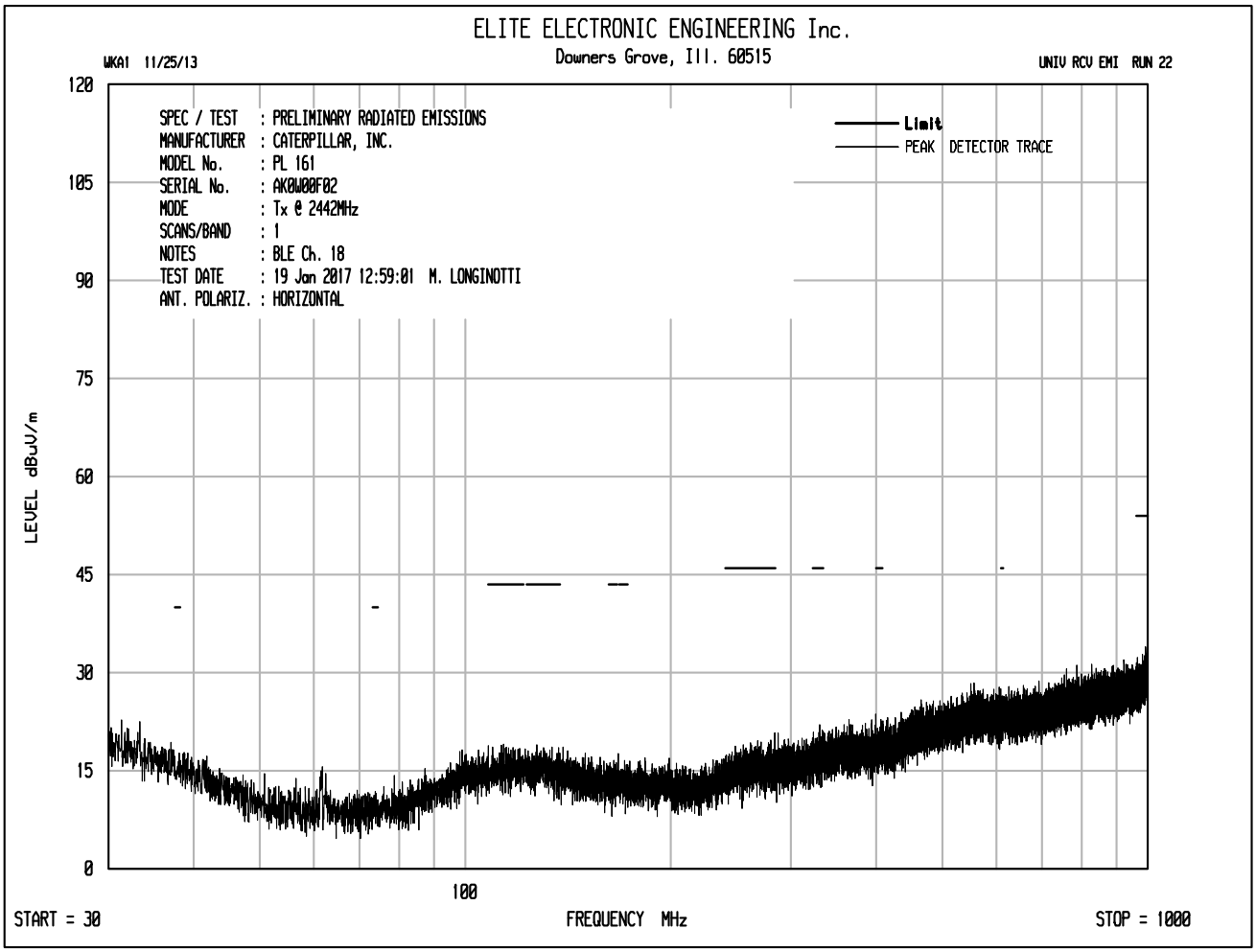

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 2
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 17 Jan 2017 13:58:29 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500

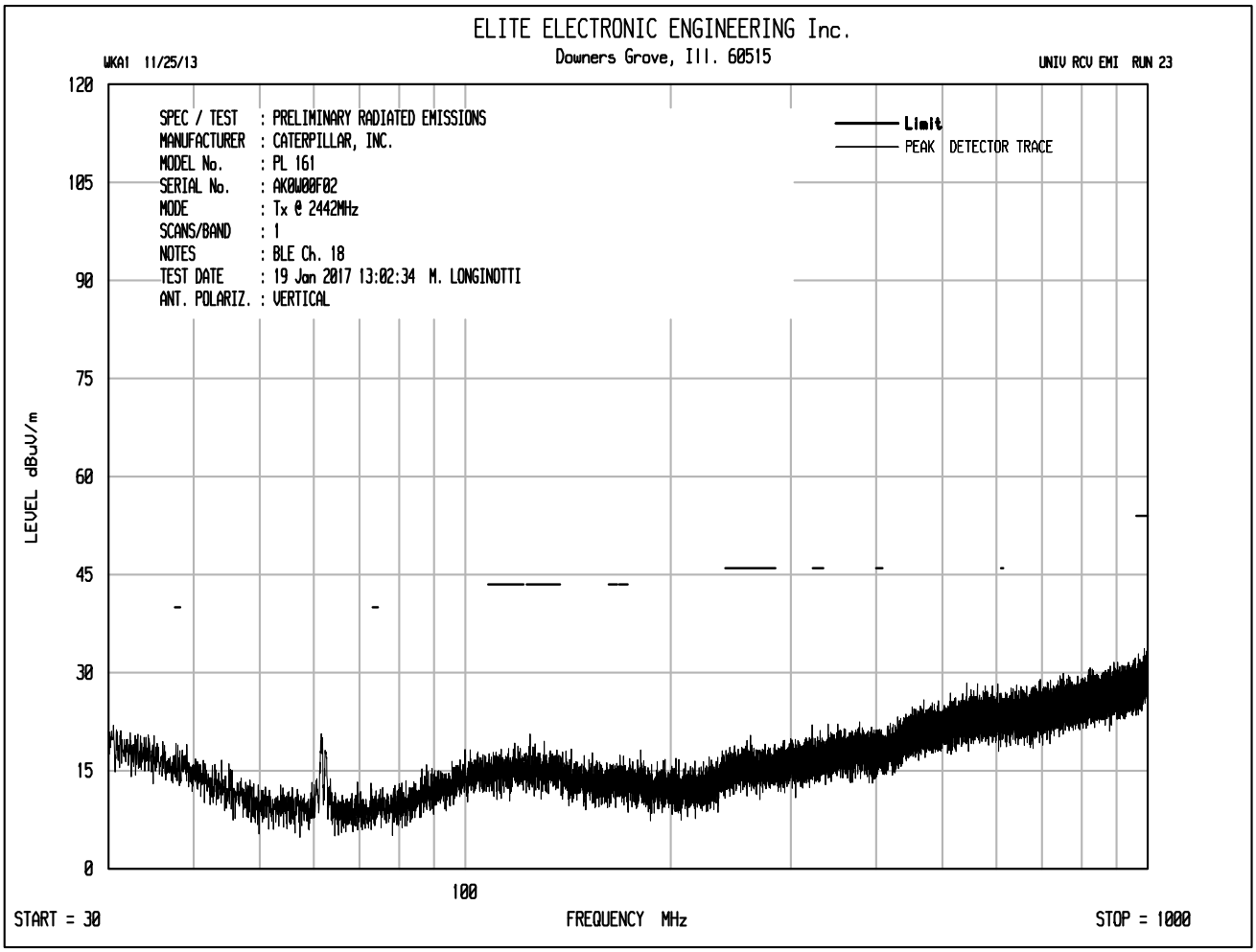

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 2
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 17 Jan 2017 14:38:47 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000

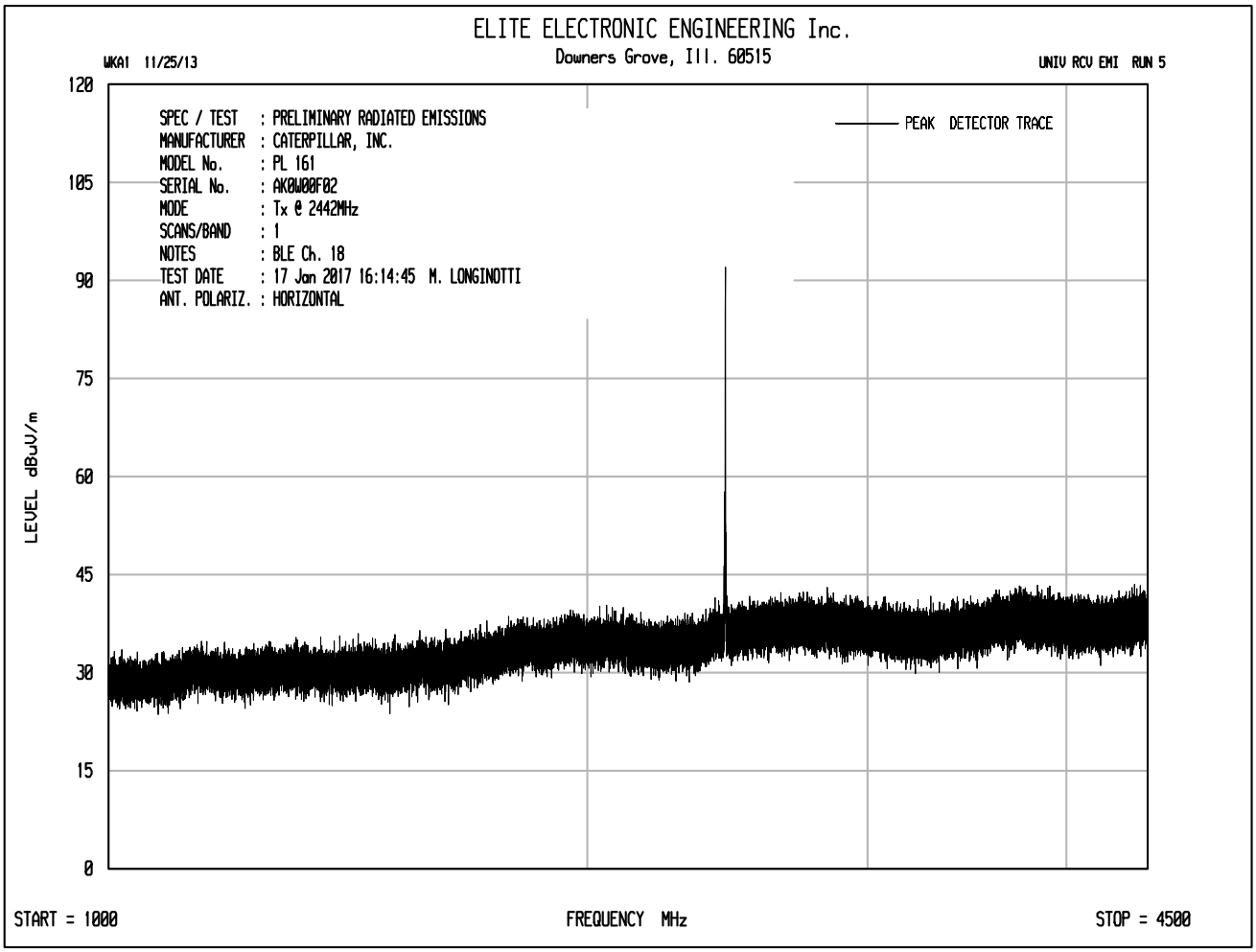

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 1
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 17 Jan 2017 14:27:47 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000

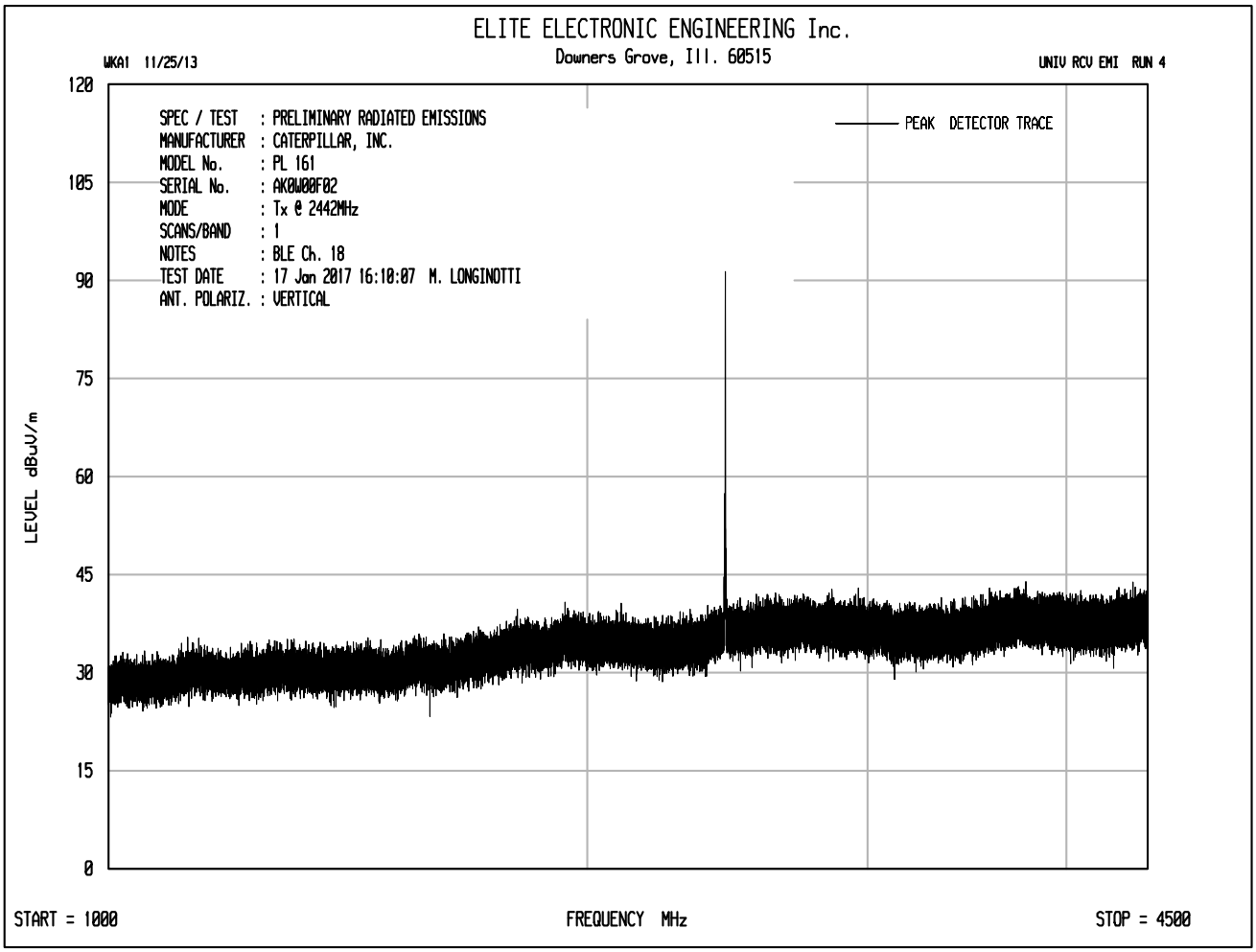

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 2
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 19 Jan 2017 14:26:14 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000

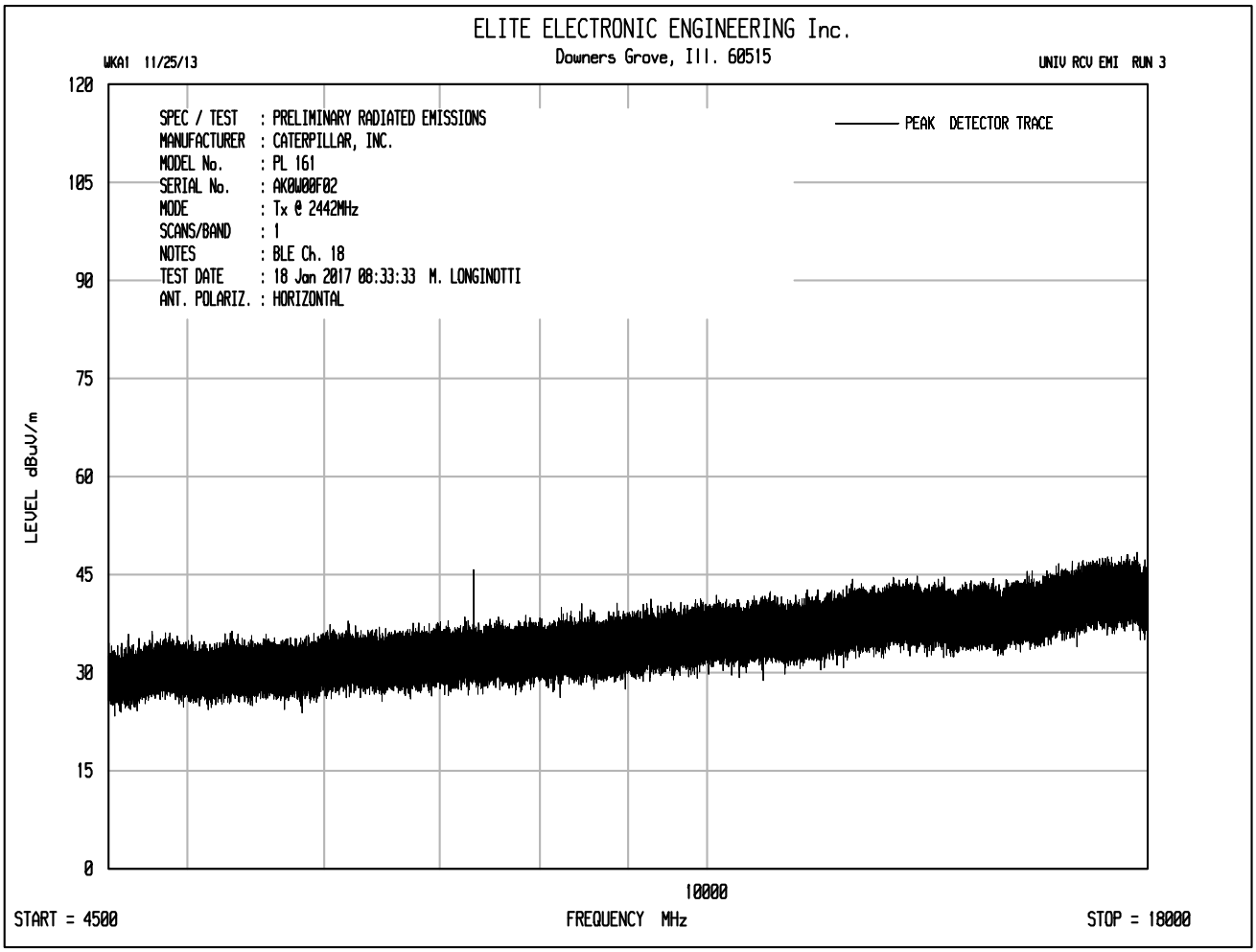

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 1
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2402MHz
SCANS/BAND : 1
NOTES : BLE Ch. 37
TEST DATE : 19 Jan 2017 14:23:56 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000

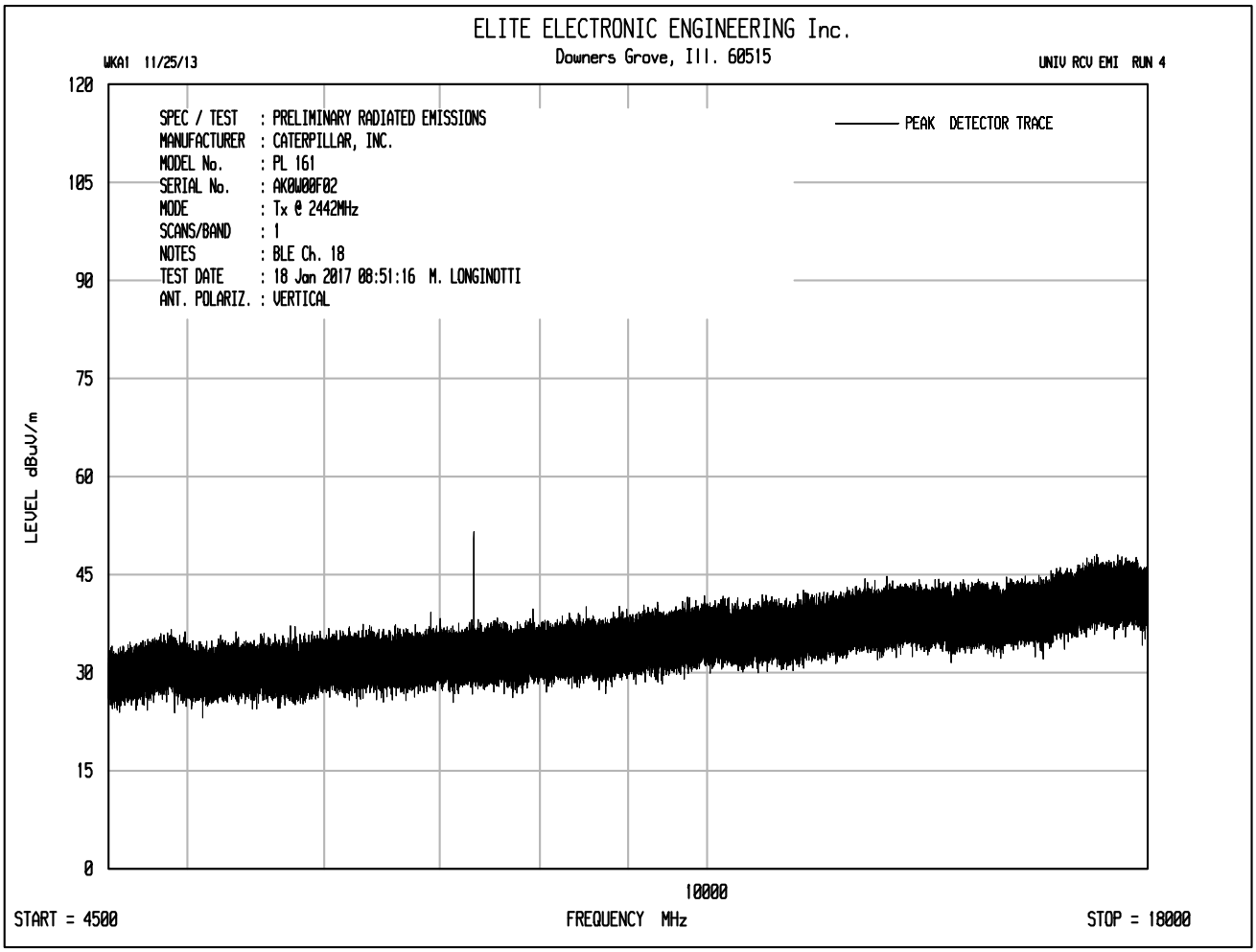

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 22
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 19 Jan 2017 12:59:01 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

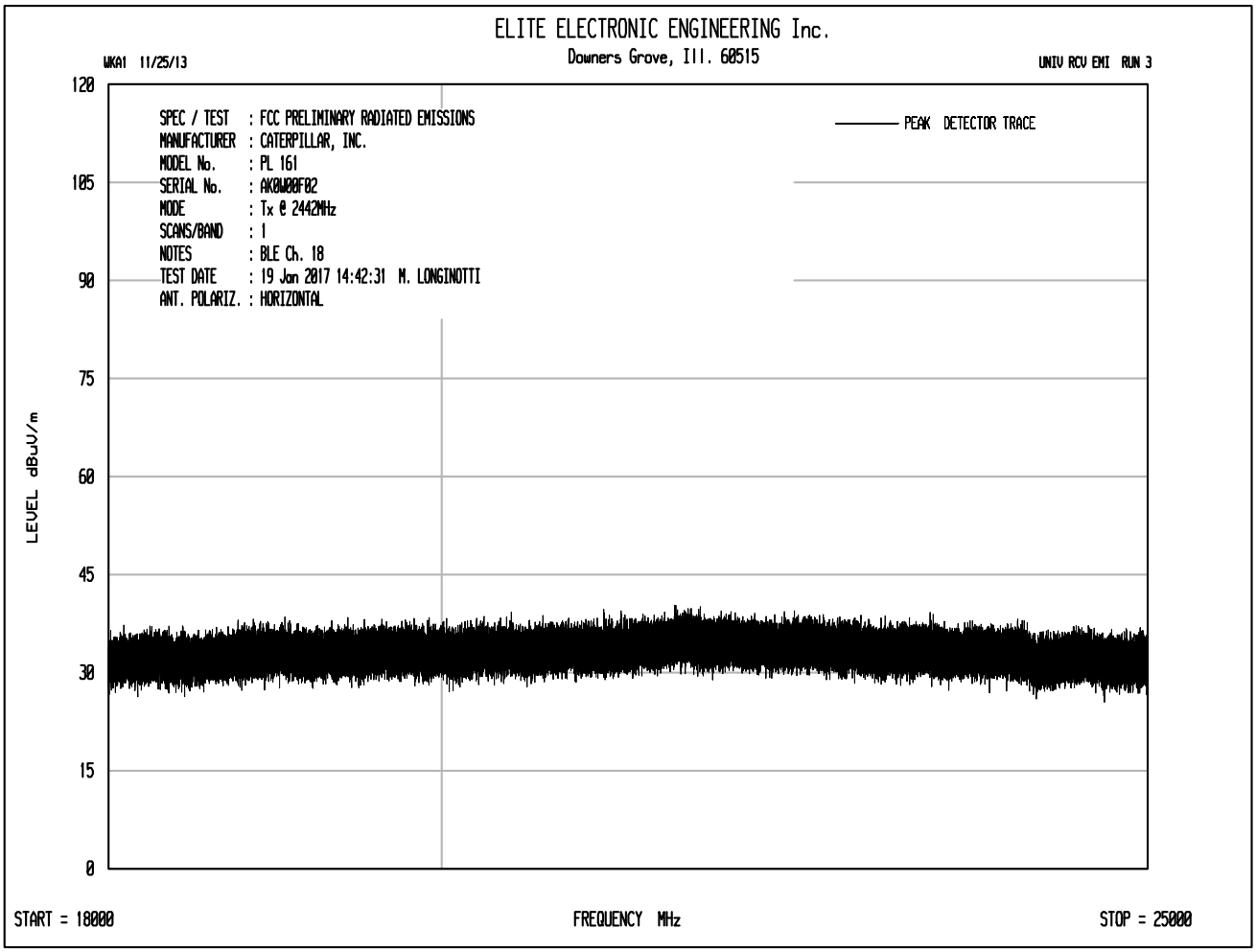

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 23
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 19 Jan 2017 13:02:34 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

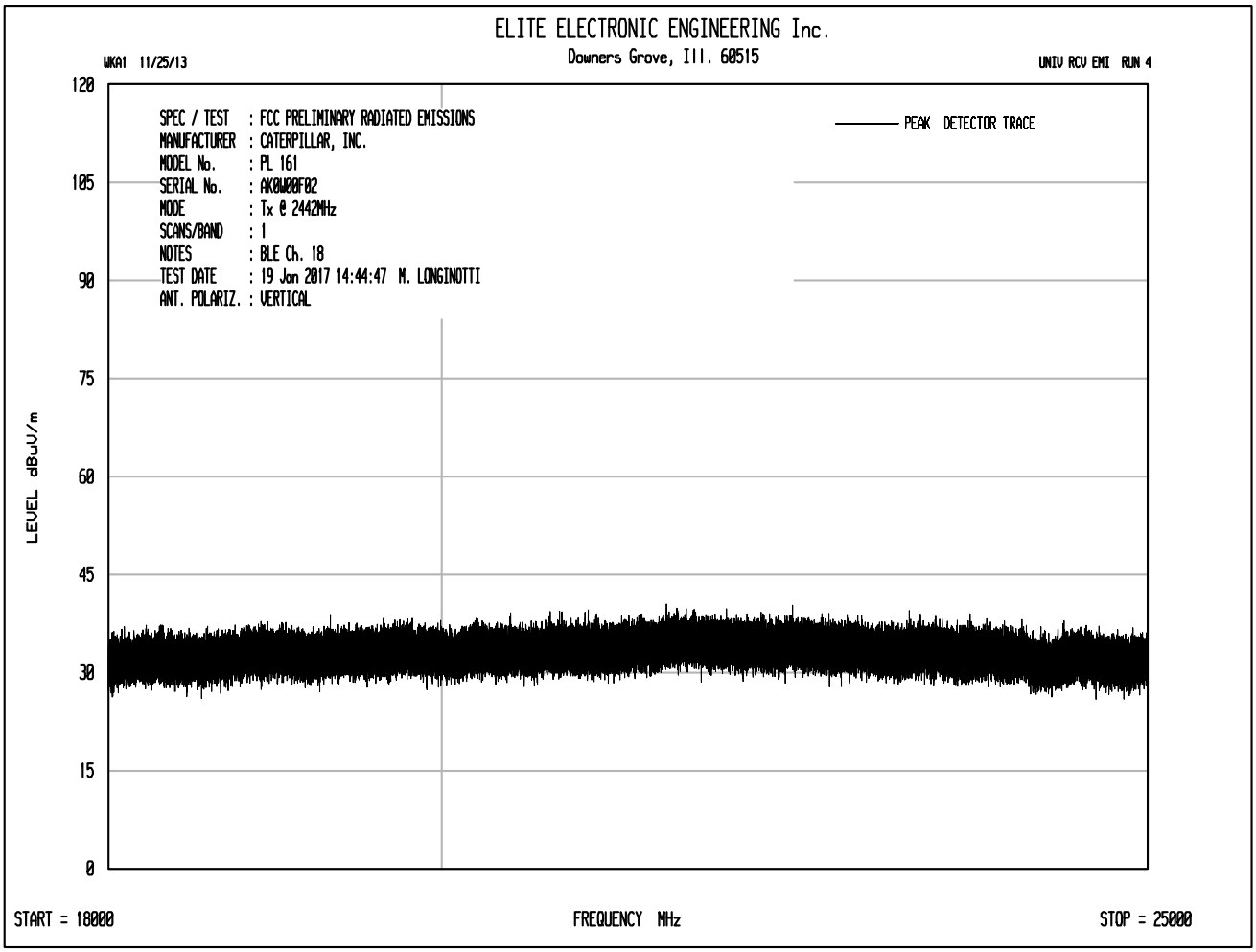

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 5
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 17 Jan 2017 16:14:45 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500

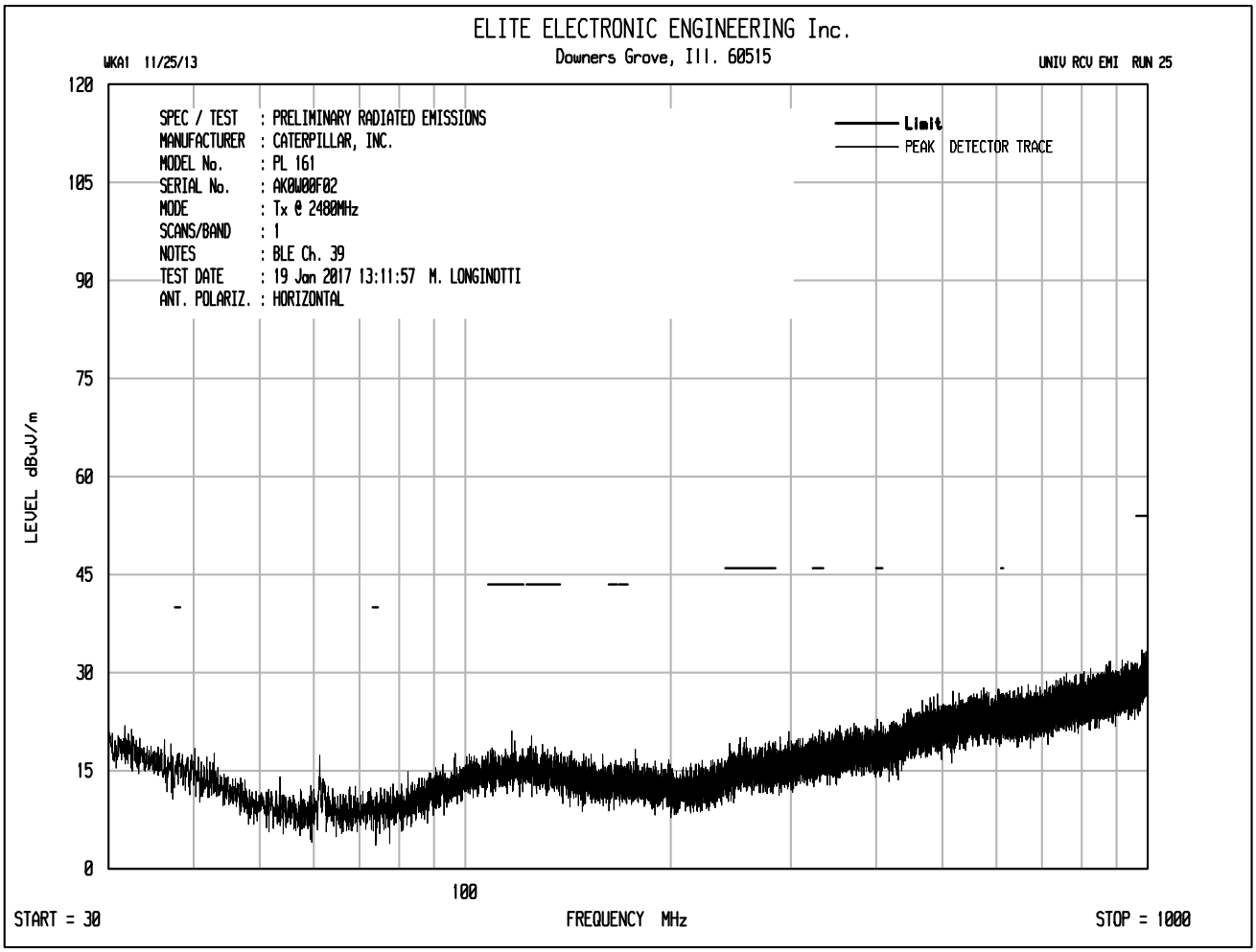

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 4
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 17 Jan 2017 16:10:07 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500

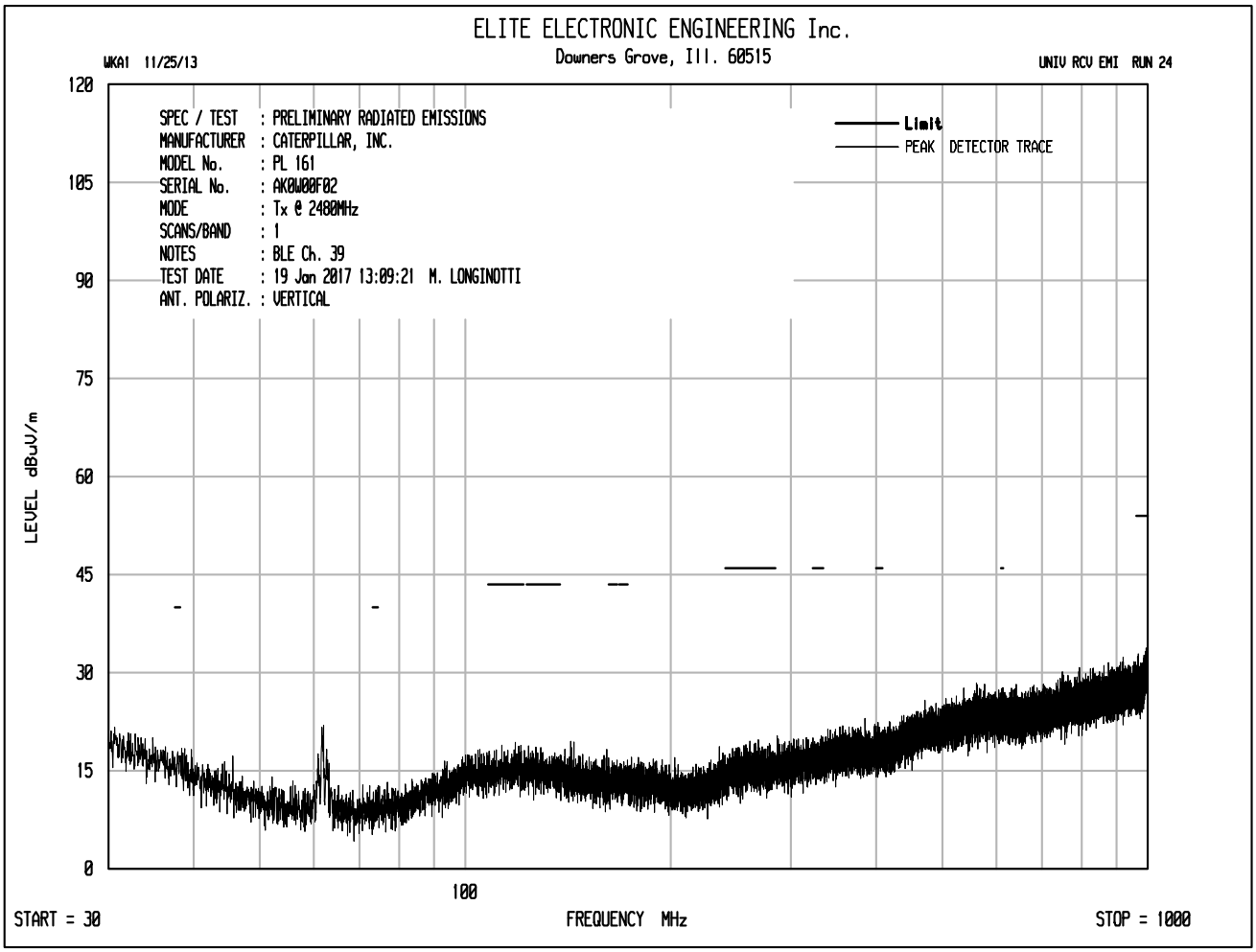

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 3
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 18 Jan 2017 08:33:33 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000

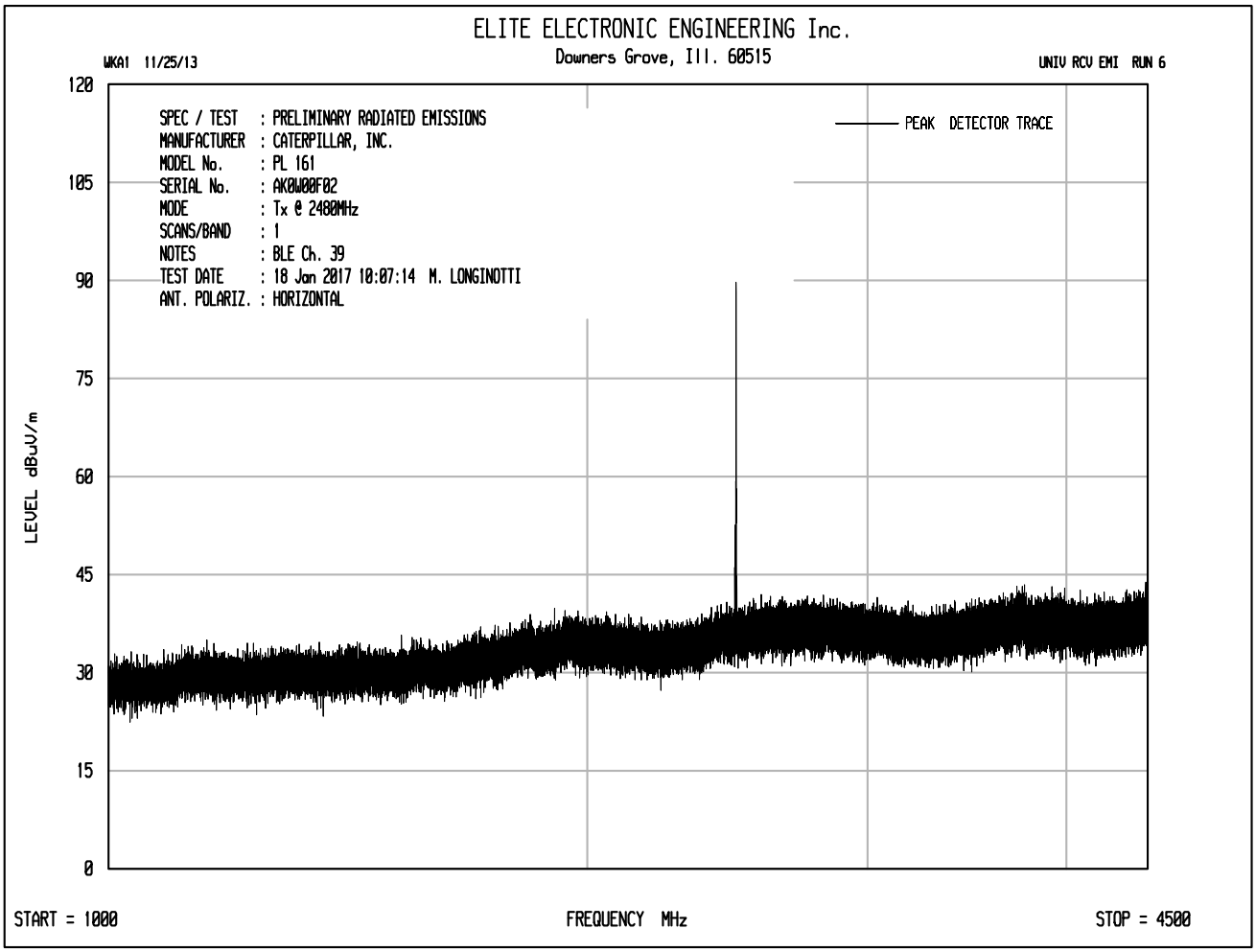

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 4
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 18 Jan 2017 08:51:16 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000

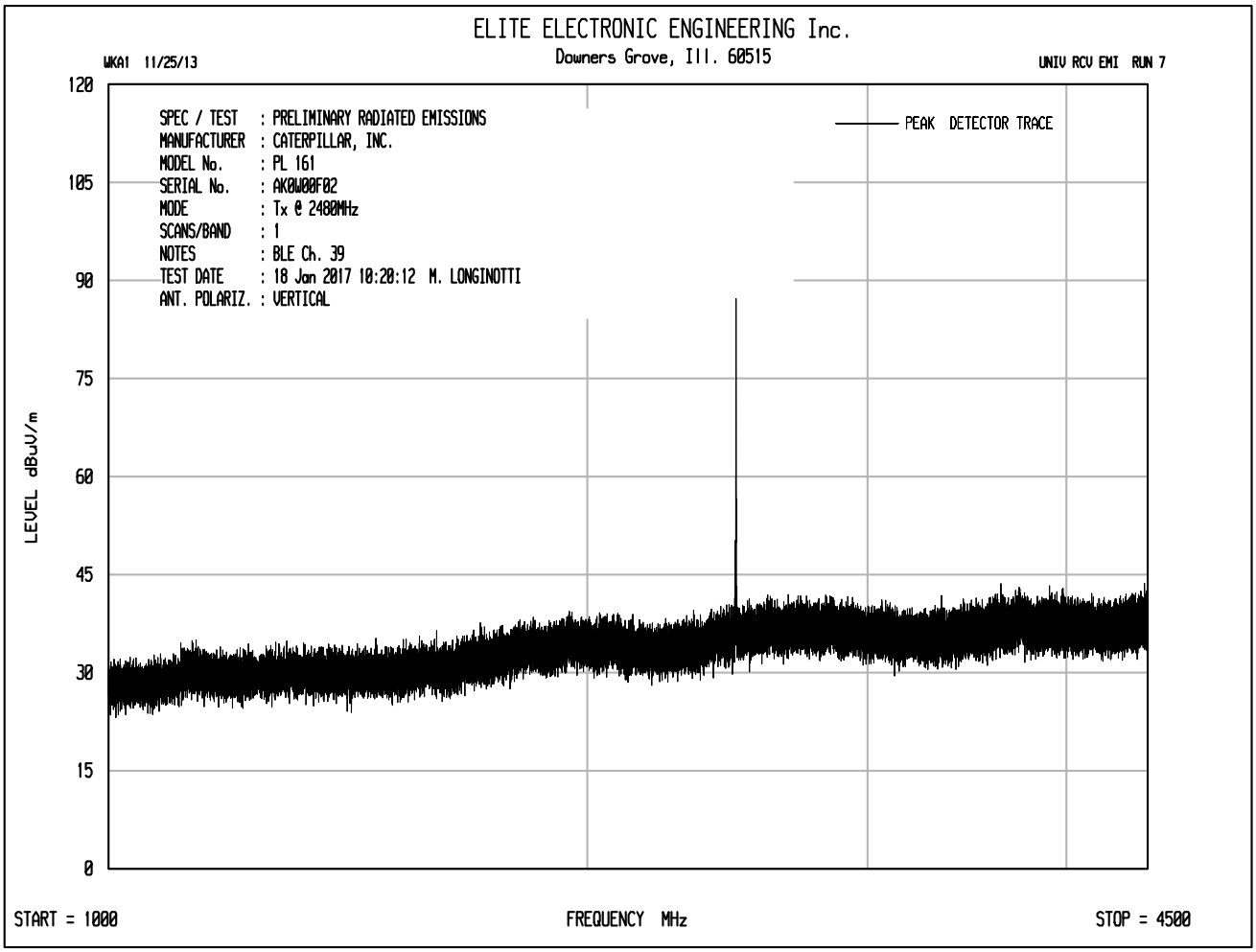

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 3
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 19 Jan 2017 14:42:31 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000

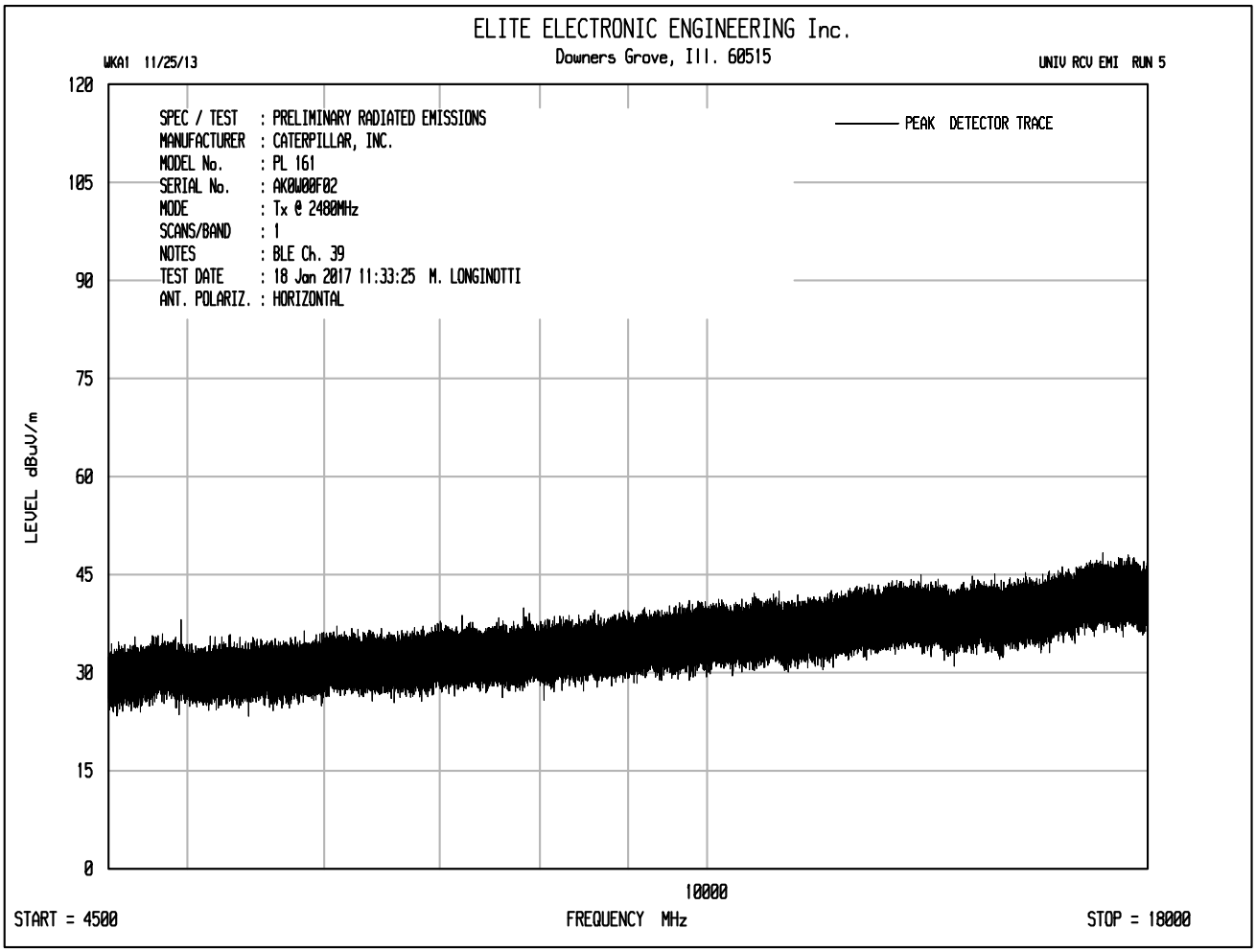

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 4
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2442MHz
SCANS/BAND : 1
NOTES : BLE Ch. 18
TEST DATE : 19 Jan 2017 14:44:47 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000

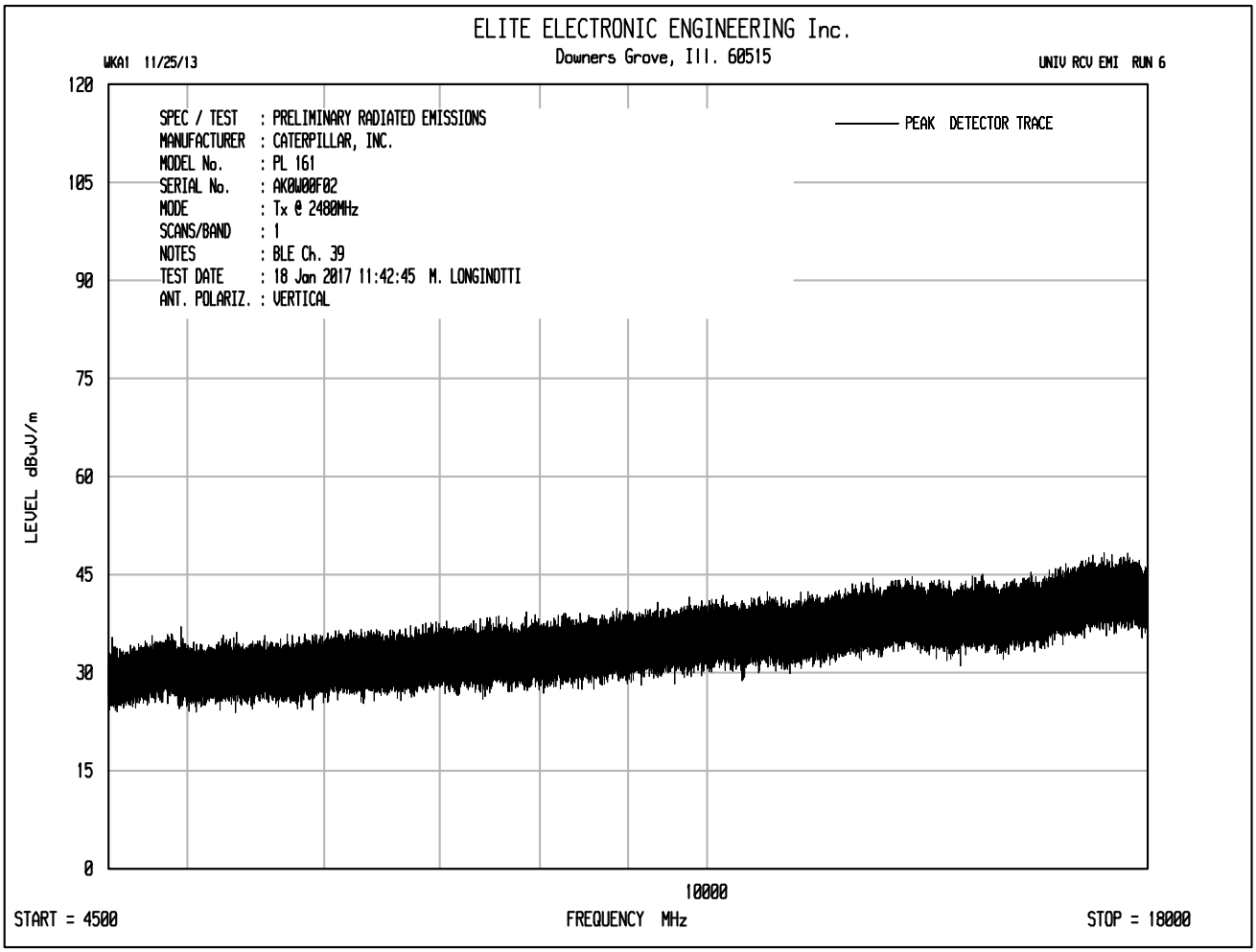

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 25
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 19 Jan 2017 13:11:57 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

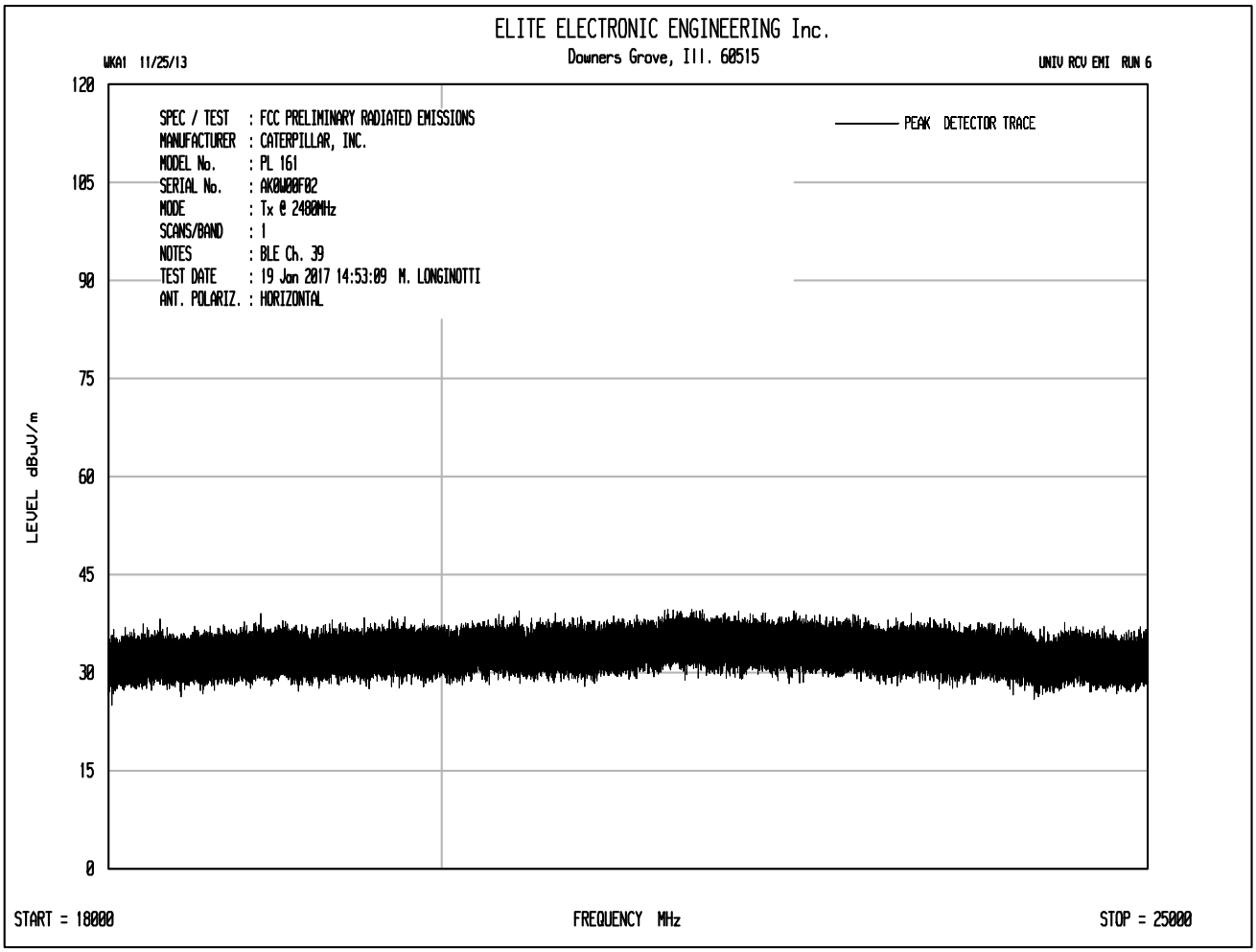

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 24
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 19 Jan 2017 13:09:21 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
Limit
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
100
START = 30
FREQUENCY MHz
STOP = 1000

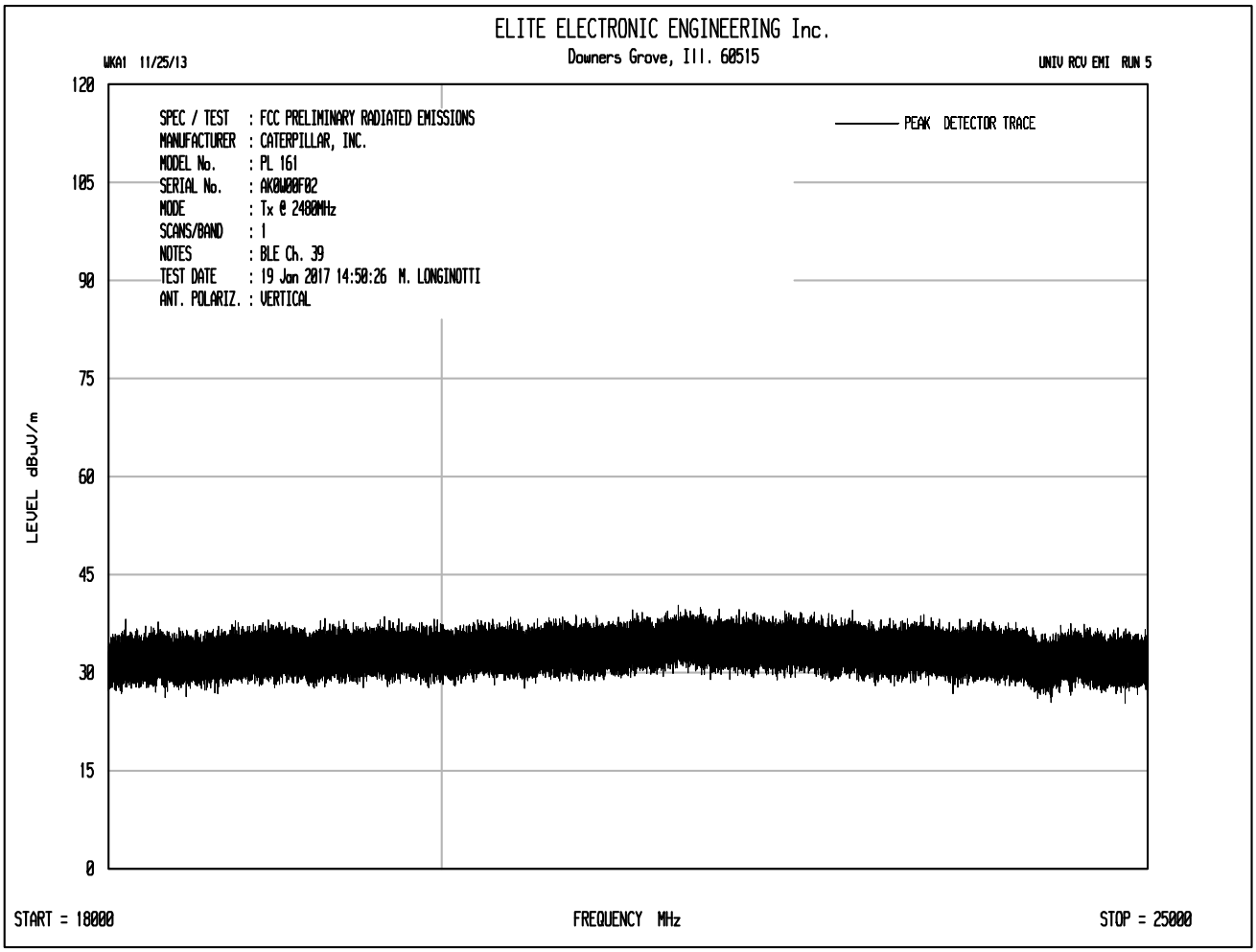

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 6
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 18 Jan 2017 10:07:14 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500


ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 7
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 18 Jan 2017 10:20:12 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 1000
FREQUENCY MHz
STOP = 4500


ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 5
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 18 Jan 2017 11:33:25 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000


ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 6
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 18 Jan 2017 11:42:45 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
10000
START = 4500
FREQUENCY MHz
STOP = 18000


ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 6
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 19 Jan 2017 14:53:09 M. LONGINOTTI
ANT. POLARIZ. : HORIZONTAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000


ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 5
SPEC / TEST : FCC PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : CATERPILLAR, INC.
MODEL No. : PL 161
SERIAL No. : AK0W00F02
MODE : Tx @ 2480MHz
SCANS/BAND : 1
NOTES : BLE Ch. 39
TEST DATE : 19 Jan 2017 14:58:26 M. LONGINOTTI
ANT. POLARIZ. : VERTICAL
PEAK DETECTOR TRACE
LEVEL dBuV/m
120
105
90
75
60
45
30
15
0
START = 18000
FREQUENCY MHz
STOP = 25000

Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	48.3	Ambient	4.8	34.6	-40.2	47.5	236.9	5000.0	-26.5
4804.00	V	48.2	Ambient	4.8	34.6	-40.2	47.4	234.2	5000.0	-26.6
12010.00	H	48.1	Ambient	8.0	38.7	-39.7	55.1	569.4	5000.0	-18.9
12010.00	V	46.9	Ambient	8.0	38.7	-39.7	53.9	495.9	5000.0	-20.1
19216.00	H	33.5	Ambient	2.2	40.4	-28.6	47.5	238.1	5000.0	-26.4
19216.00	V	33.2	Ambient	2.2	40.4	-28.6	47.2	230.0	5000.0	-26.7
4806.00	H	49.5	Ambient	4.8	34.6	-40.2	48.7	272.0	5000.0	-25.3
4806.00	V	49.1	Ambient	4.8	34.6	-40.2	48.3	259.8	5000.0	-25.7

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	36.1	Ambient	4.8	34.6	-40.2	35.3	58.2	500.0	-18.7
4804.00	V	36.1	Ambient	4.8	34.6	-40.2	35.3	58.2	500.0	-18.7
12010.00	H	35.4	Ambient	8.0	38.7	-39.7	42.4	132.0	500.0	-11.6
12010.00	V	35.3	Ambient	8.0	38.7	-39.7	42.3	130.4	500.0	-11.7
19216.00	H	21.9	Ambient	2.2	40.4	-28.6	35.9	62.6	500.0	-18.0
19216.00	V	21.6	Ambient	2.2	40.4	-28.6	35.6	60.5	500.0	-18.3
4806.00	H	38.4	Ambient	4.8	34.6	-40.2	37.6	75.8	500.0	-16.4
4806.00	V	37.6	Ambient	4.8	34.6	-40.2	36.8	69.1	500.0	-17.2

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
Date : January 17, 2017 through January 19, 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	63.8		3.4	32.0	0.0	99.2	91285.8		
2402.00	V	62.2		3.4	32.0	0.0	97.6	75928.2		
7206.00	H	52.2		6.1	35.7	-40.1	53.9	496.9	9128.6	-25.3
7206.00	V	58.4		6.1	35.7	-40.1	60.1	1014.4	9128.6	-19.1
9608.00	H	37.9	Ambient	6.8	36.6	-39.6	41.7	122.2	9128.6	-37.5
9608.00	V	40.7	Ambient	6.8	36.6	-39.6	44.5	168.6	9128.6	-34.7
14412.00	H	37.8	Ambient	8.7	39.6	-40.0	46.1	202.6	9128.6	-33.1
14412.00	V	38.1	Ambient	8.7	39.6	-40.0	46.4	209.7	9128.6	-32.8
16814.00	H	38.1	Ambient	9.4	41.7	-38.9	50.3	328.7	9128.6	-28.9
16814.00	V	37.8	Ambient	9.4	41.7	-38.9	50.0	317.5	9128.6	-29.2
21618.00	H	26.3	Ambient	2.2	40.6	-28.7	40.4	105.3	9128.6	-38.8
21618.00	V	26.6	Ambient	2.2	40.6	-28.7	40.7	109.0	9128.6	-38.5
24020.00	H	25.2	Ambient	2.2	40.6	-30.0	38.1	80.1	9128.6	-41.1
24020.00	V	24.2	Ambient	2.2	40.6	-30.0	37.1	71.4	9128.6	-42.1

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	49.4	Ambient	4.9	34.5	-40.3	48.6	268.0	5000.0	-25.4
4884.00	V	48.7	Ambient	4.9	34.5	-40.3	47.9	247.3	5000.0	-26.1
7326.00	H	52.8		6.2	35.7	-40.1	54.6	536.0	5000.0	-19.4
7326.00	V	55.1		6.2	35.7	-40.1	56.9	698.5	5000.0	-17.1
12210.00	H	48.4	Ambient	8.0	38.8	-39.6	55.6	600.5	5000.0	-18.4
12210.00	V	48.1	Ambient	8.0	38.8	-39.6	55.3	580.2	5000.0	-18.7
19536.00	H	33.6	Ambient	2.2	40.4	-28.5	47.8	244.4	5000.0	-26.2
19536.00	V	33.8	Ambient	2.2	40.4	-28.5	48.0	250.1	5000.0	-26.0
4882.00	H	49.1	Ambient	4.9	34.5	-40.3	48.3	258.9	5000.0	-25.7
4882.00	V	48.8	Ambient	4.9	34.5	-40.3	48.0	250.1	5000.0	-26.0

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	36.6	Ambient	4.9	34.5	-40.3	35.8	61.4	500.0	-18.2
4884.00	V	36.5	Ambient	4.9	34.5	-40.3	35.7	60.7	500.0	-18.3
7326.00	H	44.30		6.2	35.7	-40.1	46.1	201.5	500.0	-7.9
7326.00	V	48.4		6.2	35.7	-40.1	50.2	323.0	500.0	-3.8
12210.00	H	35.6	Ambient	8.0	38.8	-39.6	42.8	137.6	500.0	-11.2
12210.00	V	35.6	Ambient	8.0	38.8	-39.6	42.8	137.6	500.0	-11.2
19536.00	H	22.0	Ambient	2.2	40.4	-28.5	36.2	64.3	500.0	-17.8
19536.00	V	22.0	Ambient	2.2	40.4	-28.5	36.2	64.3	500.0	-17.8
4882.00	H	37.4	Ambient	4.9	34.5	-40.3	36.6	67.3	500.0	-17.4
4882.00	V	37.8	Ambient	4.9	34.5	-40.3	37.0	70.5	500.0	-17.0

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
Date : January 17, 2017 through January 19, 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	58.8		3.5	32.1	0.0	94.3	52092.8		
2442.00	V	57.3		3.5	32.1	0.0	92.8	43830.6		
9768.00	H	37.5	Ambient	6.9	36.9	-39.6	41.7	122.2	5209.3	-32.6
9768.00	V	37.5	Ambient	6.9	36.9	-39.6	41.7	122.2	5209.3	-32.6
14652.00	H	37.1	Ambient	8.8	39.6	-40.2	45.3	184.8	5209.3	-29.0
14652.00	V	37.2	Ambient	8.8	39.6	-40.2	45.4	187.0	5209.3	-28.9
17094.00	H	36.3	Ambient	9.5	41.6	-38.8	48.7	270.8	5209.3	-25.7
17094.00	V	36.3	Ambient	9.5	41.6	-38.8	48.7	270.8	5209.3	-25.7
21978.00	H	24.9	Ambient	2.2	40.6	-29.2	38.5	84.1	5209.3	-35.8
21978.00	V	25.2	Ambient	2.2	40.6	-29.2	38.8	87.1	5209.3	-35.5
24420.00	H	25.6	Ambient	2.2	40.6	-30.2	38.2	81.7	5209.3	-36.1
24420.00	V	25.0	Ambient	2.2	40.6	-30.2	37.6	76.3	5209.3	-36.7

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	47.9	Ambient	4.9	34.5	-40.3	47.0	224.8	5000.0	-26.9
4960.00	V	48.1	Ambient	4.9	34.5	-40.3	47.2	230.0	5000.0	-26.7
7440.00	H	48.2	Ambient	6.2	35.6	-40.0	50.0	316.4	5000.0	-24.0
7440.00	V	47.9	Ambient	6.2	35.6	-40.0	49.7	305.7	5000.0	-24.3
12400.00	H	47.6	Ambient	8.0	38.8	-39.5	54.9	553.6	5000.0	-19.1
12400.00	V	47.8	Ambient	8.0	38.8	-39.5	55.1	566.5	5000.0	-18.9
19840.00	H	33.6	Ambient	2.2	40.4	-28.2	48.1	253.3	5000.0	-25.9
19840.00	V	33.7	Ambient	2.2	40.4	-28.2	48.2	256.3	5000.0	-25.8
22320.00	H	35.7	Ambient	2.2	40.6	-29.1	49.4	296.8	5000.0	-24.5
22320.00	V	35.2	Ambient	2.2	40.6	-29.1	48.9	280.2	5000.0	-25.0
4958.00	H	49.0	Ambient	4.9	34.5	-40.3	48.1	255.1	5000.0	-25.8
4858.00	V	48.8	Ambient	4.9	34.6	-40.2	48.0	250.4	5000.0	-26.0

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. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : January 17, 2017 through January 19, 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	35.6	Ambient	4.9	34.5	-40.3	34.7	54.5	500.0	-19.2
4960.00	V	35.4	Ambient	4.9	34.5	-40.3	34.5	53.3	500.0	-19.4
7440.00	H	35.40	Ambient	6.2	35.6	-40.0	37.2	72.5	500.0	-16.8
7440.00	V	35.2	Ambient	6.2	35.6	-40.0	37.0	70.8	500.0	-17.0
12400.00	H	35.4	Ambient	8.0	38.8	-39.5	42.7	135.9	500.0	-11.3
12400.00	V	35.4	Ambient	8.0	38.8	-39.5	42.7	135.9	500.0	-11.3
19840.00	H	22.0	Ambient	2.2	40.4	-28.2	36.5	66.6	500.0	-17.5
19840.00	V	21.9	Ambient	2.2	40.4	-28.2	36.4	65.9	500.0	-17.6
22320.00	H	23.2	Ambient	2.2	40.6	-29.1	36.9	70.4	500.0	-17.0
22320.00	V	23.0	Ambient	2.2	40.6	-29.1	36.7	68.8	500.0	-17.2
4958.00	H	37.7	Ambient	4.9	34.5	-40.3	36.8	69.5	500.0	-17.1
4858.00	V	38.1	Ambient	4.9	34.6	-40.2	37.3	73.1	500.0	-16.7

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

Checked By: MARK E. LONGINOTTI

Mark E. Longinotti

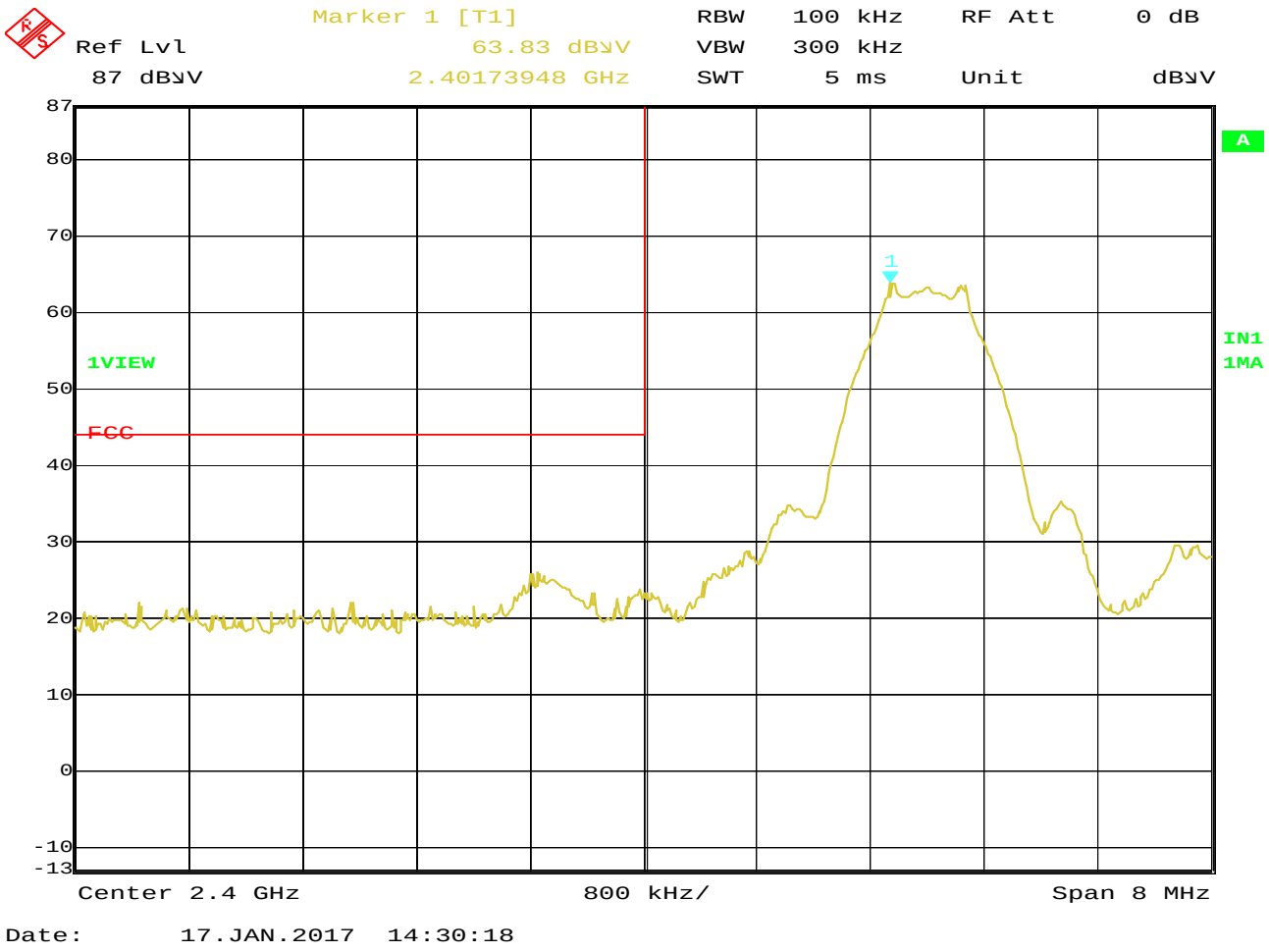
Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
Date : January 17, 2017 through January 19, 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	55.1		3.5	32.2	0.0	90.8	34493.5		
2480.00	V	54.0		3.5	32.2	0.0	89.7	30390.5		
9920.00	H	38.0	Ambient	7.0	37.0	-39.5	42.4	132.0	3449.3	-28.3
9920.00	V	37.9	Ambient	7.0	37.0	-39.5	42.3	130.5	3449.3	-28.4
14880.00	H	36.8	Ambient	8.9	39.7	-40.4	45.0	177.8	3449.3	-25.8
14880.00	V	38.1	Ambient	8.9	39.7	-40.4	46.3	206.5	3449.3	-24.5
17360.00	H	37.5	Ambient	9.7	41.4	-39.1	49.5	297.5	3449.3	-21.3
17360.00	V	37.4	Ambient	9.7	41.4	-39.1	49.4	294.0	3449.3	-21.4
24800.00	H	25.2	Ambient	2.2	40.6	-30.9	37.1	71.7	3449.3	-33.7
24800.00	V	24.8	Ambient	2.2	40.6	-30.9	36.7	68.4	3449.3	-34.1

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	:	PL 161
SERIAL NUMBER	:	AK0W00F02
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.
EQUIPMENT USED	:	RBB0, NWQ1

Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions at High Band Edge
Date : January 17, 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)
2483.54	H	14.6	Ambient	3.5	32.2	0.0	50.3	326.1	5000.0	-23.7
2484.08	V	14.7	Ambient	3.5	32.2	0.0	50.4	329.9	5000.0	-23.6

Checked By: MARK E. LONGINOTTI

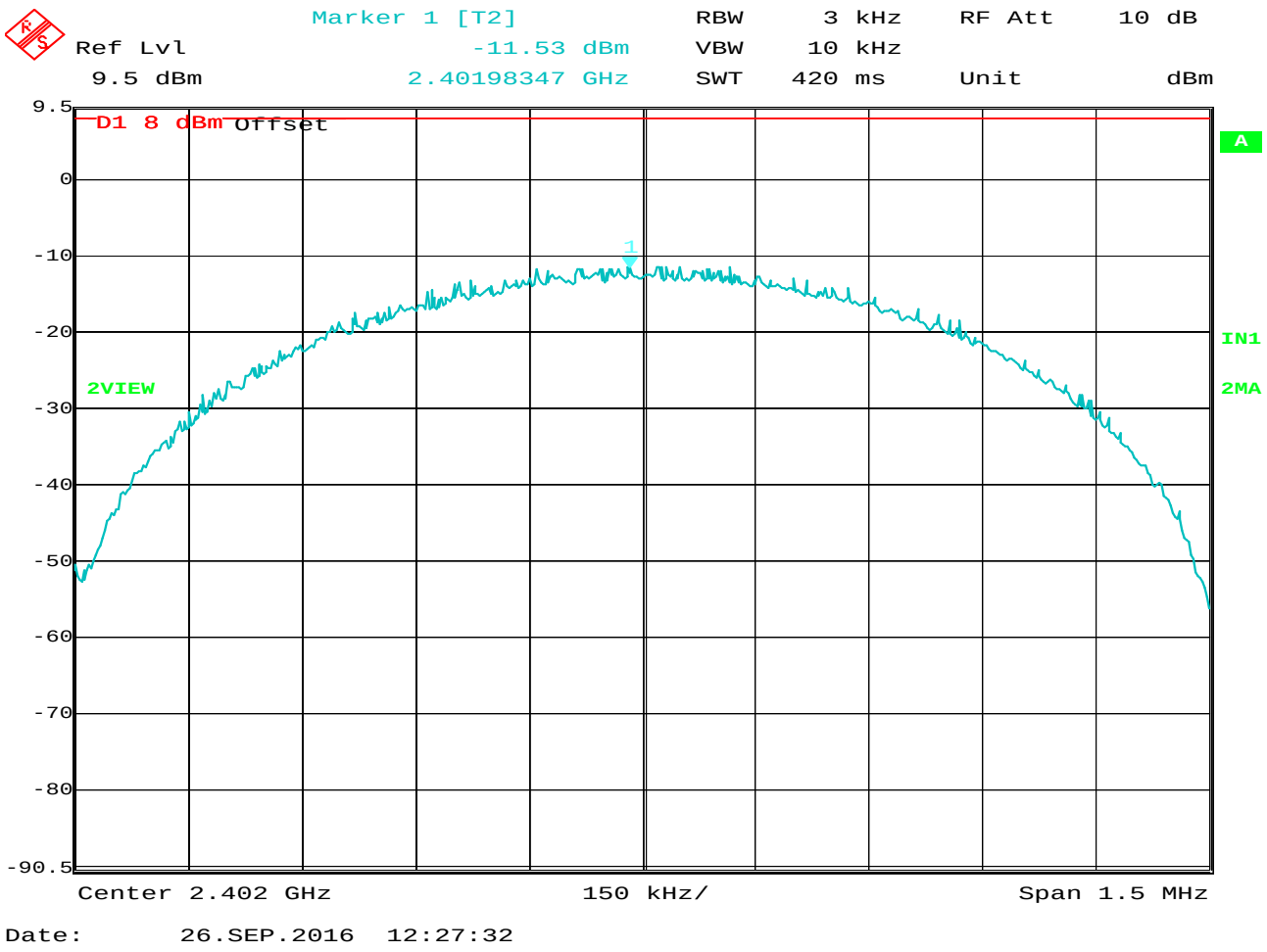
Mark E. Longinotti

Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : PL161
Serial No. : AK0W00F02
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Average Radiated Emissions at High Band Edge
Date : January 17, 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)
2483.54	H	1.8	Ambient	3.5	32.2	0.0	37.5	74.7	500.0	-16.5
2484.08	V	1.5	Ambient	3.5	32.2	0.0	37.2	72.2	500.0	-16.8

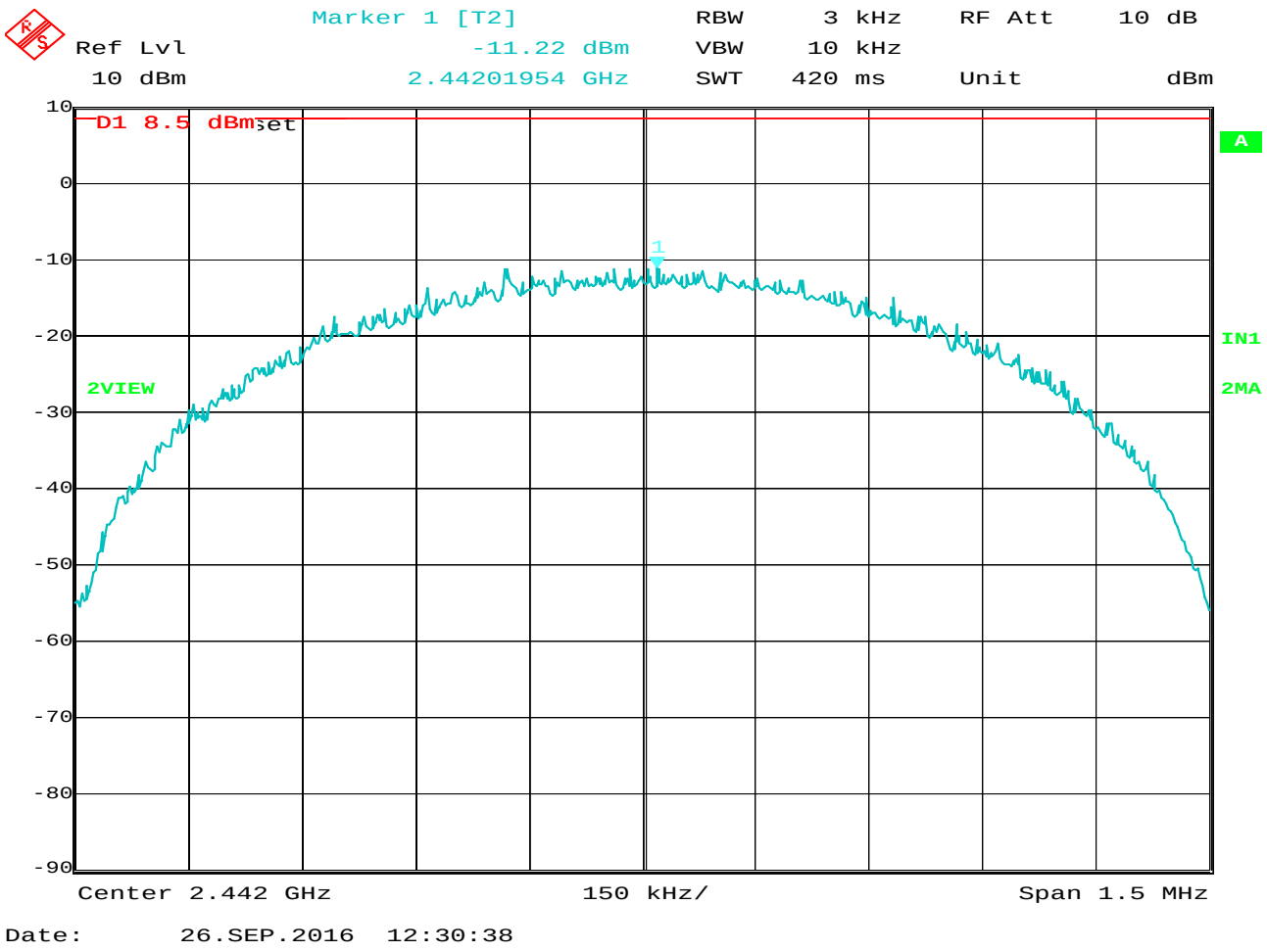
Checked By: MARK E. LONGINOTTI

Mark E. Longinotti



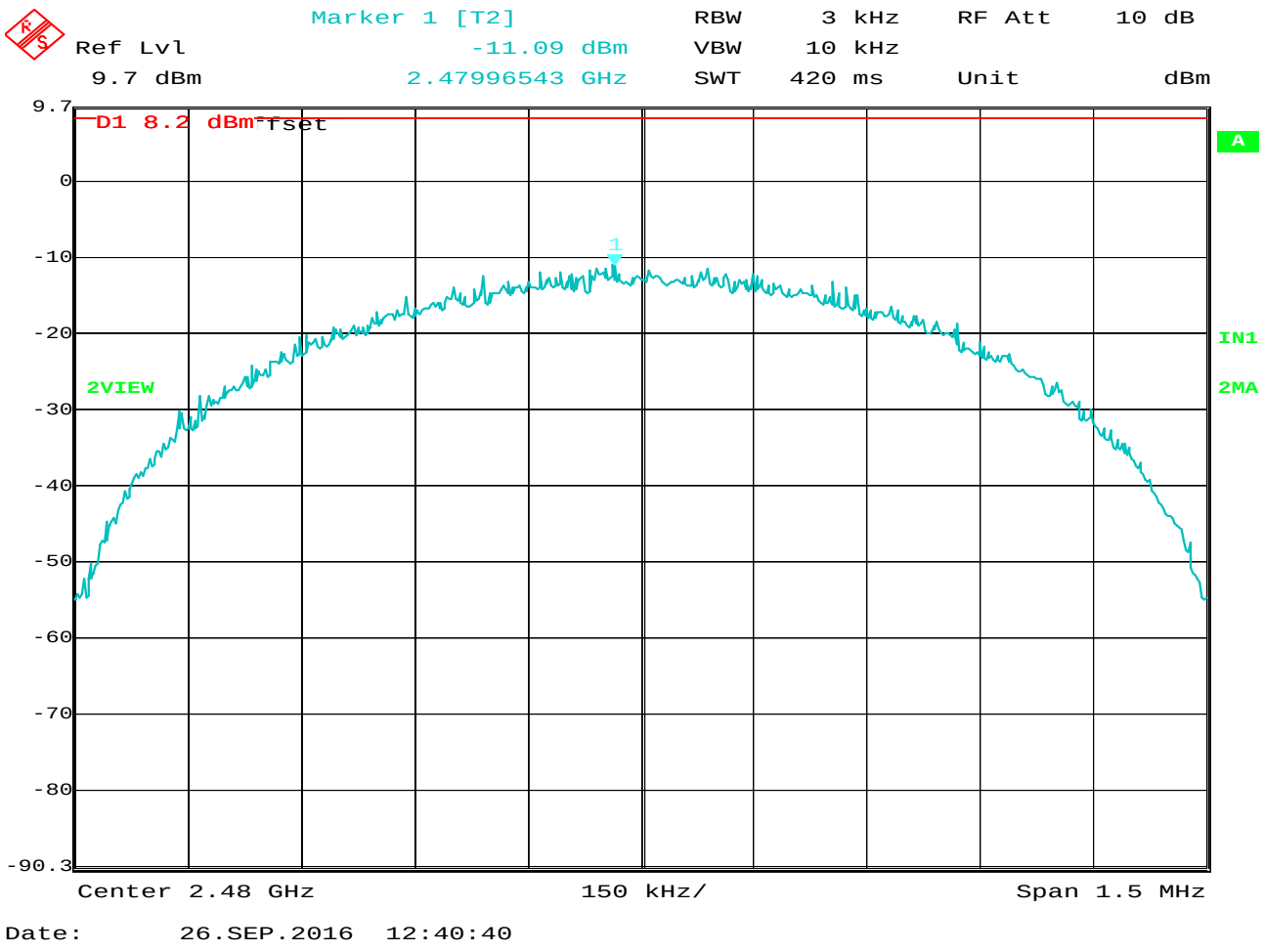
FCC 15.247 Power Spectral Density

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
NOTES	:	Power Spectral Density = -11.53dBm
EQUIPMENT USED	:	RBA1, T2SE



FCC 15.247 Power Spectral Density

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
NOTES	:	Power Spectral Density = -11.22dBm
EQUIPMENT USED	:	RBA1, T2SE



FCC 15.247 Power Spectral Density

MANUFACTURER	:	Caterpillar
MODEL NUMBER	:	PL161
SERIAL NUMBER	:	DJOW009302
TEST MODE	:	Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
NOTES	:	Power Spectral Density = -11.09dBm
EQUIPMENT USED	:	RBA1, T2SE