Measurement of RF Interference from a CM102 Cab Module Transceiver

For	Metrom Rail 1125 Mitchell Court Crystal Lake, IL 60014
P.O. Number	2056
Date Received	June 6, 2016
Date Tested	June 6, 2016 through June 8, 2016
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 Industry Canada RSS-247 Industry Canada RSS-GEN
Test Report By:	MARK E. LONGINOTTI Mark Longinotti EMC Engineer
Requested By:	Sara Woitel Metrom Rail
Approved By:	Raymond J. Klouda Raymond J. Klouda Registered Professional Engineer of Illinois - 44894

Elite Electronic Engineering Inc.
1516 CENTRE CIRCLE
DOWNERS GROVE, IL 60515
TEL: 630 - 495 - 9770
FAX: 630 - 495 - 9785
www.elitetest.com

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REVISION HISTORY

Revision	Date	Description
—	23 June 2016	Initial release

Measurement of RF Emissions from a Cab Module, Part No. CM102 Transceiver

1. INTRODUCTION

1.1 Scope of Tests

This document represents the results of the series of radio interference measurements performed on a Metrom Rail Cab Module, Part No. CM102, Serial No. None Assigned, transceiver (hereinafter referred to as the EUT). The EUT is a digital modulation transceiver. The transceiver was designed to transmit and receive in the 2400-2483.5 MHz band using a PC Tel directional gain antenna, Model No. 100920ASM001, with 11.5dBi gain. The EUT was manufactured and submitted for testing by Metrom Rail located in Crystal Lake, 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 Industry Canada Radio Standards Specification RSS-Gen Section 8.8 and Section 7.1.2 for receivers and Industry Canada Radio Standards Specification RSS-Gen Section 8.8 and Industry 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 31%.

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 2015

- 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

- Industry 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”

- Industry Canada RSS-GEN, Issue 4, November 2014, “Spectrum Management and Telecommunications Radio Standards Specification, General Requirements for Compliance of Radio Apparatus”

3. EUT SETUP AND OPERATION

3.1 General Description

The EUT is a Cab Module, Part No. CM102. A block diagram of the EUT setup is shown as Figure 1 and Figure 2.

3.1.1 Power Input

The EUT was received 12VDC power from an external gel cell battery via a 1 meter long, 2 wire power cable.

3.1.2 Peripheral Equipment

The following peripheral equipment was submitted with the EUT:

Item	Description
N/A	

3.1.3 Interconnect Cables

The following interconnect cables were submitted with the EUT:

Item	Description
N/A	

3.1.4 Grounding

The EUT was ungrounded during the tests.

3.2 Software

For all tests, the EUT had Firmware Version1.0.0 loaded onto the device to provide correct load characteristics.

3.3 Operational Mode

The EUT was energized and programmed to transmit continuously at 2441MHz.

3.4 EUT Modifications

In order to meet the spurious radiated emissions below 1GHz, the following modifications were made to the EUT:

- A shielded cable with ferrite beads at both ends of the cable was used between the display and control module

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. 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 Industry Canada RSS-Gen, Section 5.5, only radio communication receivers operating in stand-alone mode within the band 30-960 MHz, as well as scanner receivers, are subject to Industry Canada requirements. 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 was 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 30dB of attenuation.

The EUT was allowed to transmit continuously at 2441MHz. 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 wider than the 6dB bandwidth.

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 plot on page 21 shows that the minimum 6 dB bandwidth was 53.11MHz which is greater than minimum allowable 6dB bandwidth requirement of 500kHz for systems using digital modulation techniques. The 99% bandwidth was measured to be 57.82MHz.

5.2.3 Peak Output Power and EIRP

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). 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). If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the 1.0W (30dBm) limit by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

5.2.3.2 Procedures

The antenna port of the EUT was connected to a wideband power sensor, Keysight M/N: N1923A, through 30dB of attenuation. The output of the power sensor was connected to a peak power analyzer, Keysight M/N: 8990B. The EUT was programmed to transmit at 2441MHz. The peak power reading was measured and recorded (correcting for the external attenuation). The gain of the antenna was added to the conducted peak power reading to determine the peak EIRP.

5.2.3.3 Results

The results are presented on pages 22 and 23. The maximum peak output power was 14.08dBm which is below the 24.5dBm limit for transmitters using an antenna with nominal gain of 11.5dBi. The EIRP from the transmitter was 25.58dBm which is below the 36.0dBm limit.

5.2.4 Duty Cycle Factor Measurements

5.2.4.1 Procedures

The duty cycle factor is used to convert peak detected readings to average readings. This factor is computed from the time domain trace of the pulse modulation signal.

With the transmitter set up to transmit for maximum pulse density, the time domain trace is displayed on the spectrum analyzer. This trace is obtained by tuning center frequency to the transmitter frequency and then setting a zero span width with 0.5msec/div. The amplitude settings are adjusted so that the on/off transitions clear the 4th division from the bottom of the display. The markers are set at the beginning and end of the “on-time” for each pulse. The trace is recorded.

Next the spectrum analyzer center frequency is set to the transmitter frequency with a zero span width and 10msec/div. This shows if the word is longer than 100msec or shorter than 100msec. If the word period is less than 100msec, the display is set to show at least one word. The on-time and off-time are then measured. The on-time is total time signal level exceeds the 4th division. Off-time is time under for the word period. The duty cycle is then computed as the (On-time/ word period) where the word period = (On-time + Off-time).

5.2.4.2 Results

The plots of the duty cycle are shown on data pages 24 through 28. As can be seen from the data, the EUT transmits 4 pulses every 100msec. The total on time of the pulses is 2.013msec. The duty cycle correction factor was calculated to be -33.9dB (-33.9dB = 20*log(2.013msec/100msec).

5.2.5 Antenna Conducted Spurious Emissions

5.2.5.1 Requirements

Per section 15.247(c), the spurious emissions in any 100 kHz BW outside the frequency band must be at least 20dB below the highest 100 kHz BW level measured within the band.

5.2.5.2 Procedures

The antenna port of the EUT was connected to the spectrum analyzer through 30dB of attenuation. The resolution bandwidth (RBW) was set to 100kHz. The peak detector and 'Max-Hold' function were engaged. The emissions in the frequency range from 30MHz to 25GHz were observed and plotted with the EUT transmitting at 2441MHz.

5.2.5.3 Results

The results of the antenna conducted emissions levels were plotted. These plots are presented on pages 29 through 31. These plots show that the spurious emissions were at least 20 dB below the level of the fundamental.

5.2.6 Radiated Spurious Emissions Measurements

5.2.6.1 Requirements

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

5.2.6.2 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 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. The reading obtained with the 10 Hz video bandwidth may be further adjusted by a “duty cycle correction factor”, derived from 20*log(dwell time/100msec). These readings must be no greater than the limits specified in 15.209(a).

5.2.6.3 Results

Preliminary radiated emissions plots with the EUT transmitting at 2441MHz are shown on pages 32 through 39.

Final radiated emissions data are presented on data pages 40 through 42. 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 170.42MHz. The emissions level at this frequency was 4.3dB within the limit. Photographs of the test configuration which yielded the highest, or worst case, radiated emission levels are shown on Figures 4 through 6.

5.2.7 Band Edge Compliance

5.2.7.1 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).

5.2.7.2 Procedures

5.2.7.2.1 Low Band Edge

1) The antenna port of the EUT was connected to the spectrum analyzer through 30dB 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.
    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.

5.2.7.2.2 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.

5.2.7.3 Results

Pages 43 through 45 show the band-edge compliance results. As can be seen from these plots, the conducted 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.

5.2.8 Power Spectral Density

5.2.8.1 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.

5.2.8.2 Procedures

1) The antenna port of the EUT was connected to the spectrum analyzer through a 30dB pad.
2) The EUT was set to transmit at 2441MHz.
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.

Results

Page 46 shows the power spectral density results. As can be seen from this plot, the peak power density is less than 8dBm in a 3kHz band during any time interval of continuous transmission.

6. CONCLUSIONS

With a shielded cable with ferrite beads at both ends of the cable between the display and control module, it was determined that the Metrom Rail Cab Module, Part No. CM102 digital modulation transceiver, Serial No. None Assigned, 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, or 5725-5850 MHz band, when tested per ANSI C63.4-2014 and ANSI C63.10-2013.

With a shielded cable with ferrite beads at both ends of the cable between the display and control module, it was also determined that the Metrom Rail Cab Module, Part No. CM102 digital modulation transceiver, Serial No. None Assigned, did fully meet the conducted and radiated RF emission requirements of the Industry Canada Radio Standards Specification, RSS-Gen, Section 8.8 and Section 7.1.2 for receivers and the Industry Canada Radio Standards Specification RSS-Gen Section 8.8 and Radio Standards Specification RSS-247 for transmitters, when tested per ANSI C63.4-2014.

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
CDU2	LAPTOP COMPUTER	DELL	PRECISION	---	---	N/A	
CDX8	COMPUTER	ELITE	WORKSTATION			N/A	
MPW0	POWER METER	KEYSIGHT	8990B	MY51000388		2/5/2016	2/5/2017
MWPA	WIDEBAND POWER SENSOR	KEYSIGHT	N1923A	MY56080002	50MHZ-18GHZ	2/17/2016	2/17/2017
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
NWQ1	DOUBLE RIDGED WAVEGUIDE ANTENNA	ETS-LINDGREN	3117	66655	1GHZ-18GHZ	4/4/2016	4/4/2018
RAKG	RF SECTION	HEWLETT PACKARD	85462A	3549A00284	0.009-6500MHZ	2/22/2016	2/22/2017
RAKH	RF FILTER SECTION	HEWLETT PACKARD	85460A	3448A00324	---	2/22/2016	2/22/2017
RBA1	EMI TEST RECEIVER	ROHDE & SCHWARZ	ESIB26	100146	20HZ-26.5GHZ	2/12/2016	2/12/2017
SES0	24VDC POWER SUPPLY	P-TRANS	FS-32024-1M	001	18-27VDC	NOTE 1	
T1E0	10DB 25W ATTENUATOR	WEINSCHEL	46-10-43	AU1882	DC-18GHZ	5/2/2016	5/2/2017
T1P0	10dB ATTENUATOR (40GHz)	WEINSCHEL	89-10-12	254	DC-40GHz	3/3/2016	3/3/2018
T2DS	20DB, 25W ATTENUATOR	WEINSCHEL	46-20-34	BS0916	DC-18GHZ	6/9/2016	6/9/2018
T2Q0	20DB, 20W ATTENUATOR	AEROFLEX/WEINSCHEL	89-20-21	337	DC-40GHZ	8/20/2015	8/20/2017
XOB2	ADAPTER	HEWLETT PACKARD	K281C,012	09407	18-26.5GHZ	NOTE 1	

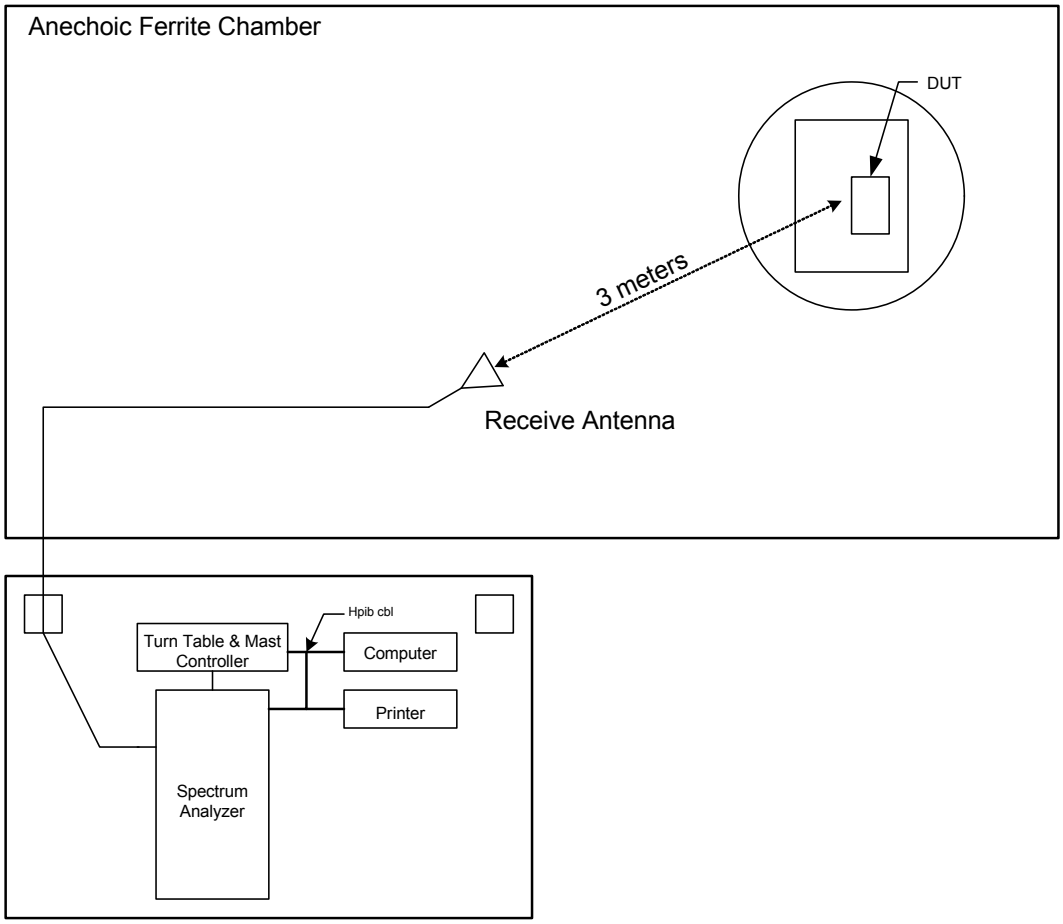


FIGURE 1 BLOCKDIAGRAM OF TEST SETUP

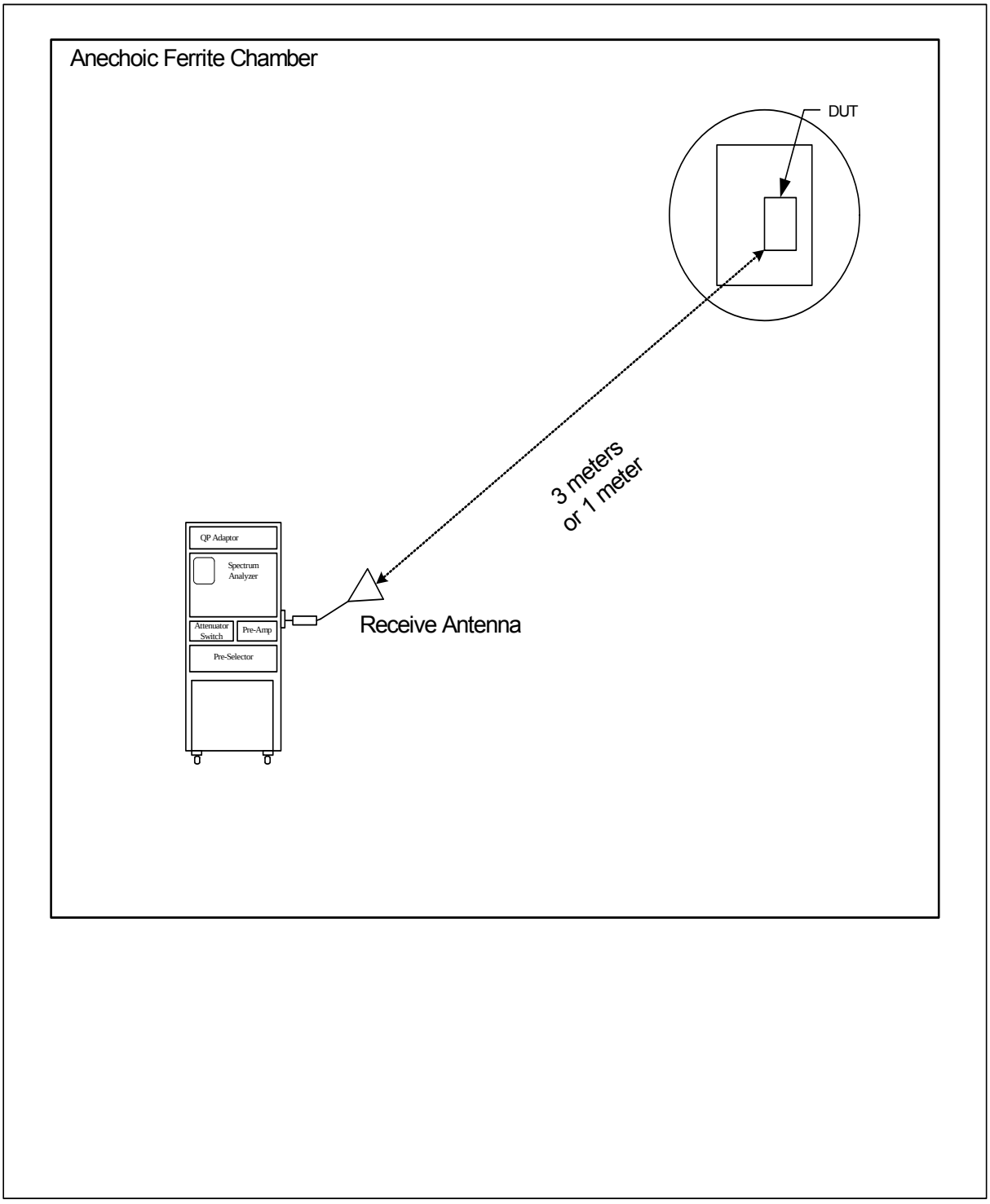


Figure 2: BLOCK DIAGRAM OF TEST SETUP FOR RADIATED EMISSIONS ABOVE 18GHZ

Figure 3

Photograph of the EUT

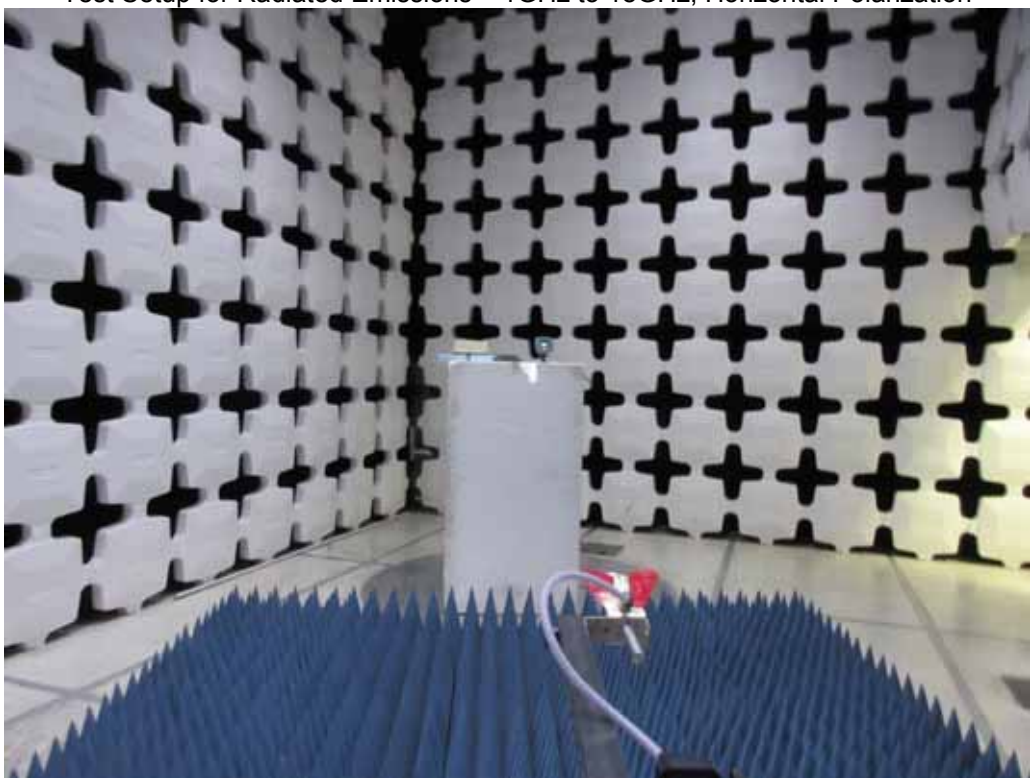
Figure 4

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

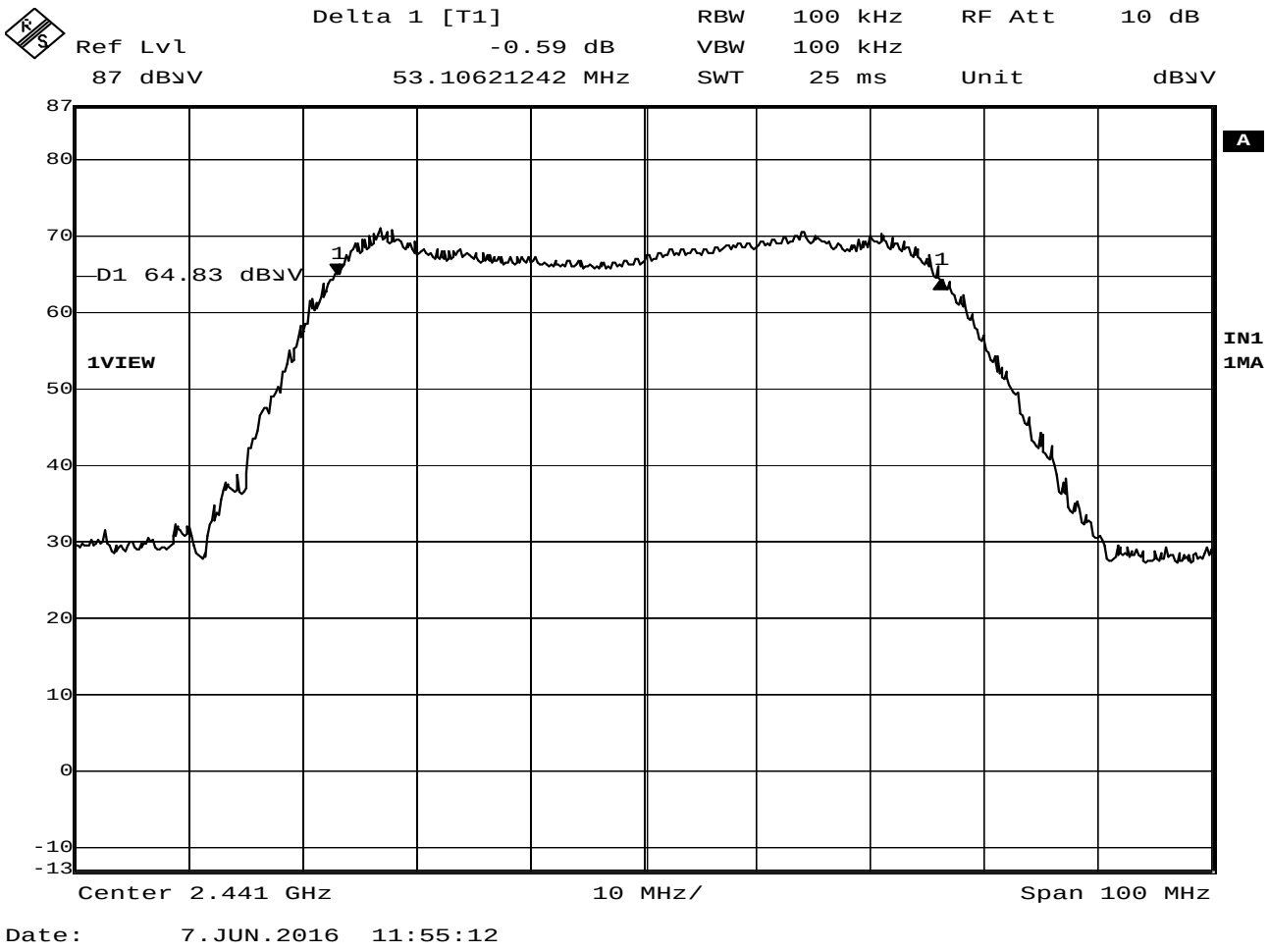


Test Setup for Radiated Emissions – 1GHz to 18GHz, Vertical Polarization

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 (DTS Bandwidth)

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	6dB (DTS) bandwidth = 53.11MHz
EQUIPMENT USED	:	RBA1, T2DS, T1E0

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, Peak Output Power
Date : June 6, 2016
Equipment Used : MPW0, MWPA, T2DS, T1E0
Notes : Antenna Port Conducted Emissions Tests
Notes : Peak Power Readings with a Peak Power Meter

Frequency MHz	Peak Power Reading dBm	Attenuator dB	Peak Output Power dBm	Peak Output Power Limit dBm
2441	-15.68	29.76	14.08	24.5

Peak Output Power (dBm) = Peak Power Reading (dBm) + Attenuator (dB)

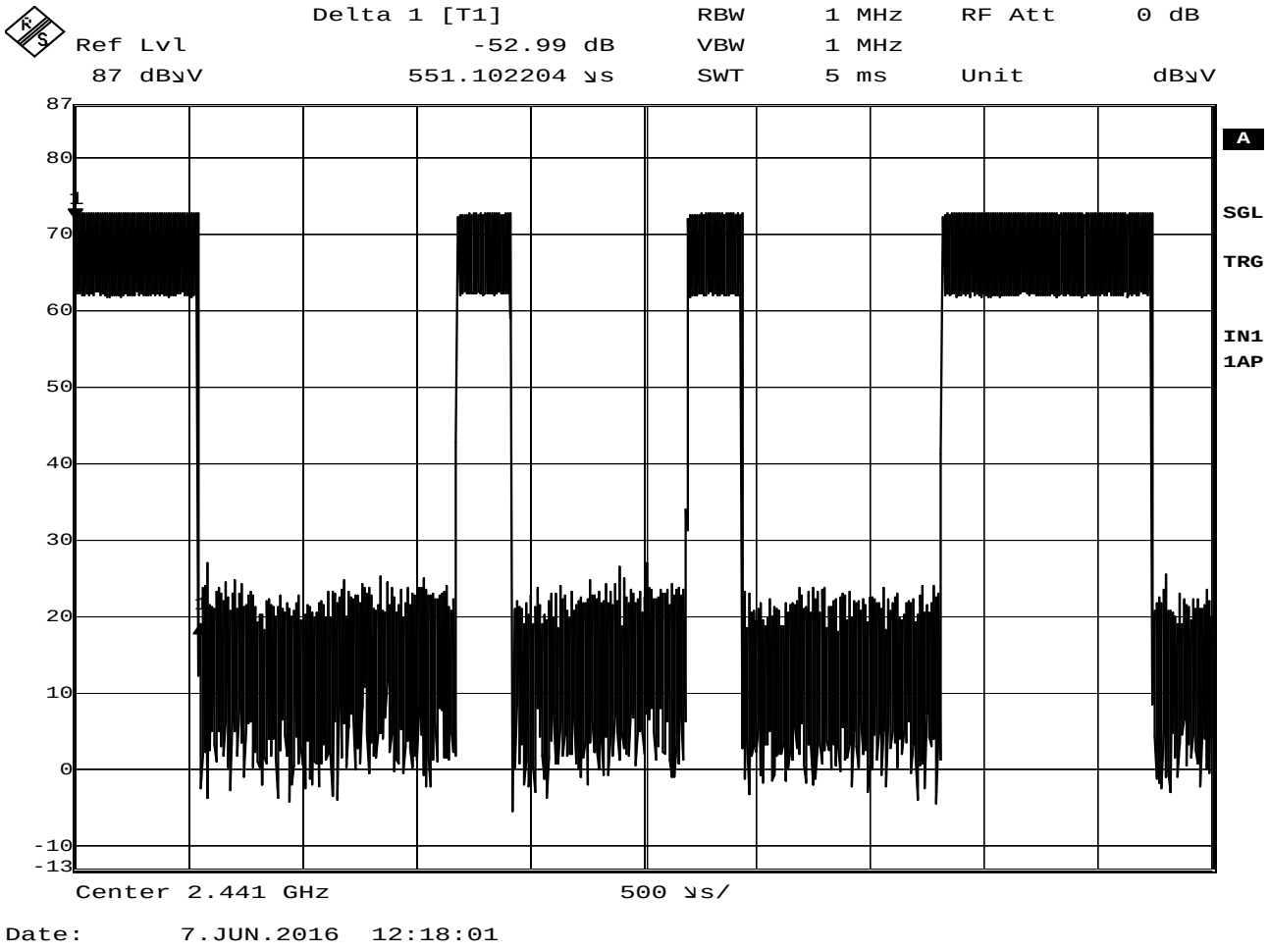
Peak Output Power Limits (dBm) = 30dBm – (the amount in dB that the directional gain of the antenna exceeds 6 dBi).

The nominal gain of the antenna was 11.5dBi. That exceeds 6dBi by 5.5dB. Therefore the limit is reduced by 5.5dB from 30dBm.

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, EIRP
Date : June 6, 2016
Equipment Used : MPW0, MWPA, T2DS, T1E0
Notes : Antenna Port Conducted Emissions Tests
Notes : Peak Power Readings with a Peak Power Meter

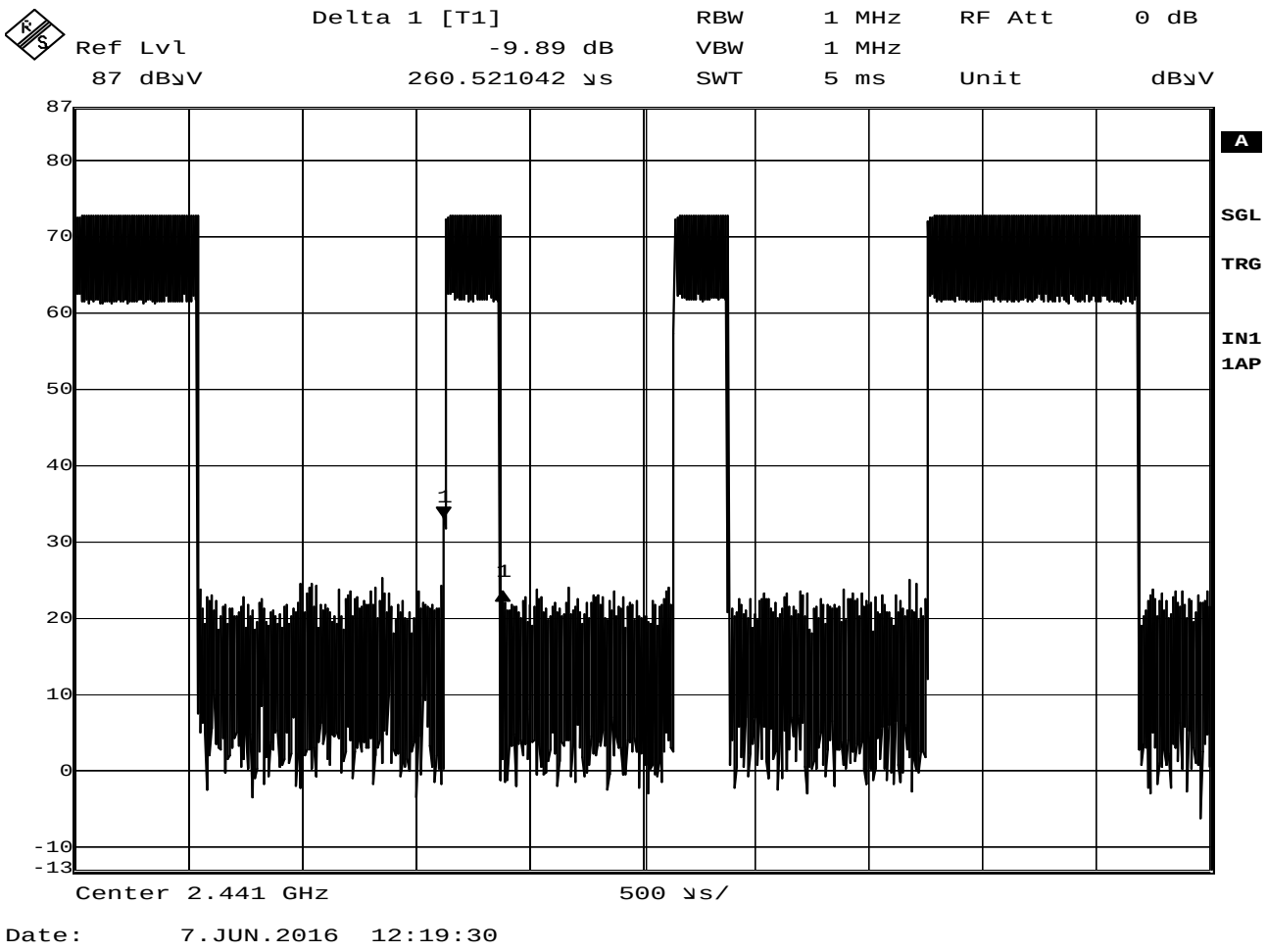
Frequency MHz	Peak Power Reading dBm	Attenuator dB	Peak Output Power dBm	Antenna Gain dBi	Peak EIRP dBm	EIRP Limit dBm
2441	-15.68	29.76	14.08	11.5	25.58	36.0

Peak EIRP (dBm) = Peak Power Reading (dBm) + Attenuation (dB) + Antenna Gain (dB)



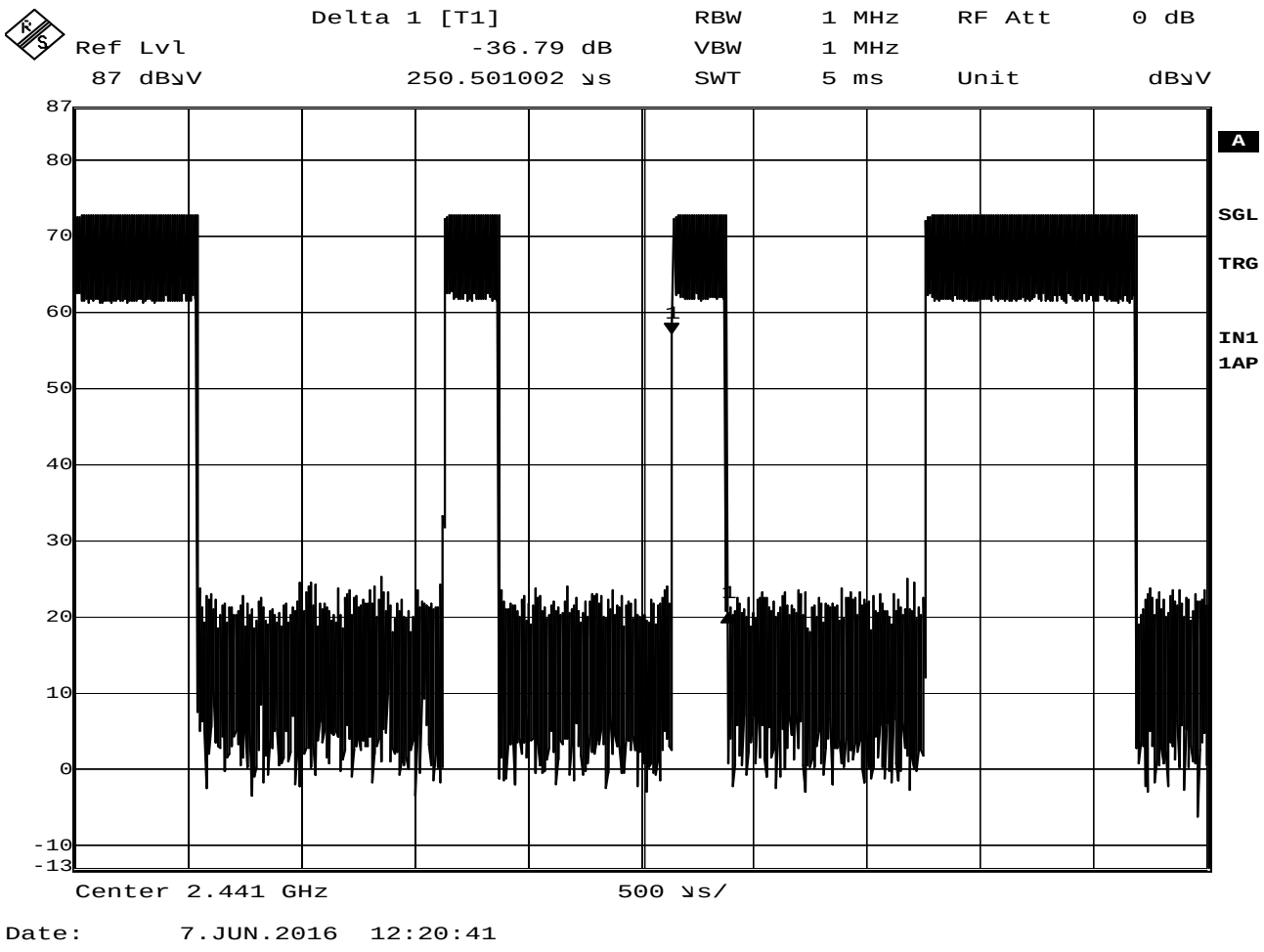
FCC 15.247 Duty Cycle Factor

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Pulse 1 is 551.1usec
EQUIPMENT USED	:	RBA1, T2DS, T1E0



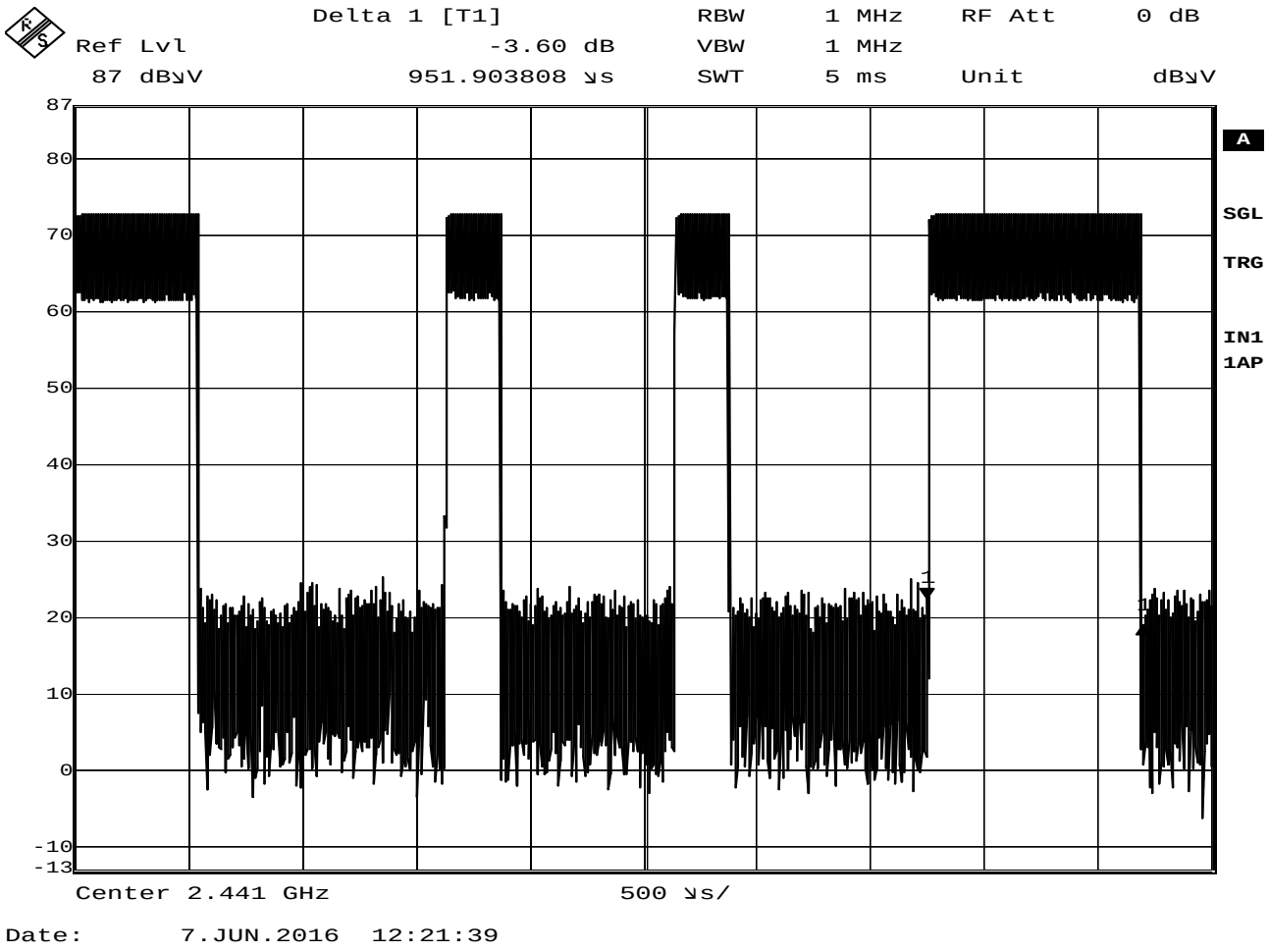
FCC 15.247 Duty Cycle Factor

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Pulse 2 = 260.5usec
EQUIPMENT USED	:	RBA1, T2DS, T1E0



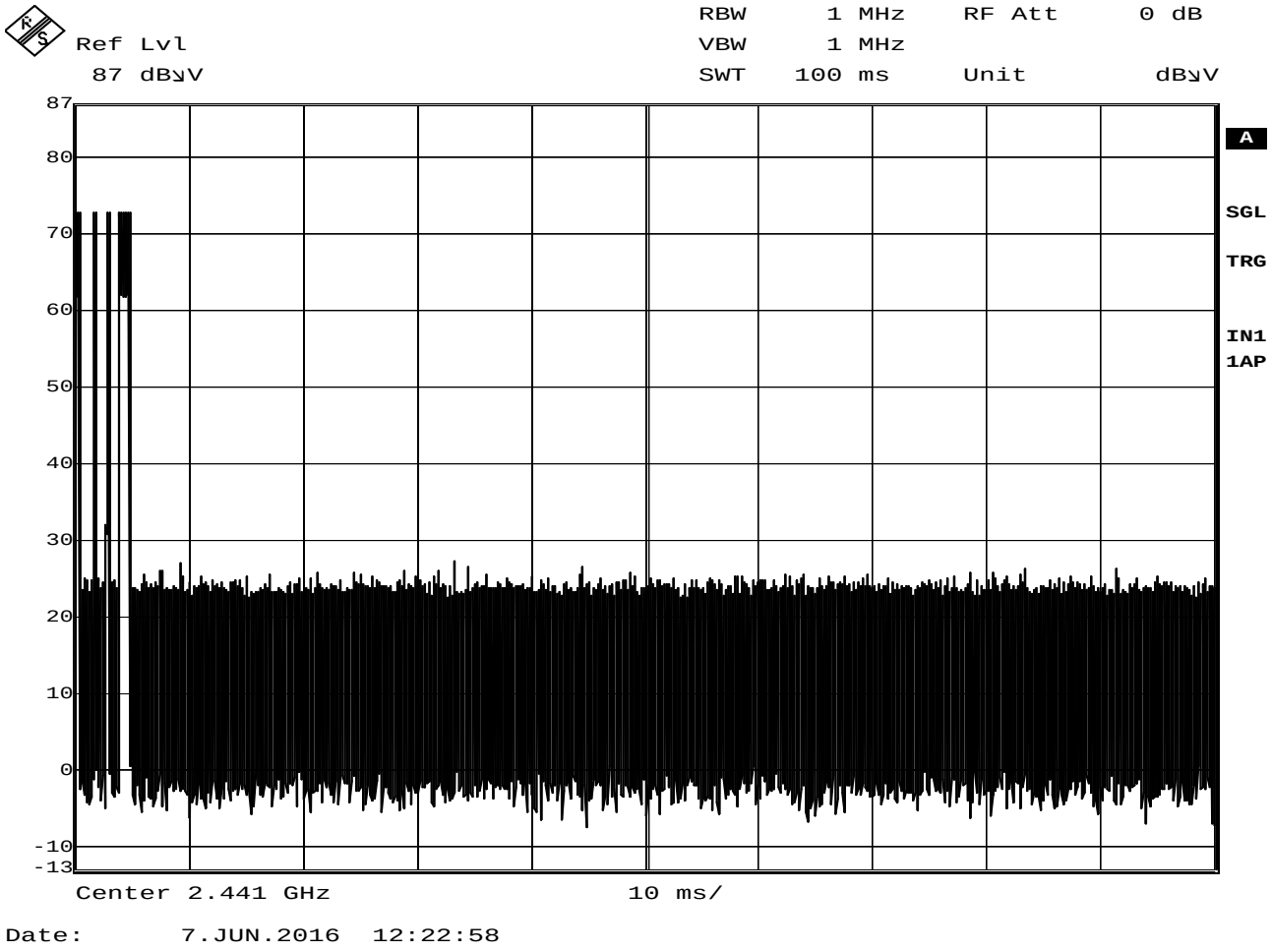
FCC 15.247 Duty Cycle Factor

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Pulse 3 = 250.5usec
EQUIPMENT USED	:	RBA1, T2DS, T1E0



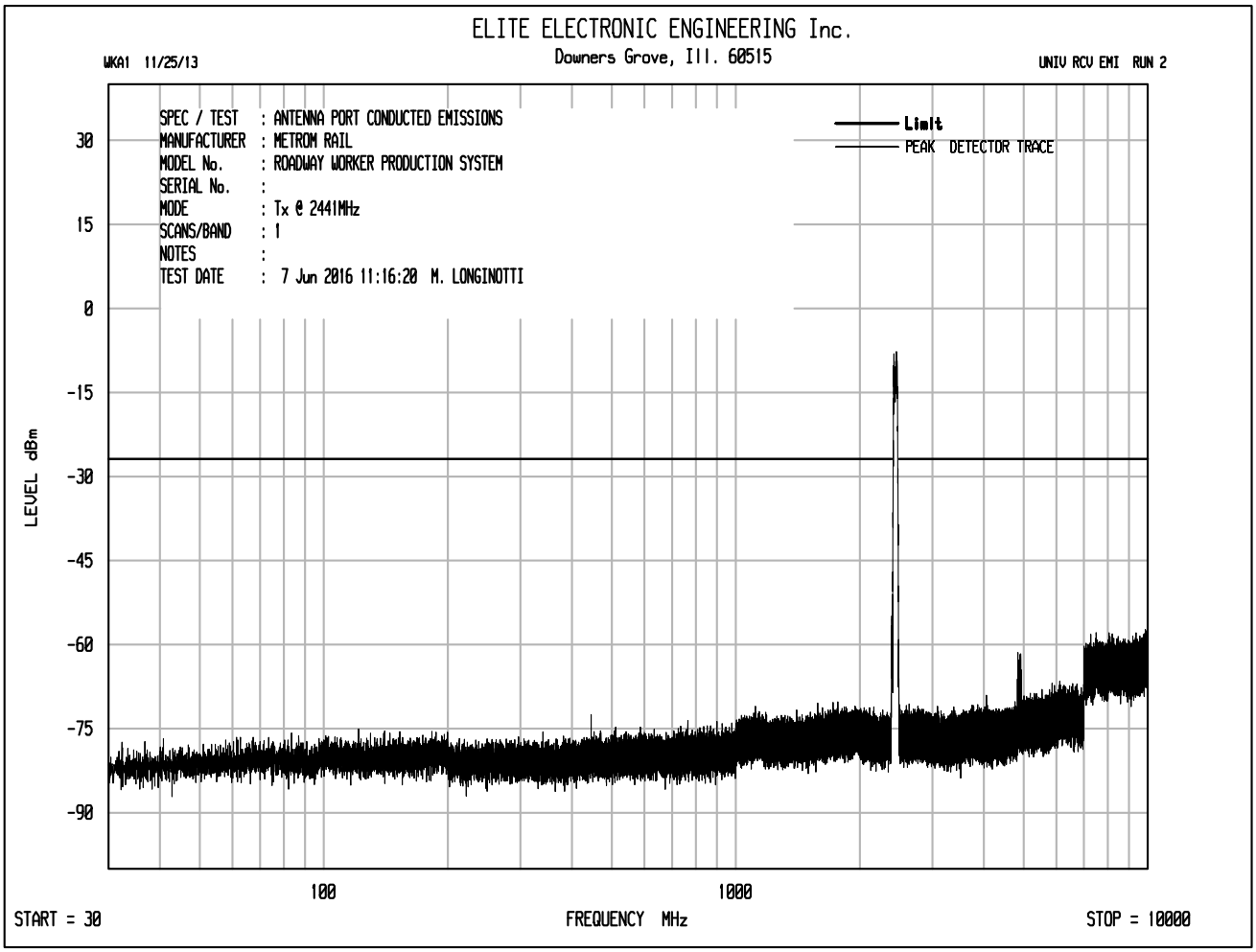
FCC 15.247 Duty Cycle Factor

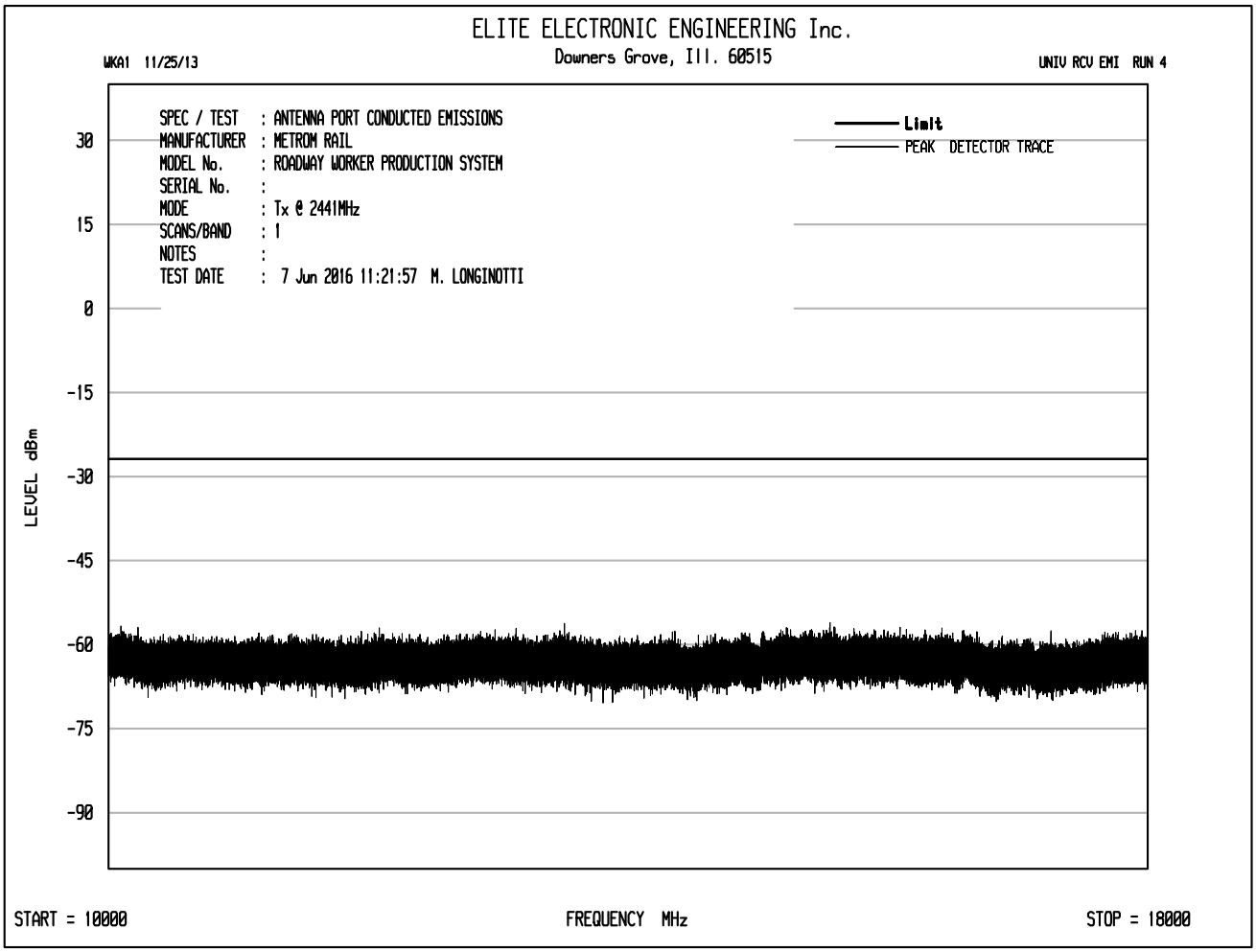
MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Pulse 3 = 250.5usec
EQUIPMENT USED	:	RBA1, T2DS, T1E0

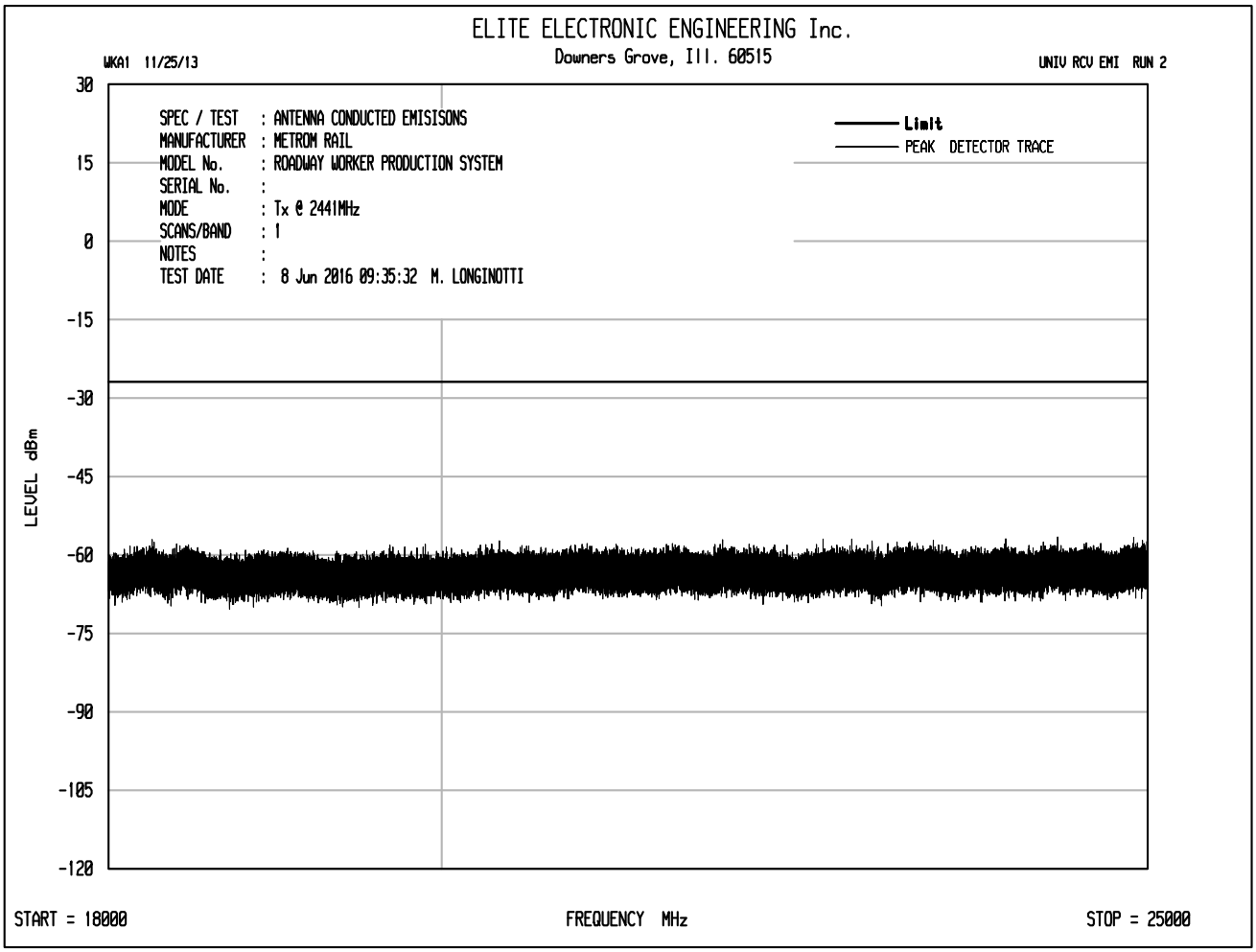


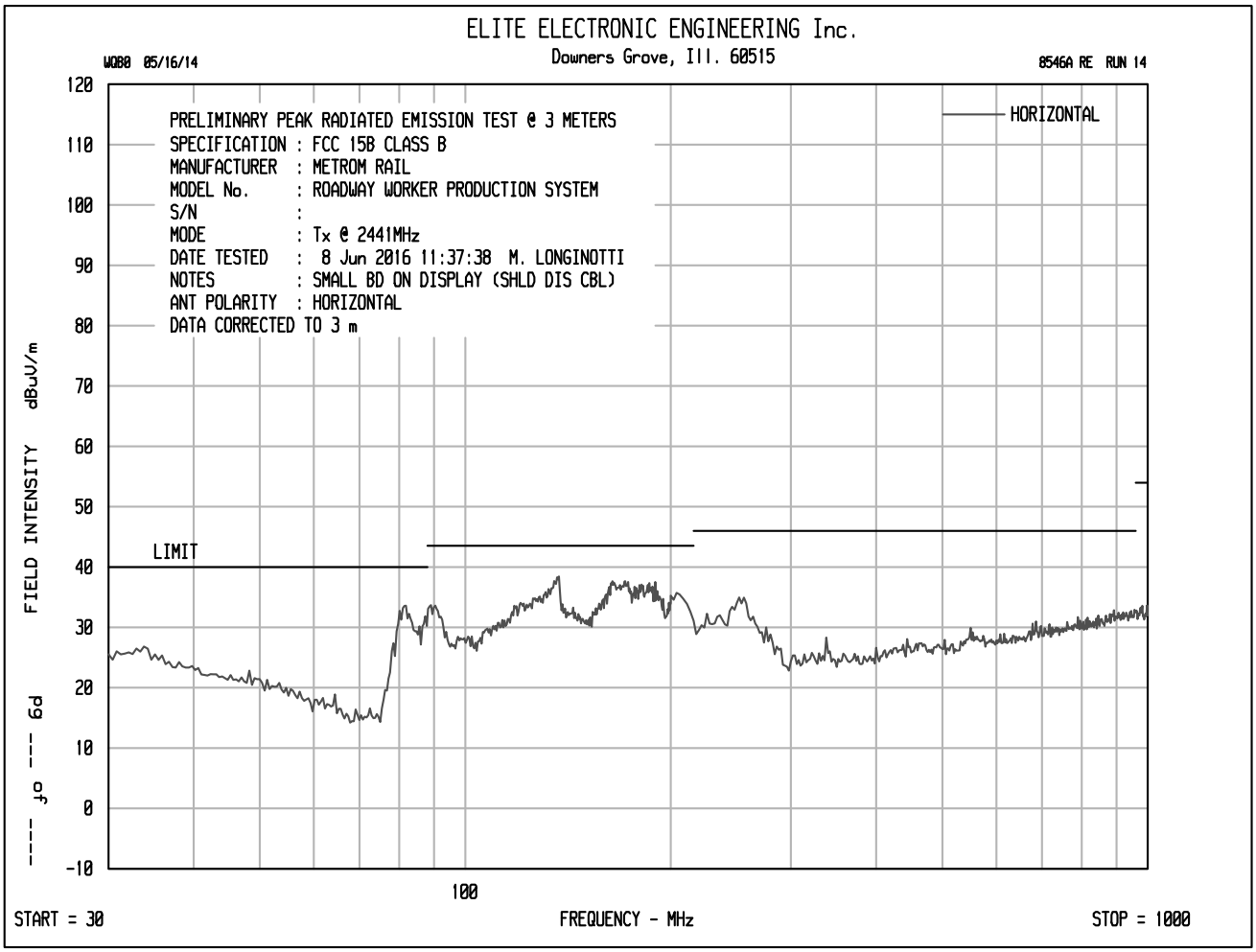
FCC 15.247 Duty Cycle Factor

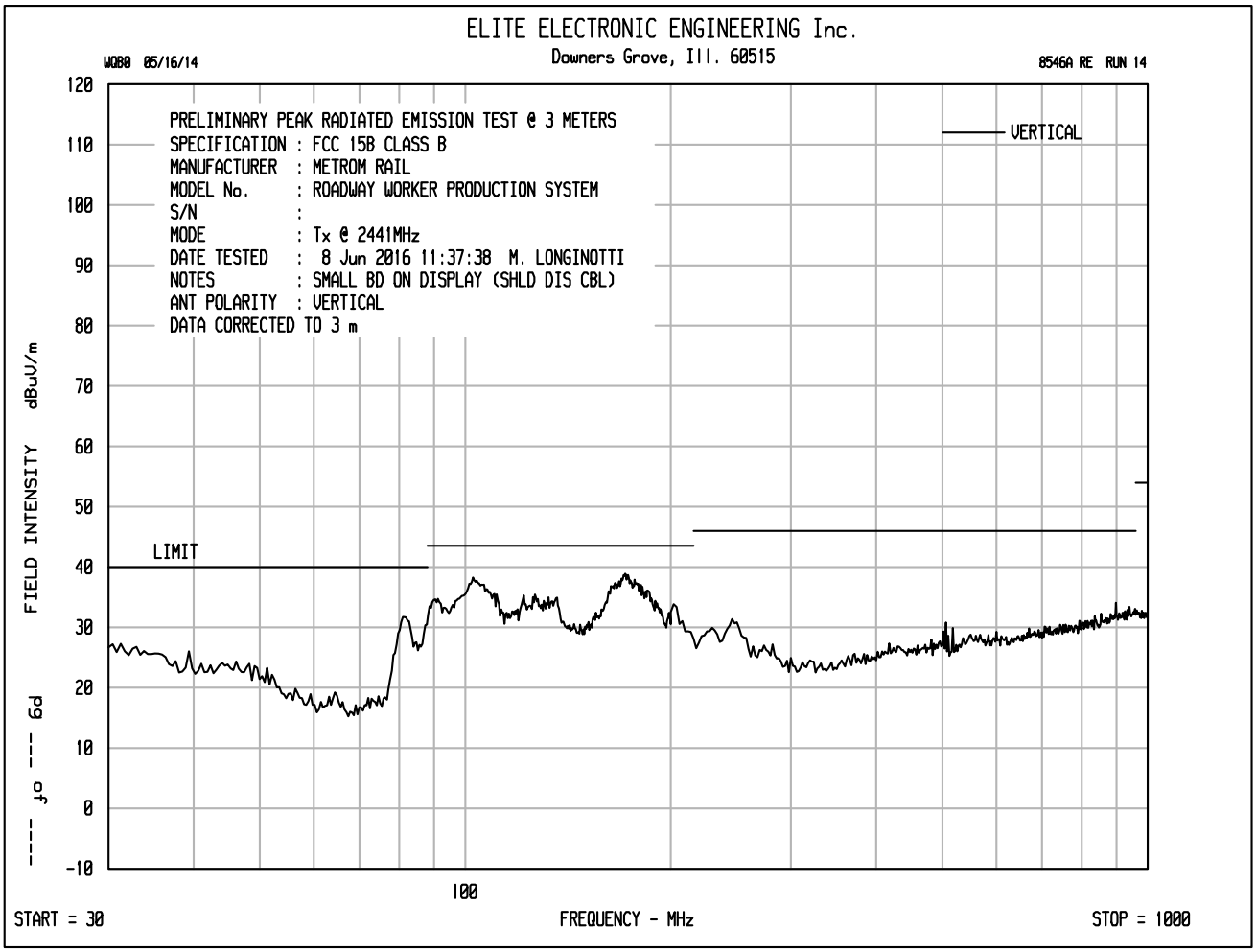
MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	1 transmission in 100msec
	:	Duty Cycle Correction Factor = 20log(pulse 1 + pulse 2 + pulse 3 + pulse 4) x
	:	(number transmissions in 100msec/100msec)
	:	Duty Cycle Correction Factor = 20log(551usec + 260.5usec + 250.5 usec +
	:	950.9usec) x 1 transmission /100msec
	:	Duty Cycle Correction Factor = -33.92dB
EQUIPMENT USED	:	RBA1, T2DS, T1E0

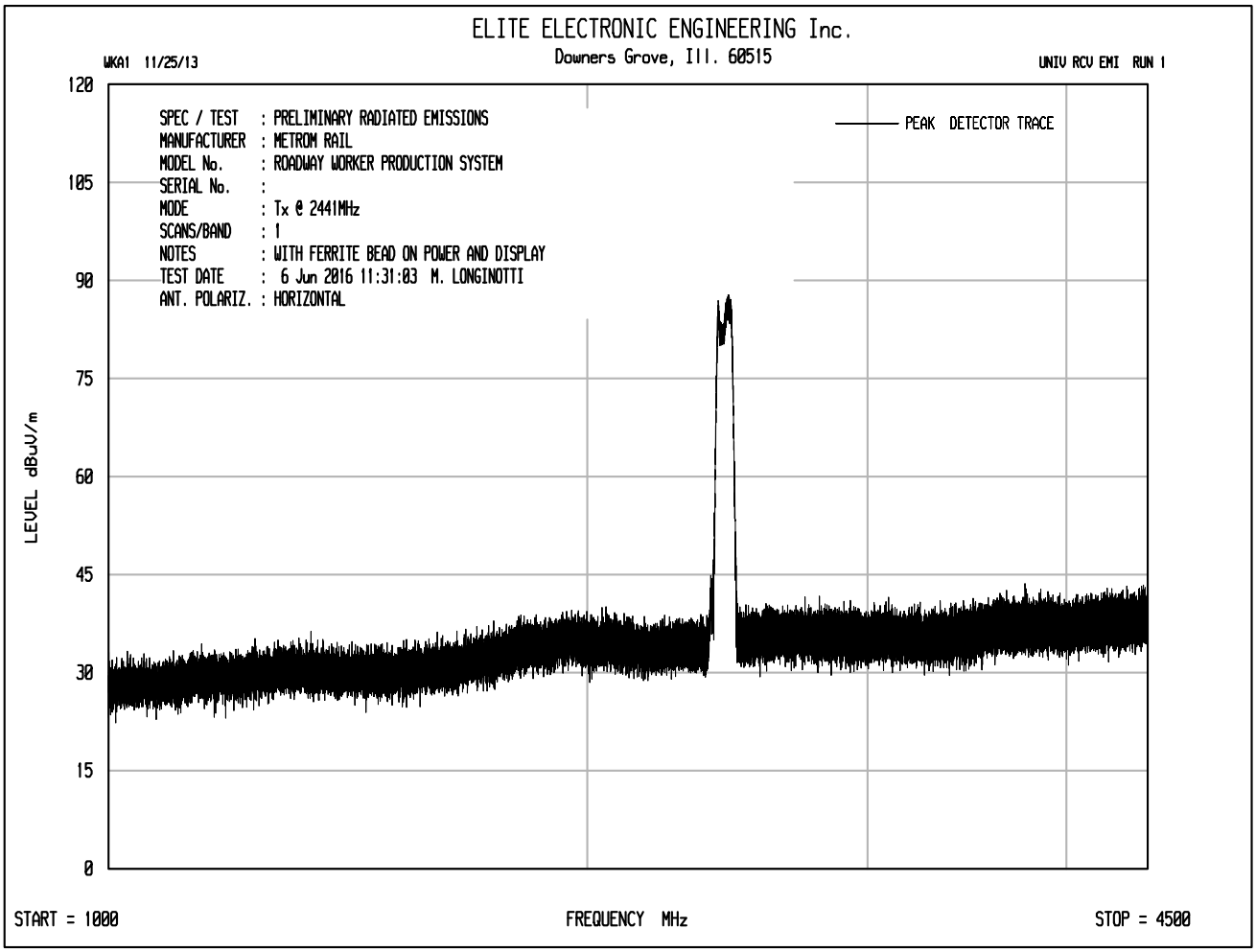

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 2
SPEC / TEST : ANTENNA PORT CONDUCTED EMISSIONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES :
TEST DATE : 7 Jun 2016 11:16:20 M. LONGINOTTI
Limit
PEAK DETECTOR TRACE
LEVEL dBm
30
15
0
-15
-30
-45
-60
-75
-90
100
1000
START = 30
FREQUENCY MHz
STOP = 10000

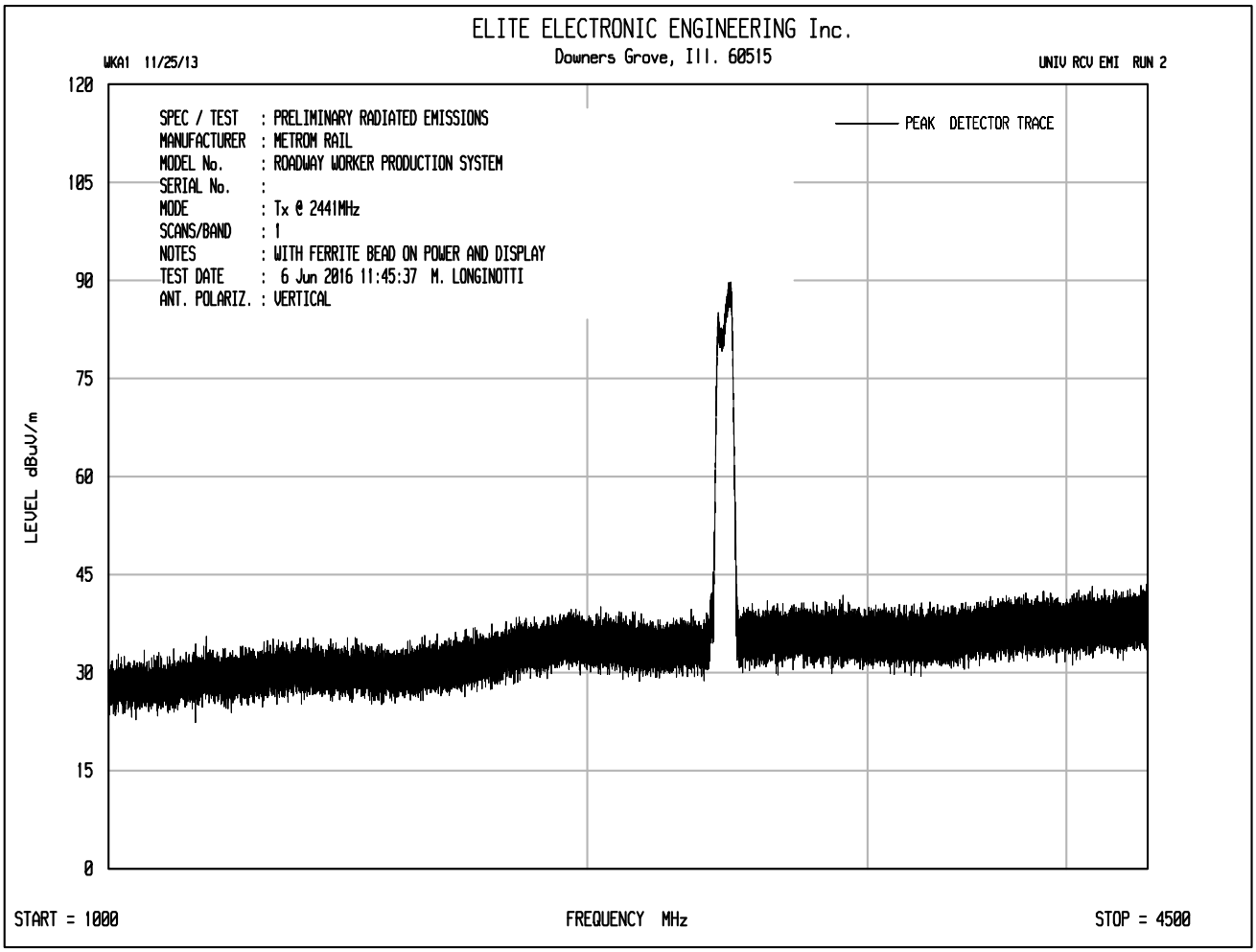

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 4
SPEC / TEST : ANTENNA PORT CONDUCTED EMISSIONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES :
TEST DATE : 7 Jun 2016 11:21:57 M. LONGINOTTI
Limit
PEAK DETECTOR TRACE
30
15
0
-15
-30
-45
-60
-75
-90
LEVEL dBm
START = 10000
FREQUENCY MHz
STOP = 18000

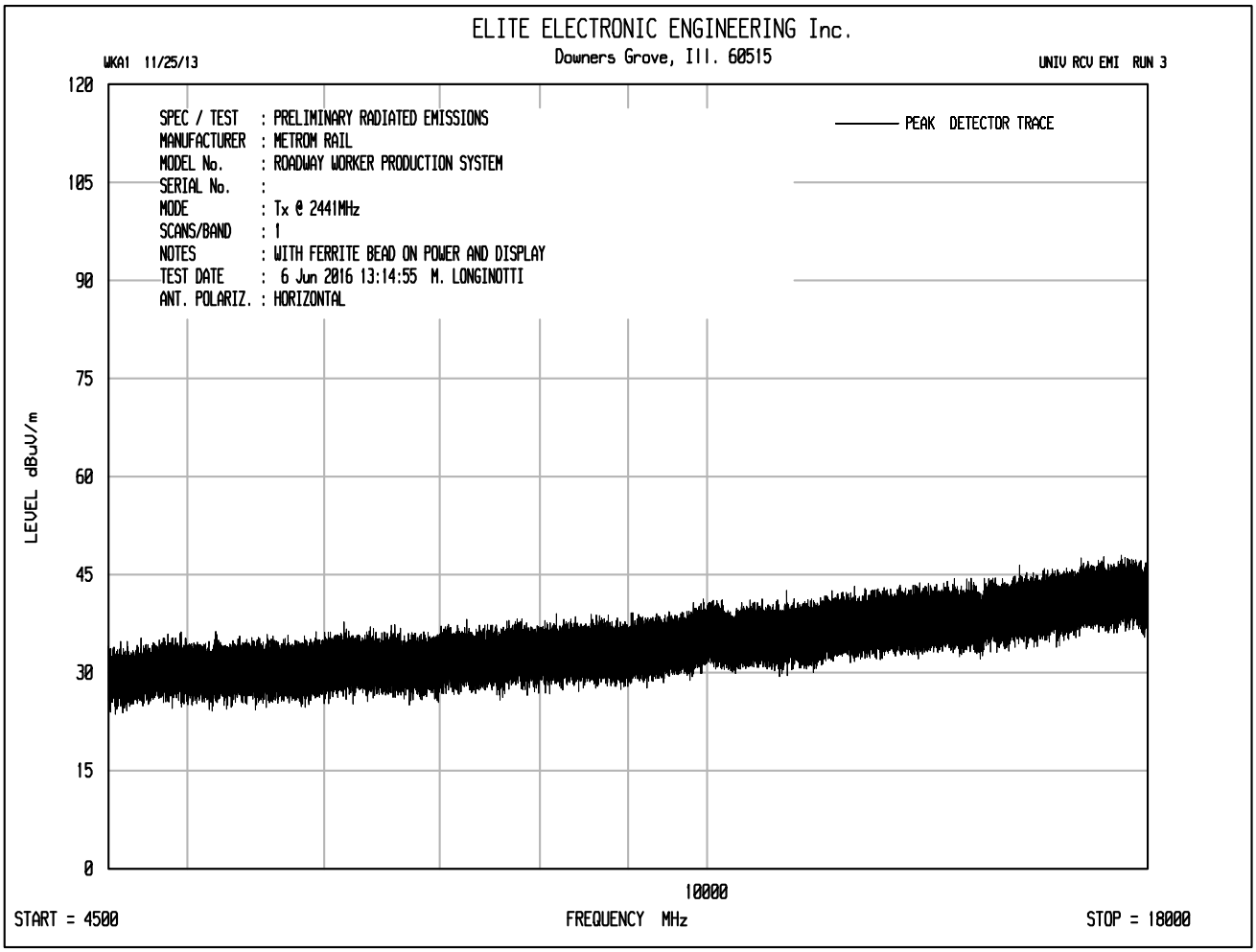

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 2
SPEC / TEST : ANTENNA CONDUCTED EMISISONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES :
TEST DATE : 8 Jun 2016 09:35:32 M. LONGINOTTI
Limit
PEAK DETECTOR TRACE
30
15
0
-15
-30
-45
-60
-75
-90
-105
-120
LEVEL dBm
START = 18000
FREQUENCY MHz
STOP = 25000

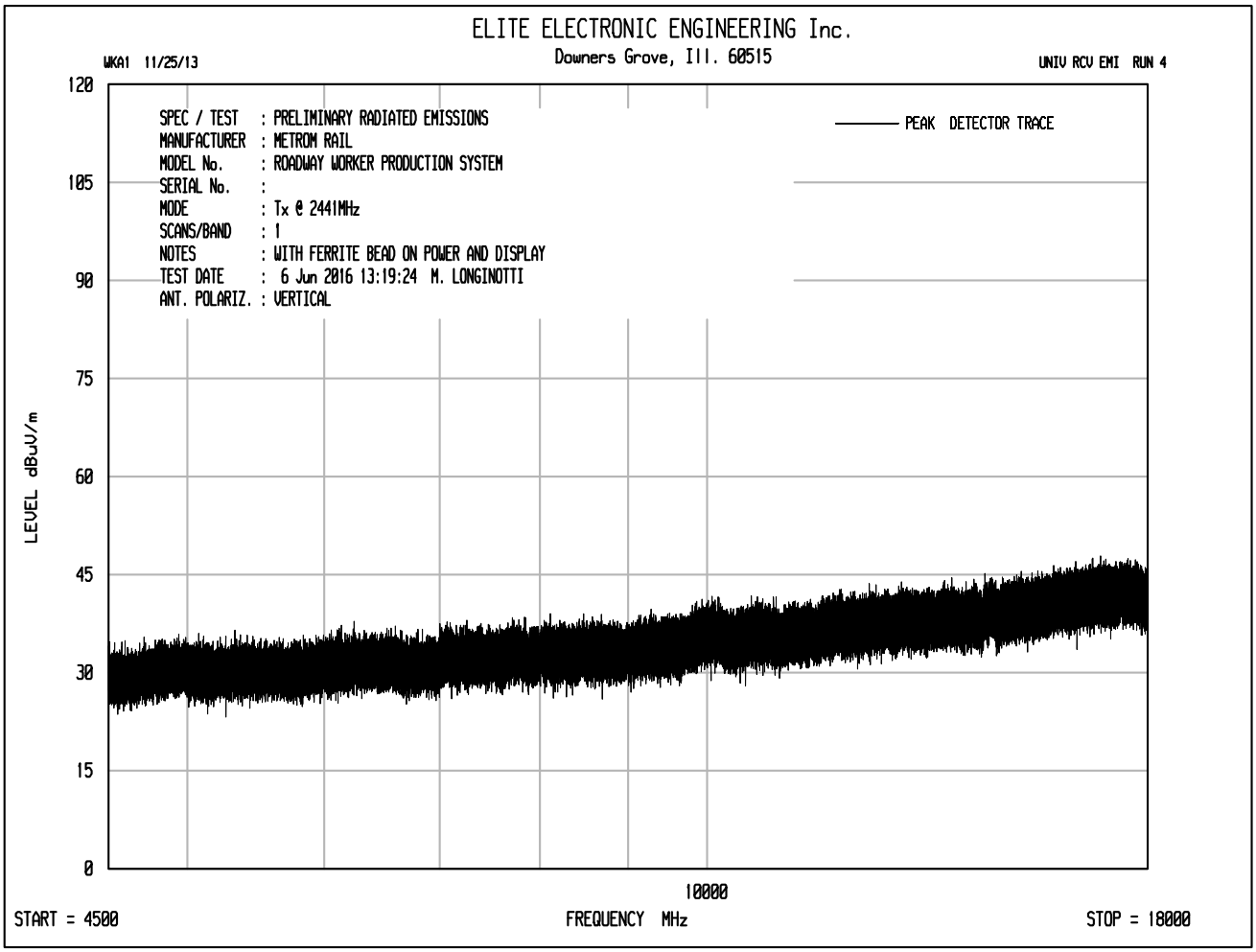

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
W080 05/16/14
8546A RE RUN 14
PRELIMINARY PEAK RADIATED EMISSION TEST @ 3 METERS
SPECIFICATION : FCC 15B CLASS B
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
S/N :
MODE : Tx @ 2441MHz
DATE TESTED : 8 Jun 2016 11:37:38 M. LONGINOTTI
NOTES : SMALL BD ON DISPLAY (SHLD DIS CBL)
ANT POLARITY : HORIZONTAL
DATA CORRECTED TO 3 m
HORIZONTAL
LIMIT
FIELD INTENSITY dBµV/m
---- µo --- 6d
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
100
START = 30
FREQUENCY - MHz
STOP = 1000

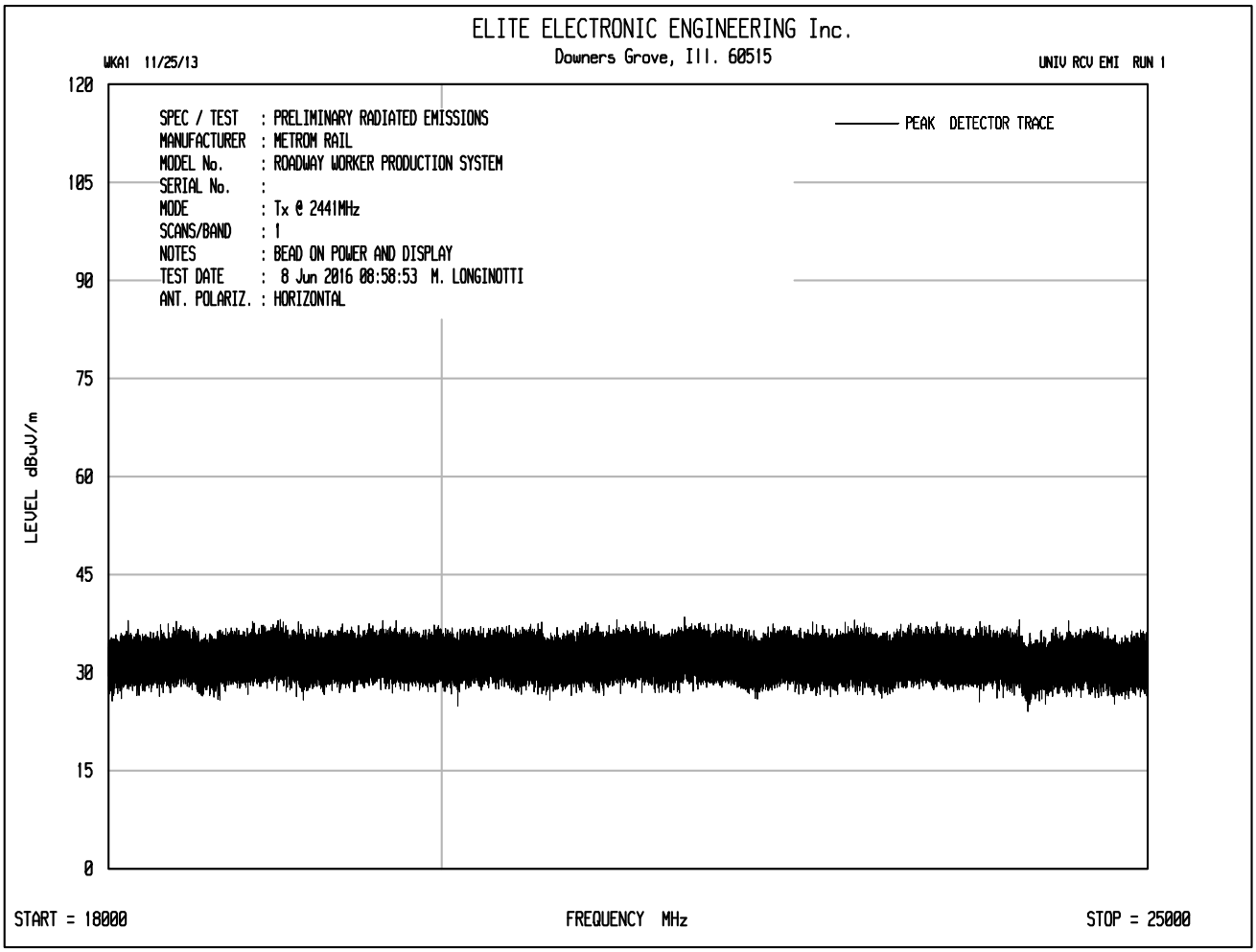

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
W080 05/16/14
8546A RE RUN 14
PRELIMINARY PEAK RADIATED EMISSION TEST @ 3 METERS
SPECIFICATION : FCC 15B CLASS B
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
S/N :
MODE : Tx @ 2441MHz
DATE TESTED : 8 Jun 2016 11:37:38 M. LONGINOTTI
NOTES : SMALL BD ON DISPLAY (SHLD DIS CBL)
ANT POLARITY : VERTICAL
DATA CORRECTED TO 3 m
VERTICAL
LIMIT
FIELD INTENSITY dBµV/m
---- µo --- 6d
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
100
START = 30
FREQUENCY - MHz
STOP = 1000

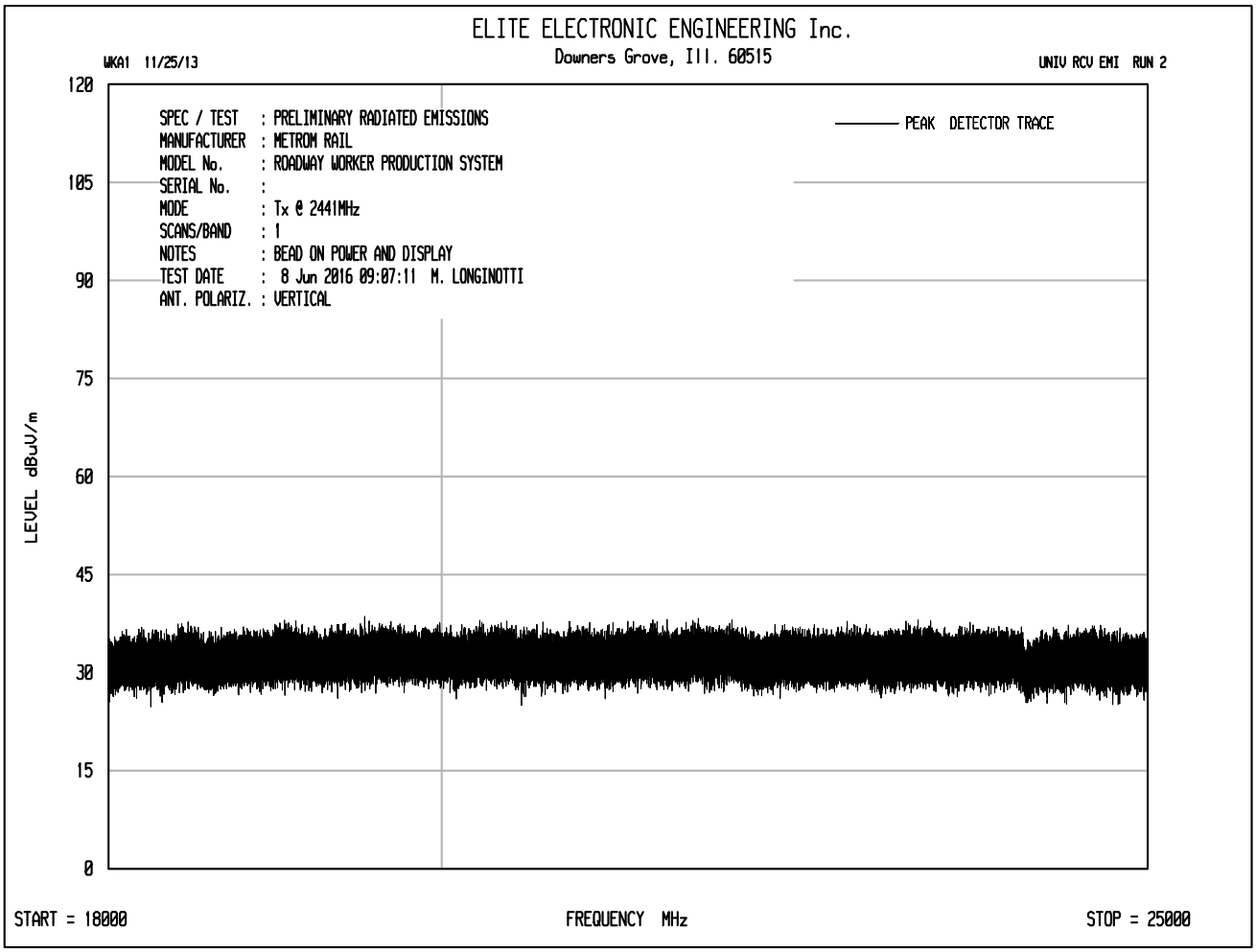

ELITE ELECTRONIC ENGINEERING Inc.
Downers Grove, Ill. 60515
WKA1 11/25/13
UNIV RCV EMI RUN 1
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : WITH FERRITE BEAD ON POWER AND DISPLAY
TEST DATE : 6 Jun 2016 11:31:03 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 : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : WITH FERRITE BEAD ON POWER AND DISPLAY
TEST DATE : 6 Jun 2016 11:45:37 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 : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : WITH FERRITE BEAD ON POWER AND DISPLAY
TEST DATE : 6 Jun 2016 13:14:55 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 : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : WITH FERRITE BEAD ON POWER AND DISPLAY
TEST DATE : 6 Jun 2016 13:19:24 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 1
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : BEAD ON POWER AND DISPLAY
TEST DATE : 8 Jun 2016 08:58:53 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 2
SPEC / TEST : PRELIMINARY RADIATED EMISSIONS
MANUFACTURER : METROM RAIL
MODEL No. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL No. :
MODE : Tx @ 2441MHz
SCANS/BAND : 1
NOTES : BEAD ON POWER AND DISPLAY
TEST DATE : 8 Jun 2016 09:07:11 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

ETR No. 8546A
DATA SHEET TEST NO. 14

RESTRICTED BAND RADIATED QP EMISSION MEASUREMENTS in a 3 m SEMI-ANECHOIC ROOM
SPECIFICATION : FCC 15B CLASS B
MANUFACTURER : METROM RAIL
MODEL NO. : ROADWAY WORKER PRODUCTION SYSTEM
SERIAL NO. :
TEST MODE : Tx @ 2441MHz
NOTES : SMALL BD ON DISPLAY (SHLD DIS CBL)
TEST DATE : 8 Jun 2016 11:37:38
TEST DISTANCE : 3 m

FREQUENCY MHz	QP READING dBuV	ANT FAC dB	CBL FAC dB	EXT ATTN dB	DIST FAC dB	TOTAL dBuV/m	QP LIMIT dBuV/m	AZ deg	ANT HT cm	ANT POL
135.56	19.8	17.8	.5	0.0	0.0	38.2	43.5	0	200	H
163.78	20.1	16.0	.7	0.0	0.0	36.7	43.5	90	200	H
170.42	23.0	15.6	.7	0.0	0.0	39.2	43.5	90	120	V
254.27	13.7	18.4	.8	0.0	0.0	32.9	46.0	180	120	H

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : June 6, 2016 through June 8, 2016
Test Distance : 3 meters
Notes : Peak Detector with 1MHz Resolution Bandwidth

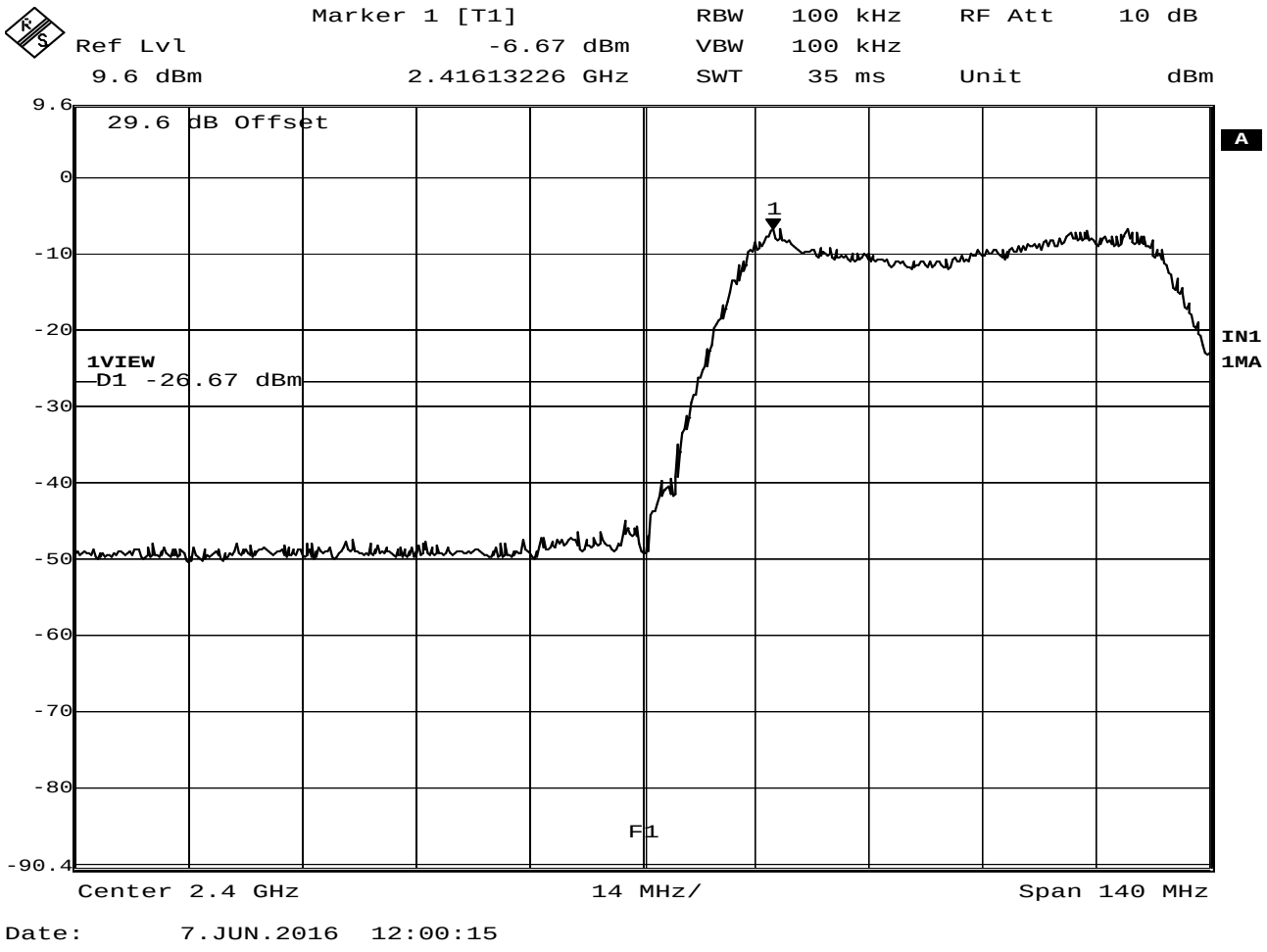
Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
4882.00	H	49.9	Ambient	3.7	34.8	-39.3	49.0	283.4	5000.0	-24.9
4882.00	V	49.4	Ambient	3.7	34.8	-39.3	48.5	267.6	5000.0	-25.4
7323.00	H	48.8	Ambient	4.7	35.6	-39.4	49.6	303.5	5000.0	-24.3
7323.00	V	48.8	Ambient	4.7	35.6	-39.4	49.6	303.5	5000.0	-24.3
12205.00	H	48.4	Ambient	6.1	39.0	-39.1	54.4	523.8	5000.0	-19.6
12205.00	V	48.9	Ambient	6.1	39.0	-39.1	54.9	554.8	5000.0	-19.1
19528.00	H	33.9	Ambient	2.2	40.4	-28.5	48.0	252.1	5000.0	-25.9
19528.00	V	33.8	Ambient	2.2	40.4	-28.5	47.9	249.2	5000.0	-26.0

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

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, RSS-247 Average Radiated Emissions in Restricted Bands
Date : June 6, 2016 through June 8, 2016
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)	Duty Cycle (dB)	Average Total dBuV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
4882.00	H	36.2	Ambient	3.7	34.8	-39.3	-33.9	1.4	1.2	500.0	-52.5
4882.00	V	36.2	Ambient	3.7	34.8	-39.3	-33.9	1.4	1.2	500.0	-52.5
7323.00	H	36.30	Ambient	4.7	35.6	-39.4	-33.9	3.2	1.5	500.0	-50.7
7323.00	V	36.3	Ambient	4.7	35.6	-39.4	-33.9	3.2	1.5	500.0	-50.7
12205.00	H	36.1	Ambient	6.1	39.0	-39.1	-33.9	8.2	2.6	500.0	-45.8
12205.00	V	36.2	Ambient	6.1	39.0	-39.1	-33.9	8.3	2.6	500.0	-45.7
19528.00	H	22.3	Ambient	2.2	40.4	-28.5	-33.9	2.5	1.3	500.0	-51.4
19528.00	V	22.5	Ambient	2.2	40.4	-28.5	-33.9	2.7	1.4	500.0	-51.2

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



FCC 15.247 Band Edge

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Display Line (D1) represents the level 20 dB below that in the 100 kHz bandwidth
	:	within the band that contains the highest level of the desired power. Display Line
	:	(F1) represents the band edge (2400MHz).
EQUIPMENT USED	:	RBA1, T2DS, T1E0

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, RSS-247 Band Edge
Date : June 6, 2016 through June 8, 2016
Test Distance : 3 meters
Notes : Peak Detector with 1MHz Resolution Bandwidth

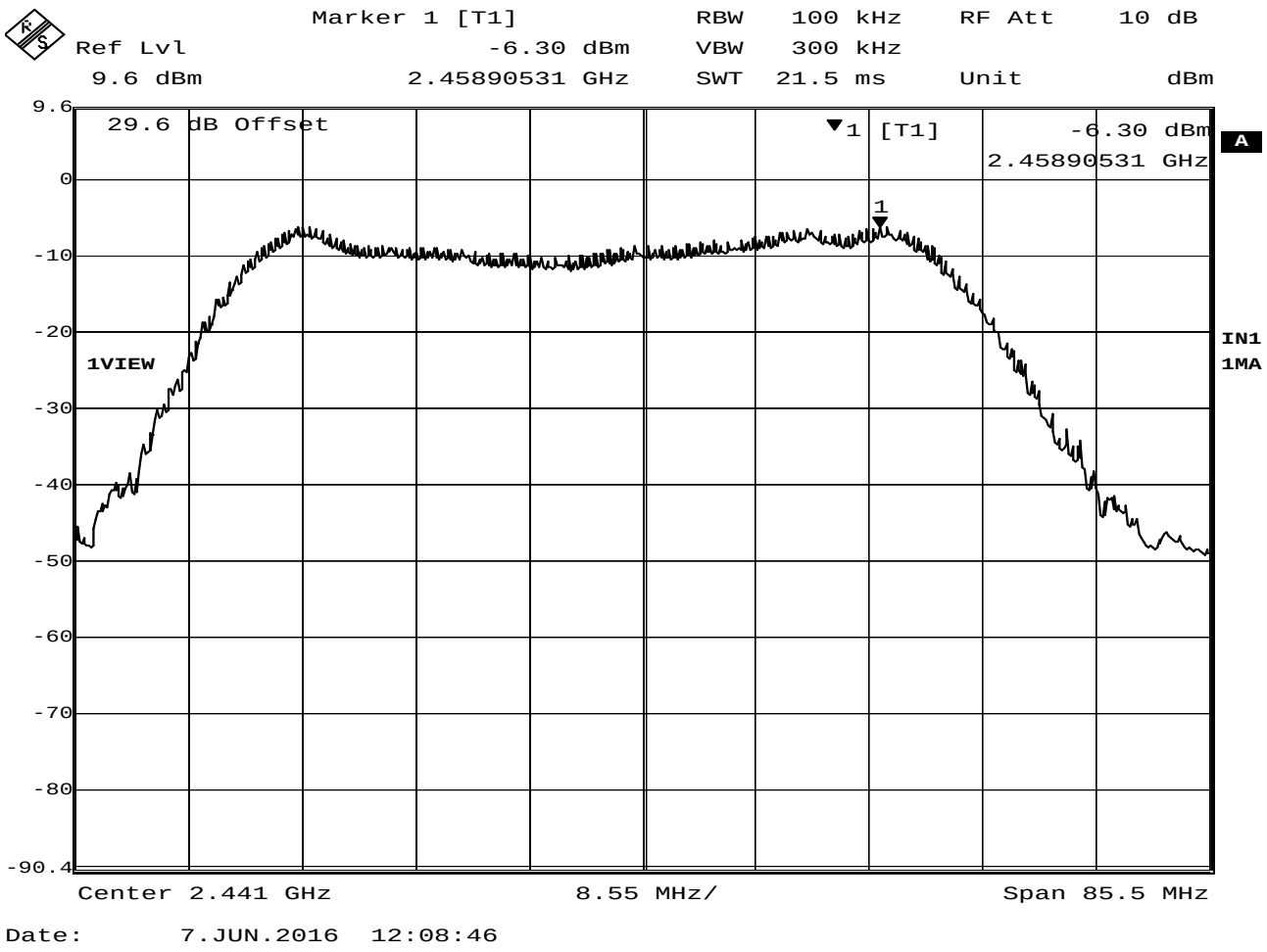
Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
2483.60	H	15.1		2.7	32.4	0.0	50.1	321.2	5000.0	-23.8
2483.60	V	15.4		2.7	32.4	0.0	50.4	332.5	5000.0	-23.5

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

Manufacturer : Metrom Rail
Test Item : Cab Module
Model No. : CM102
Serial No. : None Assigned
Mode : Transmit at 2441MHz
Test Specification : FCC-15.247, RSS-247 Average Radiated Emissions in Restricted Bands
Date : June 6, 2016 through June 8, 2016
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)	Duty Cycle (dB)	Average Total dBuV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
2483.60	H	4.2		2.7	32.4	0.0	-33.9	5.3	1.8	500.0	-48.6
2483.60	V	6.0		2.7	32.4	0.0	-33.9	7.1	2.3	500.0	-46.8

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



FCC 15.247 Power Spectral Density

MANUFACTURER	:	Metrom Rail
MODEL NUMBER	:	Roadway Worker Production System
TEST MODE	:	Transmit at 2441MHz
NOTES	:	Power Spectral Density = -6.3dBm in a 100kHz bandwidth
EQUIPMENT USED	:	RBA1, T2DS, T1E0