Test Report No: 01-11-35005/499

Electromagnetic Compatibility
Of A
Machine Security System (MSS)
156-6155

Customer: **Caterpillar, Inc.**
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Electromagnetic Compatibility Of A Machine Security System (MSS)

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Report Date: 6-29-01

FCC Registration: PQMMSS1

Contents

Basic System Description

The Caterpillar Machine Security System (MSS) reduces the potential for theft or unwanted operation of a Caterpillar machine by disabling critical machine functions thereby not allowing the machine to be started. Functionally it is very similar to automotive immobilizers which use RFID (Radio Frequency ID) transponders embedded in the key to determine the authorization level of a machine operator.

The MSS system consists of an ECM (Electronic Control Module), a coil which energizes the RFID transponder and also receives data from the transponder, an electronic key which includes an RFID transponder, a Bi-Color LED which indicates system status to the operator, and two output drivers used to provide 2 points for disabling the machine.

The exciter coil is mounted on the machine console such that it encircles the keylock. The Bi-Color LED is also mounted on the machine console. The ECM is mounted in an inconspicuous location separated from the coil by as much as 15 ft.

Theory of Operation

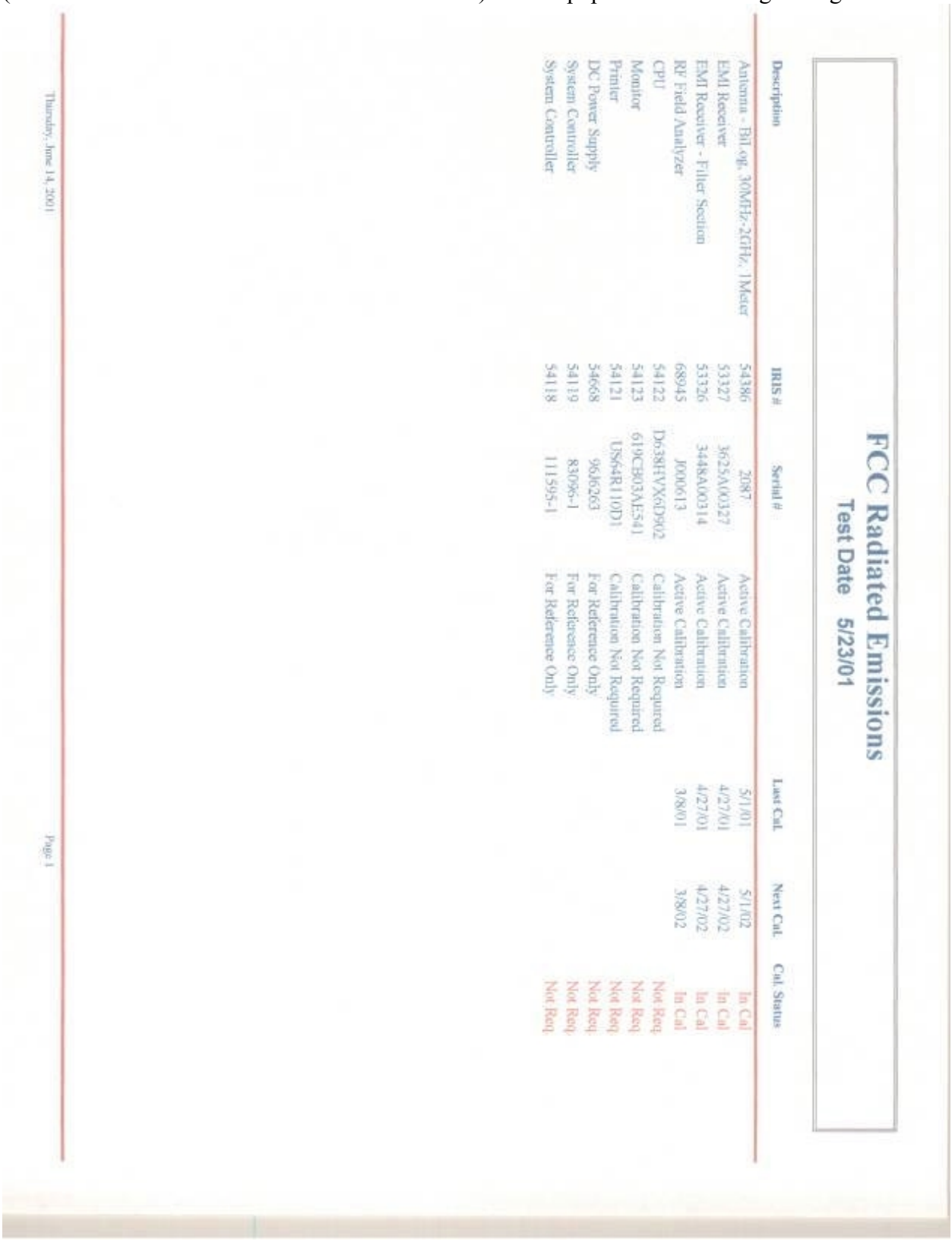
When an operator attempts to start a Caterpillar machine equipped with MSS he first activates the MSS system and requests key authorization by turning the key to the "on" position. The coil is then energized at a constant 134.2 KHz for approximately 50 ms. This energy is used to "charge up" the transponder embedded in the electronic ignition key. Power is then removed from the coil and the transponder transmits its ID and other relevant information to the ECM via the same coil for a period of 20 ms. This cycle is repeated 3 times in succession to confirm integrity of the transmitted message. The ECM then analyzes the authorization level of the key. If it is determined that the key is authorized for use on that machine then power is provided to two output drivers which are wired by the individual machines to enable critical functions (such as main power relay, starter motor, fuel shutoff solenoid, etc.). Power for each of these driver functions is provided on separate input lines to the control enabling logical control of these functions upstream of the MSS control.

An authorized key results in a green light from the Bi-Color LED. An unauthorized key produces a red light. A faulted condition causes the LED to flash red.

Once the machine has been successfully started the MSS system continues to provide power to the 2 driver circuits but no further "read" attempts are made on the key (i.e. the coil never gets energized after the initial read period which precedes cranking). Also, no further decisions are made regarding authorization level (i.e. the control will not attempt to disable the machine once it has been started).

Test Procedure and Equipment Used

Testing was performed at EMC Testing, Inc. which has their setup documented at the FCC (EMC Testing is registered with FCC #99460). Testing was performed 5/23/01 & 5/25/01 per FCC part 15 (measurement standards defined in Section 15.31). The equipment used during testing is as follo ws:



FCC Radiated Emissions

Test Date 5/23/01

Description	IRIS #	Serial #		Last Cal.	Next Cal.	Cal. Status
Antenna - Bil og, 30MHz-2GHz, 1Meter	54386	2087	Active Calibration	5/1/01	5/1/02	In Cal
EMI Receiver	53327	3625A00327	Active Calibration	4/27/01	4/27/02	In Cal
EMI Receiver - Filter Section	53326	3448A00314	Active Calibration	4/27/01	4/27/02	In Cal
RF Field Analyzer	68945	J000613	Active Calibration	3/8/01	3/8/02	In Cal
CPU	54122	D638HVX6D902	Calibration Not Required			Not Req
Monitor	54123	619CB03AE541	Calibration Not Required			Not Req
Printer	54121	US64R110D1	Calibration Not Required			Not Req
DC Power Supply	54668	960263	For Reference Only			Not Req
System Controller	54119	83096-1	For Reference Only			Not Req
System Controller	54118	111595-1	For Reference Only			Not Req

Thursday, June 14, 2001

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FCC Low Frequency Radiated Emissions

Test Date 5/25/01

Description	IRIS #	Serial #		Last Cal.	Next Cal.	Cal. Status
Antenna - Active Rod	64665	9806-4016	Active Calibration	1/12/01	1/12/02	In Cal
EMI Receiver	53327	3625A00327	Active Calibration	4/27/01	4/27/02	In Cal
EMI Receiver - Filter Section	53326	3448A00314	Active Calibration	4/27/01	4/27/02	In Cal
H-field Loop Antenna	81412	3423	Active Calibration	4/16/01	4/16/02	In Cal
RF Field Analyzer	68945	J000613	Active Calibration	3/8/01	3/8/02	In Cal
CPU	54122	D638HVX6D902	Calibration Not Required			Not Req.
Monitor	54123	619CB03AE541	Calibration Not Required			Not Req.
Printer	54121	US64R110D1	Calibration Not Required			Not Req.
DC Power Supply	54668	96J6263	For Reference Only			Not Req.

Configuration and Identification of Device Under Test

Description	Part Number
MSS ECM (Electronic Control Module)	156-6155 chg 03
MSS ECM PCB Identification	22104-0035
Coil (antenna)	205-8257 chg 00
Key (w/transponder)	206-5165 chg 00
Wiring Harness	Test Harness
Key Lock	9G-7641 chg 13
Steel Washer (backing ring for coil)	207-5271 chg 01
Bi-Color LED	165-5655 chg 01

The MSS has two modes of operation: Key Read; and Steady State. During the 210 ms Key Read period which occurs each time the machine is started the exciter coil is energized for 150 ms. During the Steady State portion the coil is not energized, but the two output drivers are energized.

For ease of measurement of the RF emissions during the Key Read state the ECM was placed in a special operating mode in which the coil was constantly energized (identified as “Constant RF” in the plots).

For steady state operation the MSS ECM was connected to a main power relay (part number 168-7908 chg 03) and a fuel shutoff relay (part number 115-1615 chg 03). These relays remained in a powered state throughout the duration of the Steady State portion of the test.

A third possibility is one in which an invalid key was read, but in that case the system would remain inactive and therefore no emissions would be present in that state and no data was taken for that condition (although the plots would be the same as those shown as “Baseline”).

Plots of data from both modes are attached in the “Tests and Results” section of this document.

The Test Harness used for the wiring harness was representative of a “worst-case” configuration on a machine.

Radiated Emission Limits

The System being tested falls under the category of Intentional Radiators and Digital Devices; subject to Subparts A & C, Section 15.209 and Subpart B, Section 15.109 (transmitter generated signals excluded); and Subpart A, Section 15.33. The applicable testing frequencies with corresponding emission limits are given in the tables below. As a digital device, it is exempt. However since testing was conducted on the system throughout the entire frequency range up to 1,000 MHz we have included plots of this data and from them it can be seen that this system complies with Class A specifications for an intentional radiator.

Section 15.33 Frequency range of radiated measurements

a) Unless otherwise noted in the specific rule section under which the equipment operates for an intentional radiator, the spectrum shall be investigated from the lowest radio frequency signal generated in the device, without going below 9 kHz, up to at least the frequency shown in this paragraph:

1) If the intentional radiator operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency, or to 40 GHz, whichever is lower.

NOTE: The fundamental frequency of this system is 134.2 kHz, therefore the tenth harmonic is 1.342 MHz.

4) If the intentional radiator contains a digital device, regardless of whether this digital device controls the functions of the intentional radiator or the digital device is used for additional control or function purposes other than to enable operation of the intentional radiator, the frequency range shall be investigated up to the range specified in paragraphs (a)(1)-(a)(3) of this section or the range applicable to the digital device, as shown in paragraph (b)(1) of this Section, whichever is the higher frequency range of investigation.

NOTE: According to (b)(1) the maximum frequency for investigation would be 1 GHz because there are crystals inside the ECM with frequencies as high as 17.1776 MHz, HOWEVER, based on Section 15.103 Exempted devices subparagraph (a) is states that **"a digital device utilized exclusively in any transportation vehicle including motor vehicles and aircraft"** is subject only to the general conditions of operation in Sections 15.5 and 15.29 and are exempt from the specific technical standards and other requirements contained in this part.

Section 15.209 Radiated emission limits, general requirements

(The following applies to the intentional radiator portion of the Machine Security System)

a) Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field Strength (uV/m)	Meas. Distance (meters)
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30.0	30	30
30 – 88	100 **	3
88 – 216	150 **	3
216 – 960	200 **	3
above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241.

NOTE: The fundamental frequency of the Machine Security System (MSS) is 134.2 KHz

As defined by Section 15.31 Measurement standards, subparagraph (f)(1) At frequencies at or above 30 MHz, measurements may be performed at a distance other than what is specified provided: measurements are appropriate due to the characteristics of the device; and it can be demonstrated that the signal levels needed to be measured at the distance employed can be detected by the measurement equipment. Measurement shall not be performed at a distance greater than 30 meters … When performing measurements at a distance other than that specified the results shall be extrapolated to the specified distance using an extrapolation factor of 20 dB/decade (inverse linear-distance for field strength measurements; inverse-linear-distance squared for power density measurements).

c) The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission. For intentional radiators which operate under the provisions of other Sections within this Part and are required to reduce their unwanted emissions to the limits specified in this table, the limits in this table are based on the frequency of the unwanted emission and not the fundamental frequency. However the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

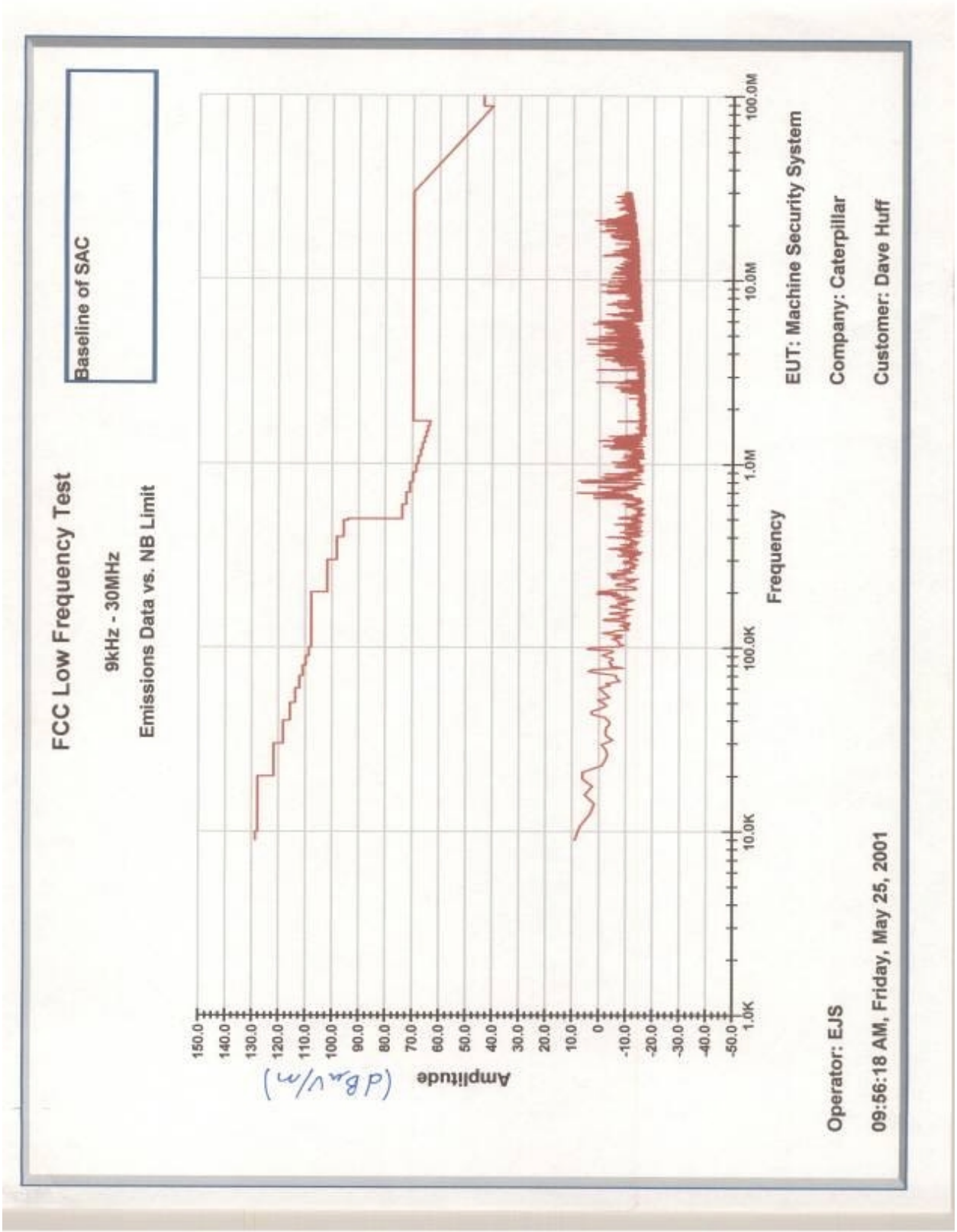
Section 15.109 Radiated Emission limits

b) The field strength of radiated emissions from a Class A digital device, as determined at a distance of 10 meters, shall not exceed the following:

Frequency of Emission (MHz)	Field Strength (uV/m)
30 – 88	90
88 – 216	150
216 – 960	210
above 960	300

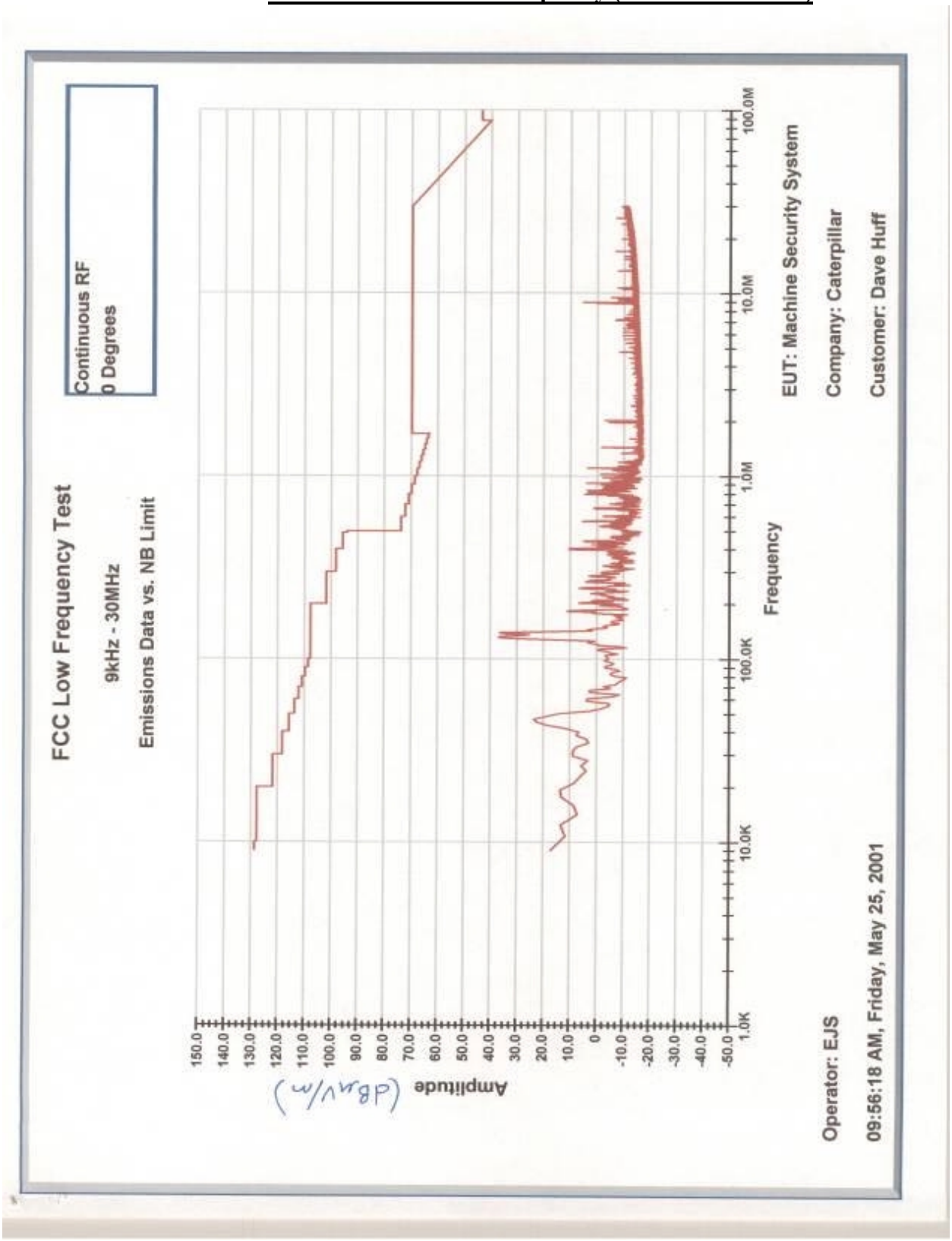
under Section 15.3 Definitions subparagraph (h) it defines a Class A digital device as: A digital device that is marketed for use in commercial, **industrial**, or business environment, exclusive of a device which is marketed for use by the general public, or is intended to be used in the home.

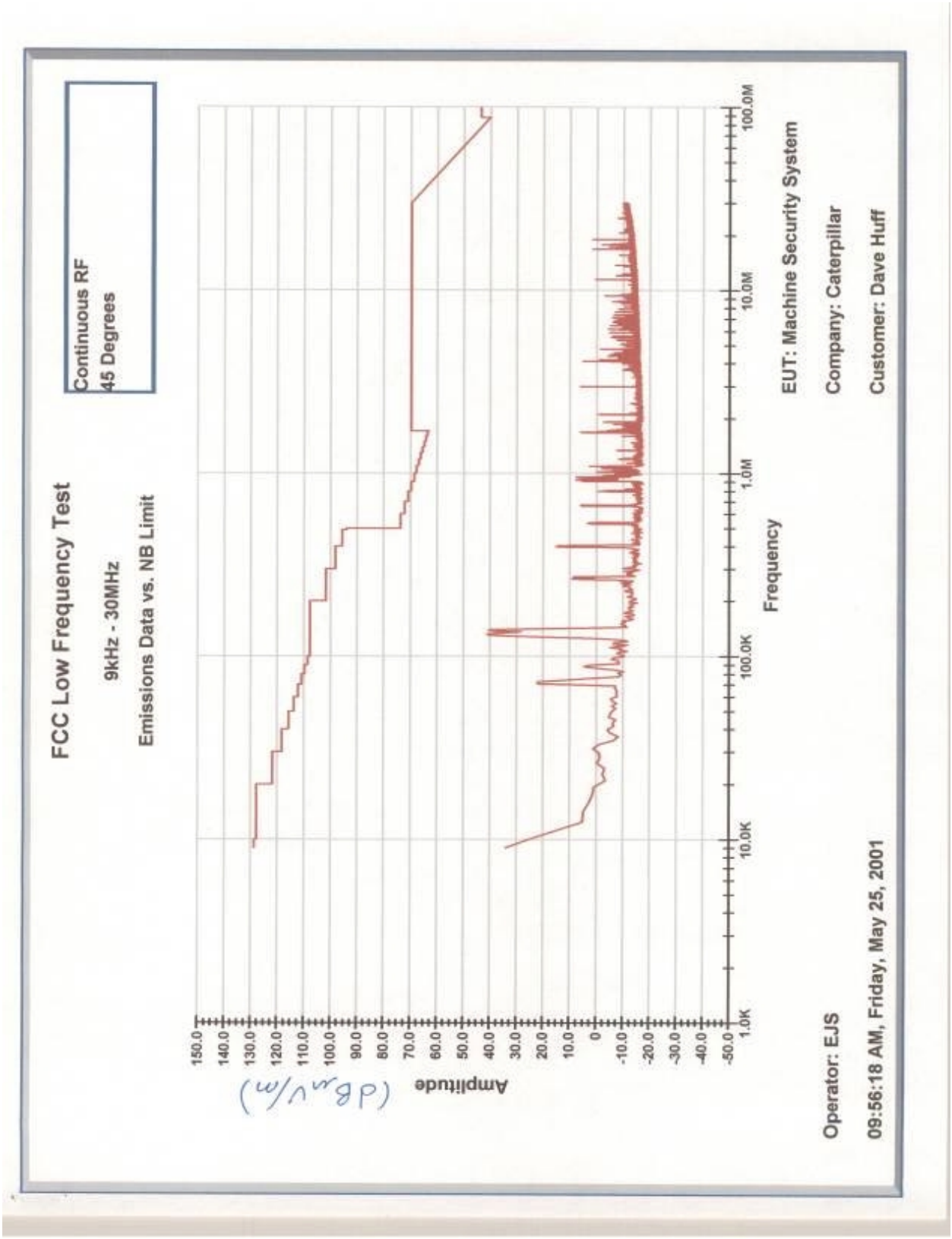
Radiated Emission Tests and Results

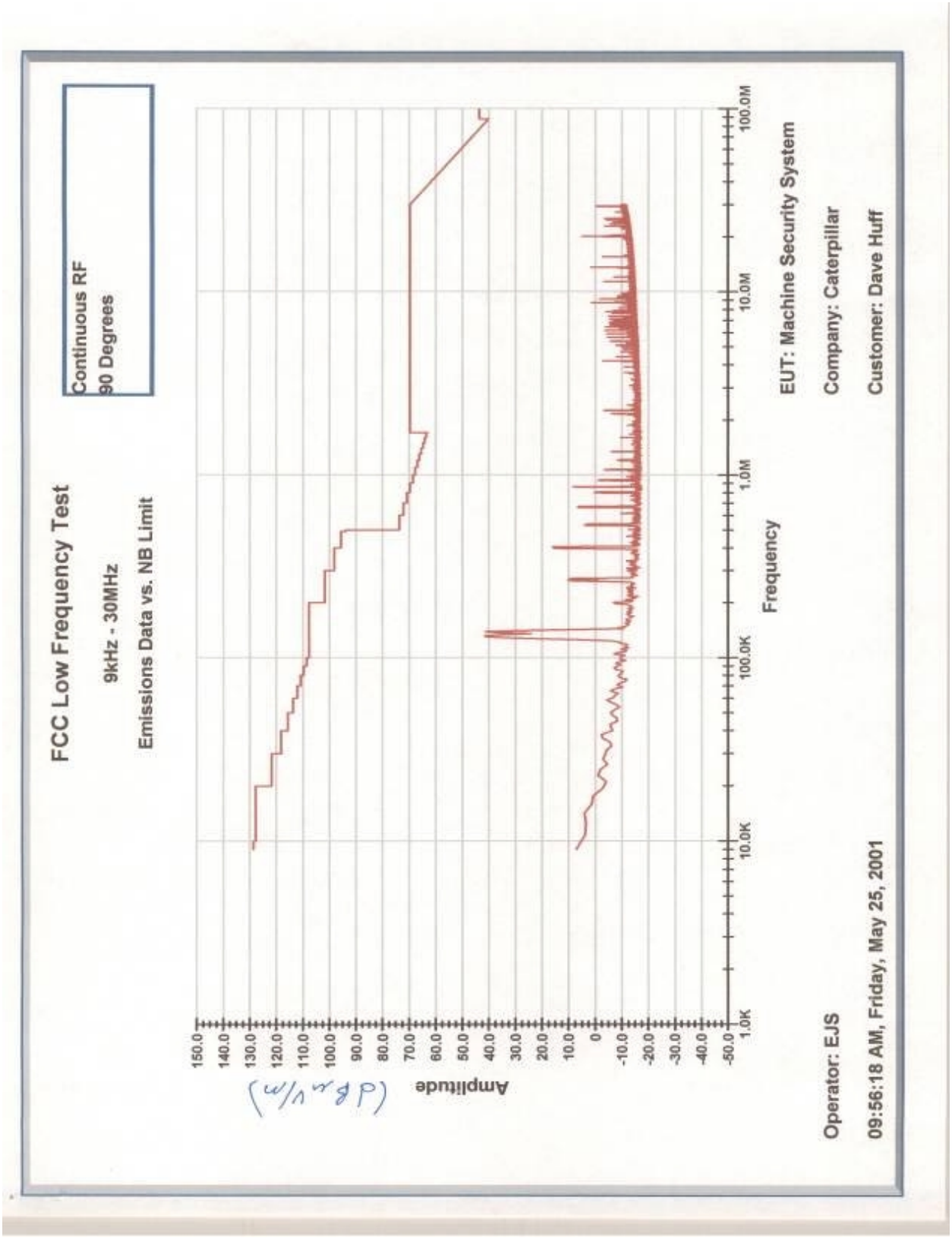


Baseline measurement for Low Frequency (9 KHz to 30 MHz):

Continuous RF - Low Frequency (9 KHz to 30 MHz)




FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
45 Degrees
Amplitude
(dBuV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
EUT: Machine Security System
Company: Caterpillar
Customer: Dave Huff
Operator: EJS
09:56:18 AM, Friday, May 25, 2001


FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
90 Degrees
Amplitude
(dBuV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
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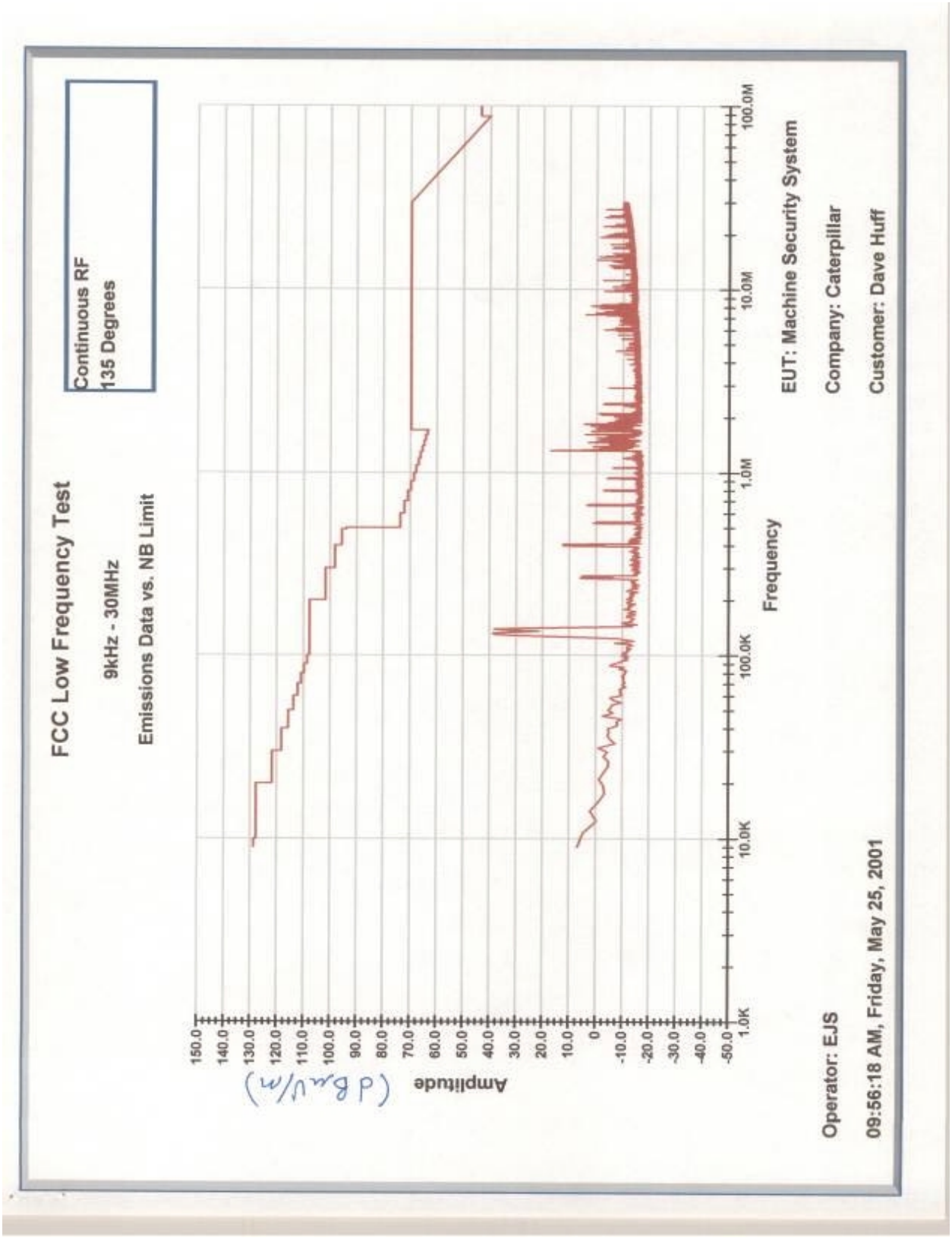
FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
135 Degrees
Amplitude
(dBuV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
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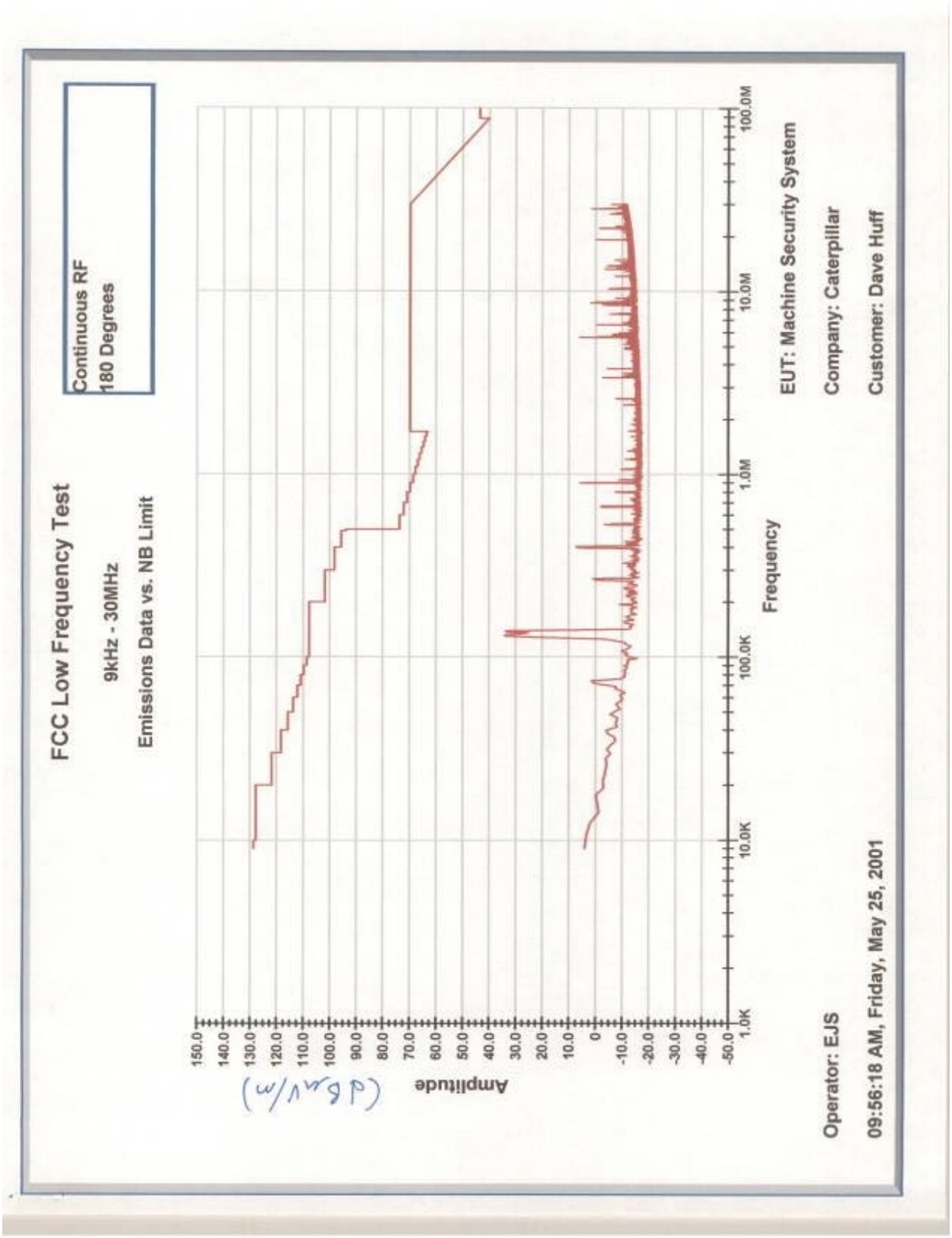
FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
180 Degrees
Amplitude
(dBuV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
EUT: Machine Security System
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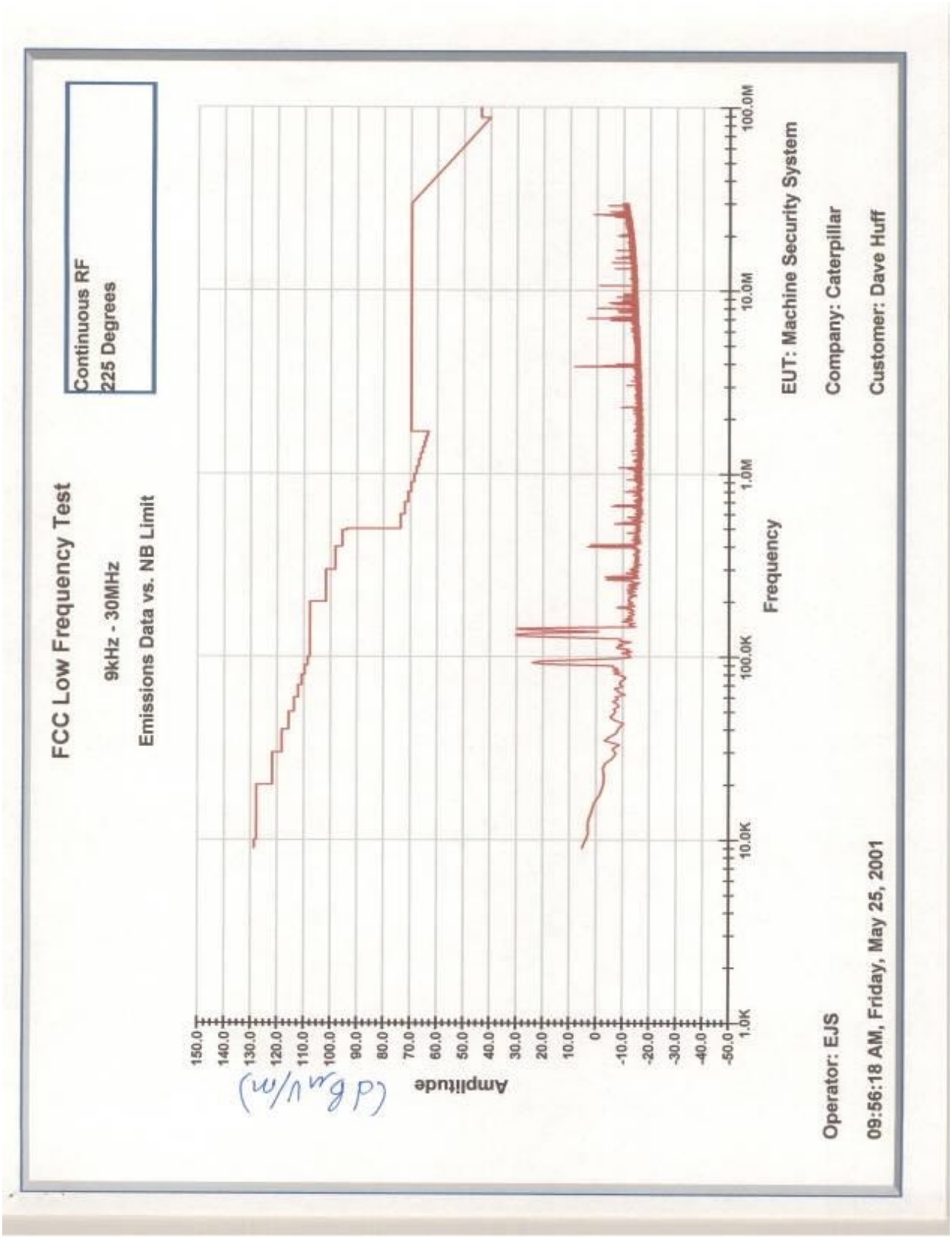
FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
225 Degrees
Amplitude
(dBµV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
EUT: Machine Security System
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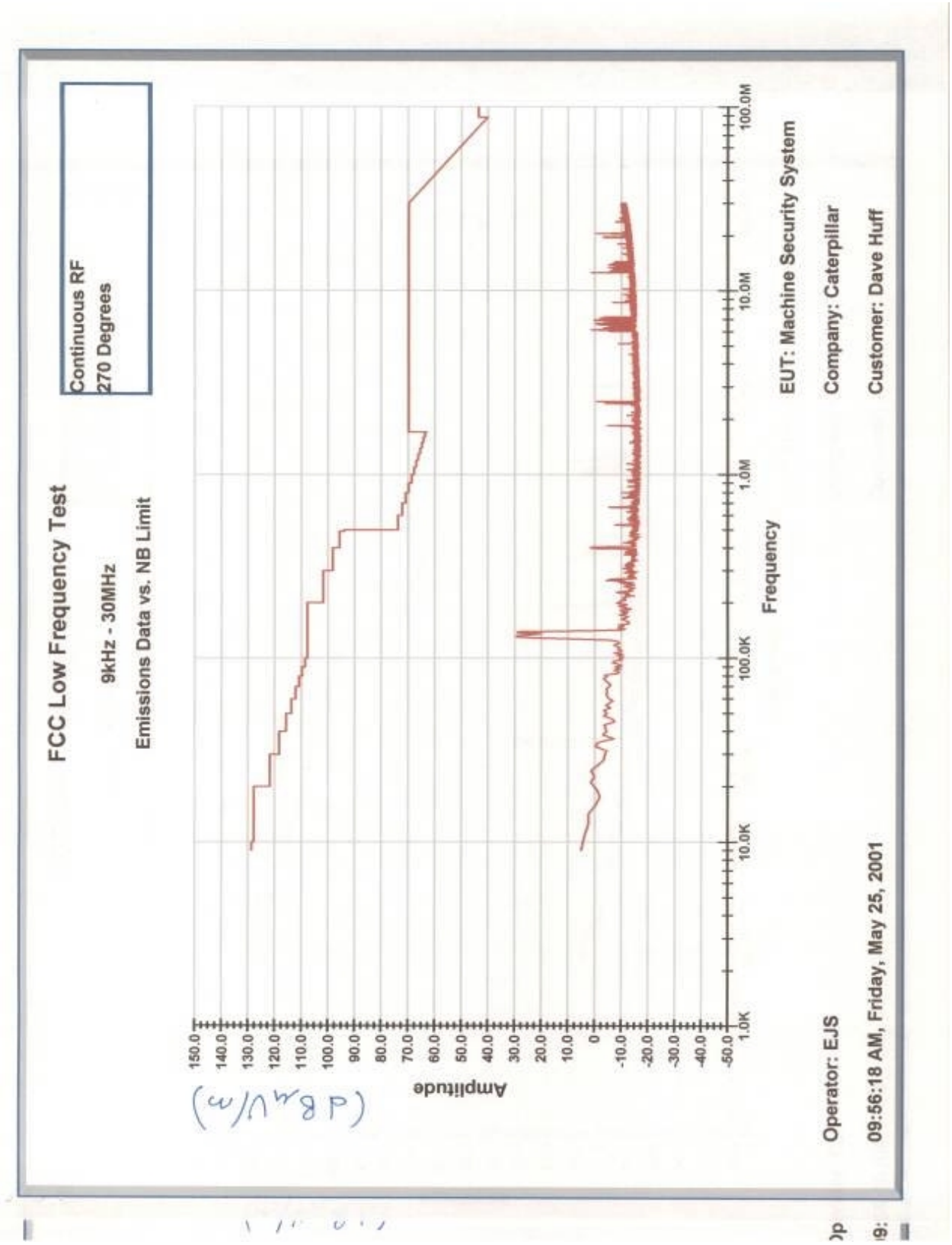
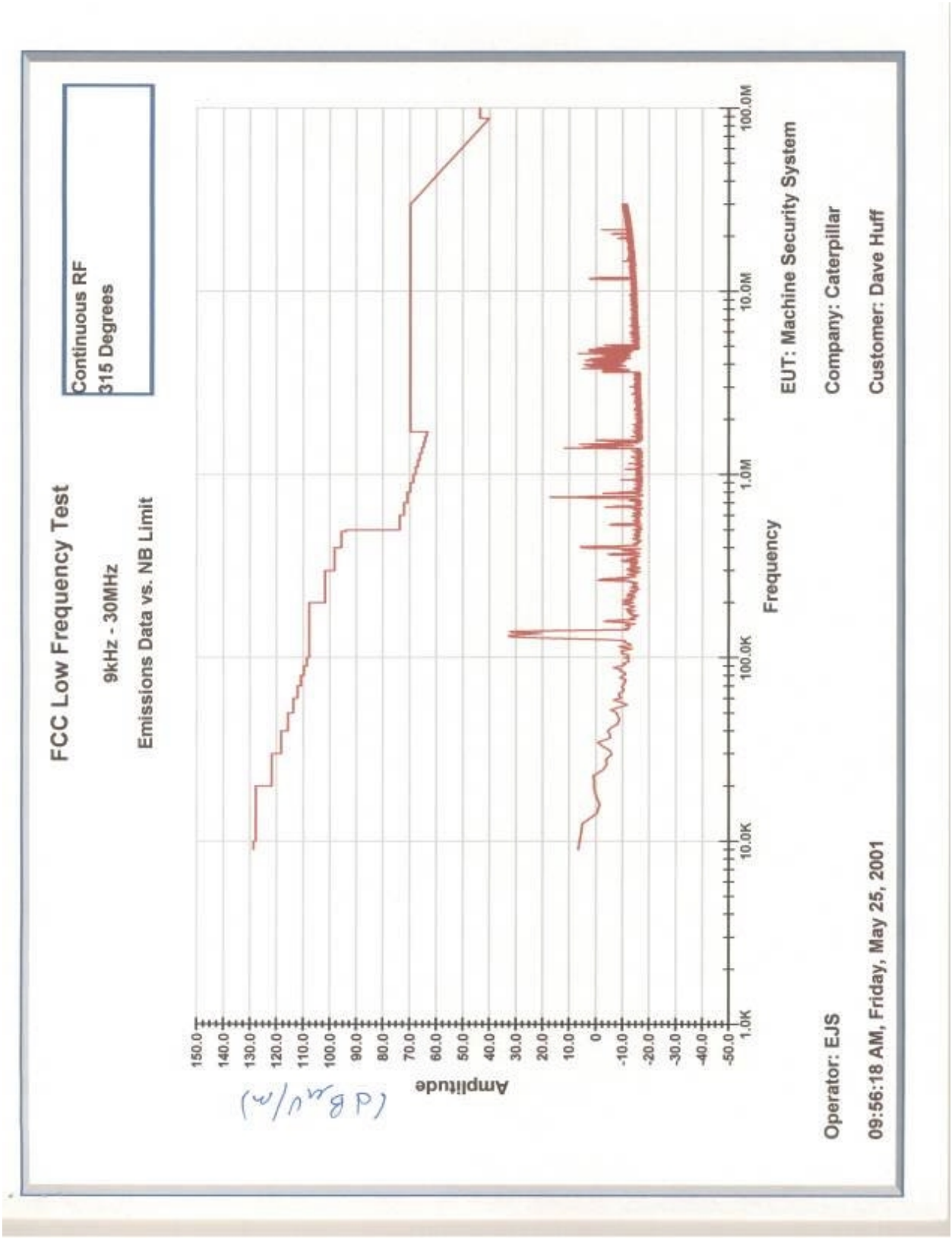

FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
270 Degrees
Amplitude
Frequency
EUT: Machine Security System
Company: Caterpillar
Customer: Dave Huff
Operator: EJS
09:56:18 AM, Friday, May 25, 2001


FCC Low Frequency Test
9kHz - 30MHz
Emissions Data vs. NB Limit
Continuous RF
315 Degrees
Amplitude
(dBuV/m)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
1.0K
10.0K
100.0K
1.0M
10.0M
100.0M
Frequency
EUT: Machine Security System
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Steady State - Low Frequency (9 KHz to 30 MHz)