NO. UMTA-MA-06-0031-73,IX

ELECTROMAGNETIC ENVIRONMENT MEASUREMENTS OF PRT SYSTEMS AT "TRANSPO®72"
VOLUME IX
FORD SYSTEM

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JANUARY 1974

FINAL REPORT

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16. Abstract

This report covers the measurements of the broadband conducted noise present on the A.C. power lines feeding the Personalized Rapid Transit (PRT) systems at Dulles Airport with each system operating individually.

The purpose of the measurement effort was to evaluate the electrical environment existing on each of the PRT "hot" and neutral A.C. power lines and to assess the effect of each system on the power line with all other PRT systems turned off.

The measurements obtained during this test will be used for a comparison with data obtained with no PRT systems operating and with all four PRT systems operating simultaneously.

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PREFACE

The work described in this report was performed as part of a test program conducted to evaluate the Safety and Performance characteristics of the four Personalized Rapid Transit Systems (PRT) on display at Transpo® 72. Sponsored by the U.S. Department of Transportation, Transpo® 72 was the first United States International Transportation Exposition and was intended to demonstrate to the general public new technologies in transportation.

The PRT demonstration program was the responsibility of the Urban Mass Transportation Administration (UMTA) and was conducted to provide detailed engineering test data in addition to providing mature candidates for an Urban demonstration.

POWER LINE CONDUCTED NOISE MEASUREMENTS

FORD SYSTEM - TRANSPO®'72

1. INTRODUCTION

The technical report presents the data obtained in the performance of tests for power line conducted noise at the personal rapid transit (PRT) system of FORD at TRANSPO®'72, Dulles Airport, Washington, D. C. This report covers one of the four tests defined under Item 5 of Contract DOT-TSC-375, and as performed by National Scientific Laboratories, Inc.

Item 5 calls for the performance of conducted noise measurements on PRT a.c. power lines in the frequency range from d.c. to at least 10 KHz, with one PRT system on. The objective of the tests was to gather operational data for each of the PRT systems. Such data will enable characterization of the noise increase attributable to system operations, when considered in comparison with the ambient data collected and documented* previously by NSL.

The measurements reported in this document were made during the forenoon of August 2, 1972.

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* Technical Report, Item 4, Ambient Power Line Conducted Noise Survey, PRT Systems, March 1972, Contract No. DOT-TSC-375, Department of Transportation, Transportation Systems Center, 55 Broadway, Cambridge, Massachusetts 02142.

2. METHOD OF MEASUREMENT

2.1 Instruments

All measurements were made using test set-ups and instruments as nearly identical as possible to those used during ambient testing. The power line conducted measurements were performed using a Fairchild Model EMC-10 Interference Analyzer. This device is a battery-operated calibrated RFI/EMI meter, which, when operated as a narrowband tunable device, covers the frequency range of d.c. to 50 KHz. The receiver has an internal calibration source and incorporates a meter circuit of such design that signal levels are expressed in decibels on a linear scale. In addition, the receiver incorporates circuitry providing buffered voltage outputs in proportion to meter indication and tuned frequency. A Hewlett Packard Model 3005B X-Y Plotter was driven from the receiver.

Some observations were made at frequencies above 50 KHz through the use of a Hewlett Packard Model 8552/8553A spectrum analyzer. Data was recorded photographically with a Hewlett Packard Model 198A oscilloscope camera. The analyzer is an extremely versatile instrument in that it has numerous frequency scan and bandwidth settings throughout the frequency spectrum of a few cycles up to 100 MHz.

Signals were obtained from the power lines by means of a Fairchild Model PCL-10 Current Probe. This device is a clamp-on current transformer which provides an output voltage in proportion to the current on the conductor which passes through its aperture. This probe has a specified transfer-admittance characteristic which is a function of frequency.

2.2 Power Line Arrangement

The power provided to the PRT site via an underground feeder is 480 v.a.c., three phase (Ø). The feeder lines enter commercial switchgear in the Ford building and are coded as follows:

Phase	Color Code
A	Orange
B	Brown
C (Grounded)	Yellow

The current probe was attached at the point where the feeders enter the switchgear which is the same point as used when making the ambient tests described in report Item 4.

2.3 Measurement Technique

Each of the three power conductors were tested by scanning two frequency ranges, d.c. to 1 KHz using a 5 Hz bandwidth, and 1 KHz to 50 KHz using a 50 Hz bandwidth. Two recordings have been made for each frequency range, on each of the three power lines. The scanning time per recording averaged four to six minutes.

These recordings are reproduced in the Appendix as the upper half of pages A-2 through A-13. The recordings are presented in order of phase rather than the order in which they were produced. The dB scale refers to the level at the instrument input connector. Some of the charts have two amplitude scales. Located somewhere along the bottom of the chart is an upside down letter "Y" which denotes the point of changeover from the scale on the left side to the scale on the right side.

The spectrum analyzer was used to record data in the frequency range up to 1 MHz, particularly in the area of 150 KHz to 250 KHz wherein the vehicle and computer communicate.

3. INTERPRETATION OF DATA

The amplitude/frequency charts produced during the tests are reproduced in the upper half of each page of Appendix A-2 through A-13. The lower chart on each page is a plot of approximately one level in each major frequency increment of the chart directly above it. Peaks were selected whenever available. A correction factor for the current probe (current probe amplitude response is non-linear with frequency) has been included in the levels plotted in the lower chart.

In the upper charts, noise peaks recorded in the top major amplitude division are out of the calibrated range of the instrumentation system. Thus, the levels plotted for peaks that enter the upper division are plotted as having an amplitude of the highest level indicated numerically on the chart for that particular frequency.

Notations are written on the charts which denote vehicle start and stop on the guideway as well as at the station. Also, vehicle entering and leaving the stations were noted, as were similar functions at the north end of the guideway.

Spectrograms on page A-14 show the conduction noise on ØA up to 1 MHz for two vehicle conditions. The current probe is linear for frequencies above 50 KHz, thus, each gradicule amplitude division is a 10 dB level change.

Attempts were made to locate the communication frequencies of 150 KHz (Control to Vehicle) and 225 KHz to 250 KHz FSK (Vehicle to Control). The 150 KHz carrier was evident at such time as the vehicle was not drawing motive power, but at no time were the FSK frequencies recognized. The spectrograms in pages A-15 to A-17 show the conduction signals for various vehicle situations; note the 150 KHz carrier. The various other spikes were not identified.

4. TIME LOG

Ford had only one vehicle running during the test period--0800 to 1200. The log of events is contained in the Appendix on pages A-18 to A-20.

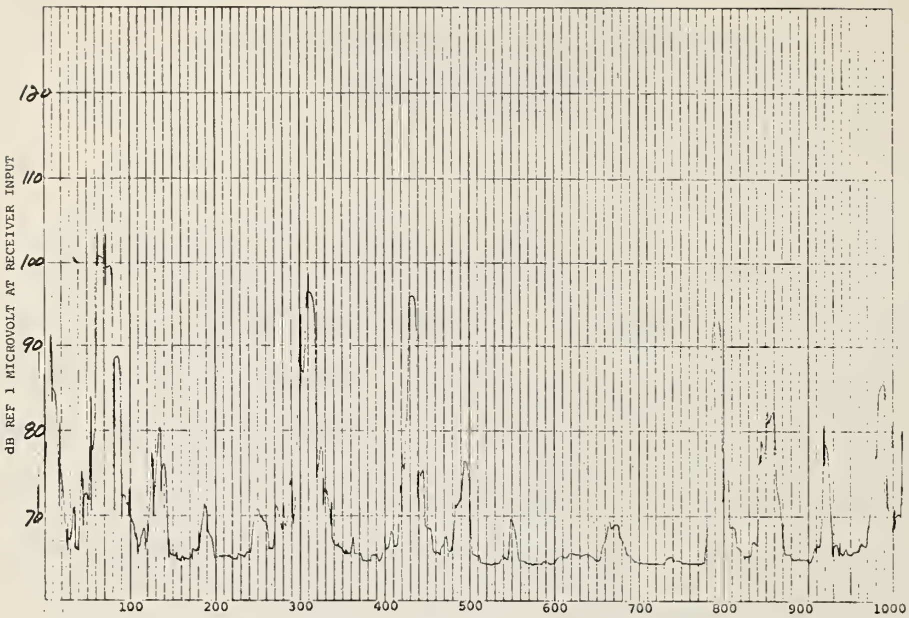
APPENDIX

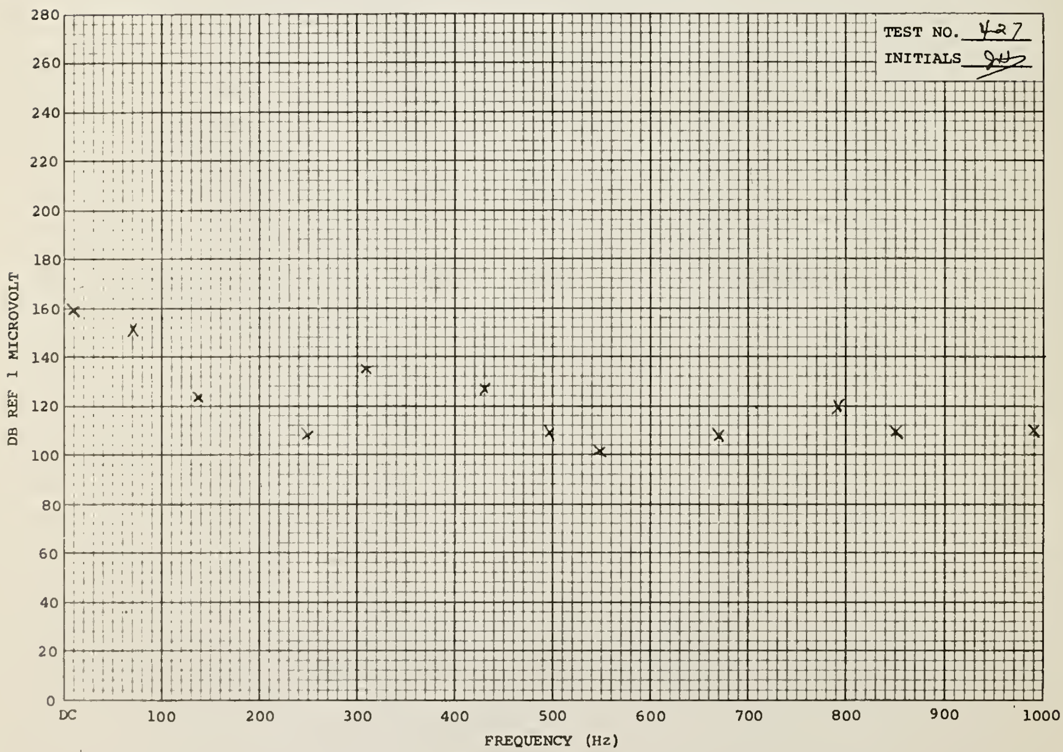
POWER LINE CONDUCTION

MEASUREMENTS DATA

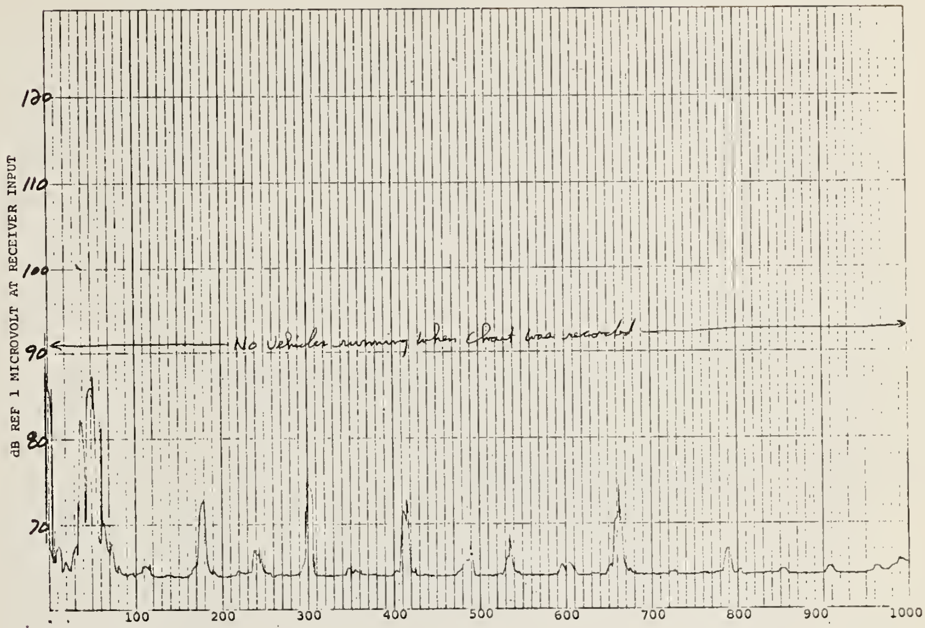
This appendix contains data charts for tests No. 423 through 435 (432 omitted), and spectrograms 436, 438, 440 to 444. The charts are presented in order of phase--A, B and C--for ease of analysis, rather than in numerical order as the tests were performed. The spectrograms are also rearranged for analysis purposes. The time log of operational events is at the end of the Appendix.

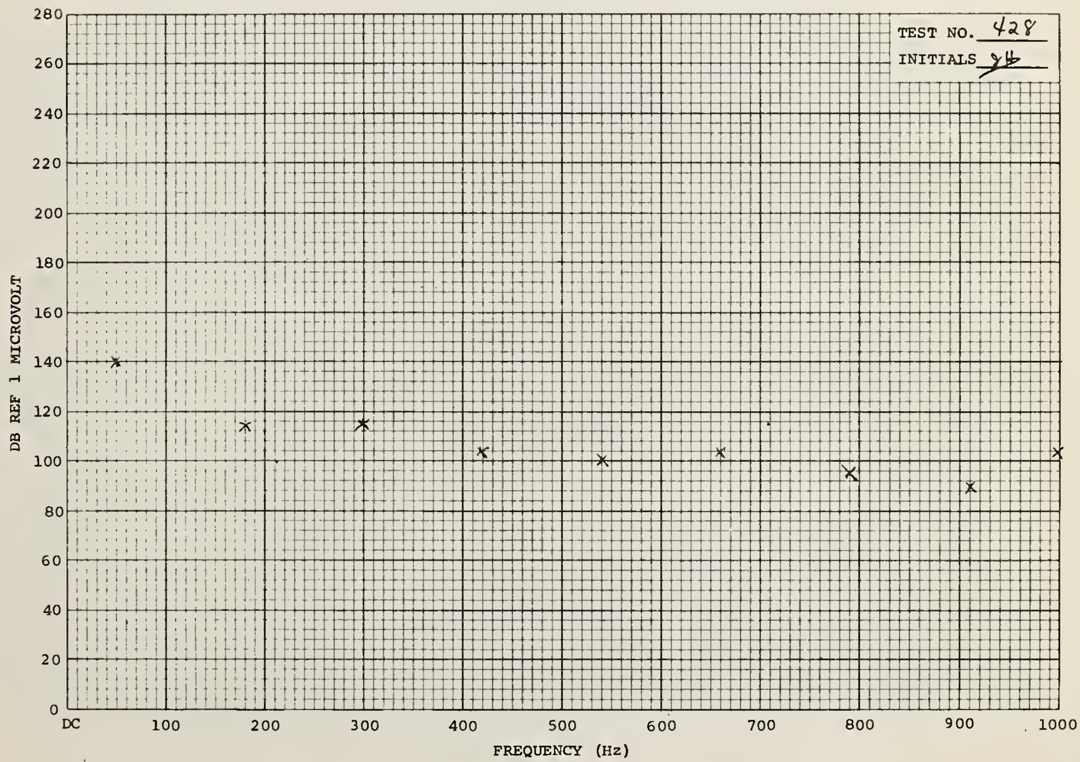
TEST NO. 427 TEST TYPE PLC BANDWIDTH 5 Hz 0902
TEST SPECIMEN Ø A TEST EQUIP. EMC-10 DATE 8-2-72 EEJ
Ford



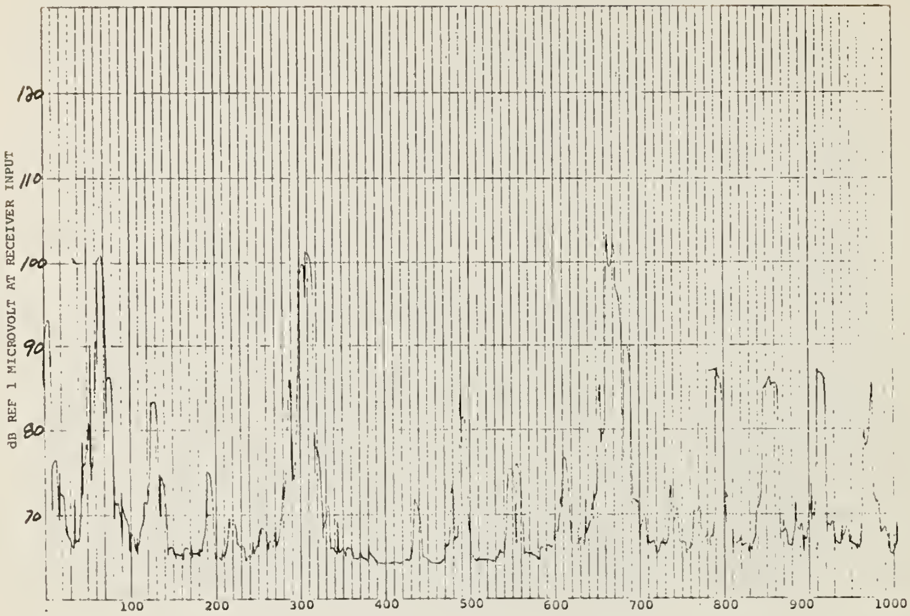


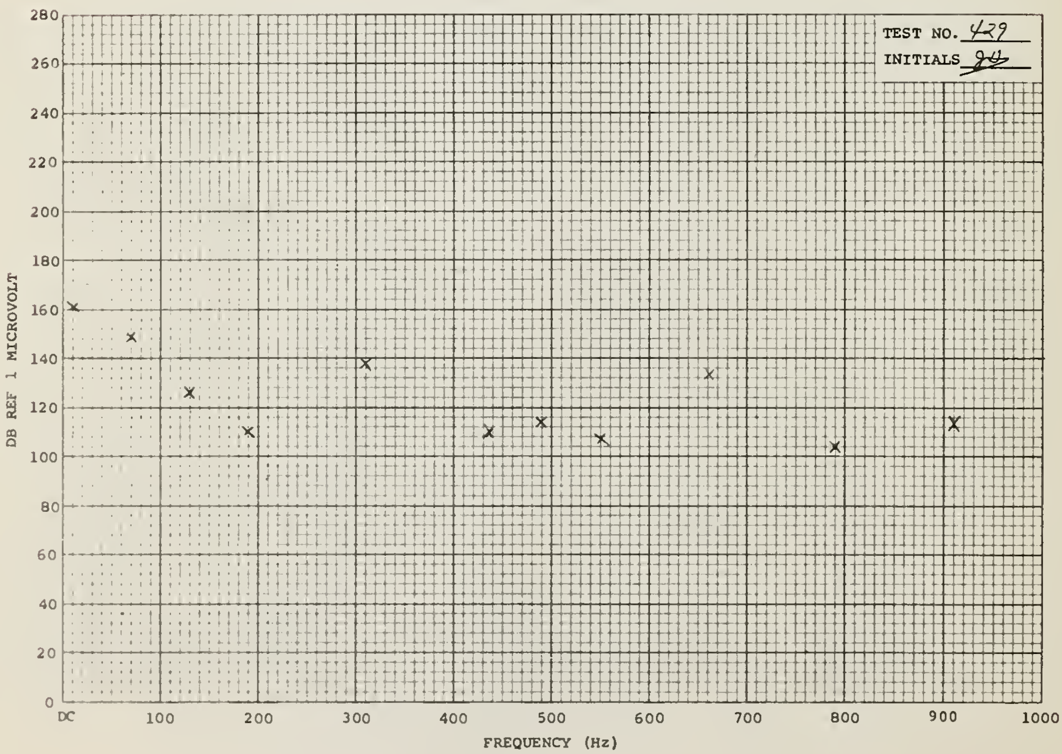
TEST NO. 428 TEST TYPE PLC BANDWIDTH 5 HZ 0905
TEST SPECIMEN ØA TEST EQUIP. EMC-10 DATE 8-2-72 EEJ
FORD



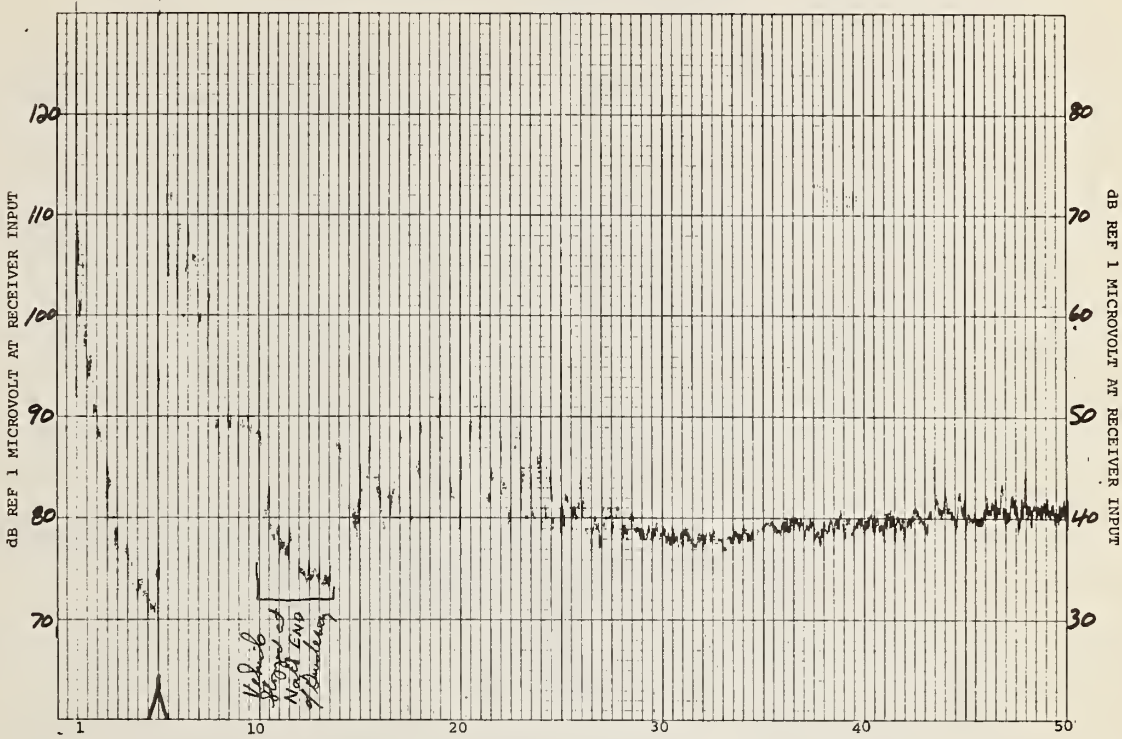


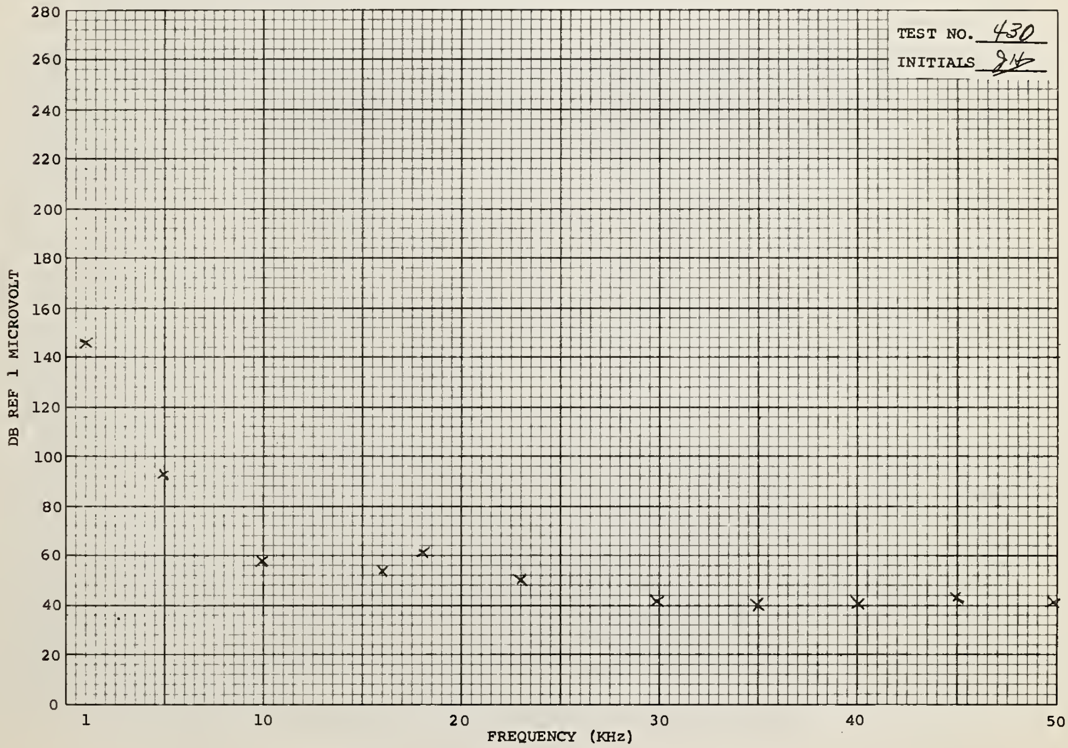
TEST NO. 429 TEST TYPE PLC BANDWIDTH 5 Hz 0920
TEST SPECIMEN ØA Ford TEST EQUIP. ENC-10 DATE 8-2-72





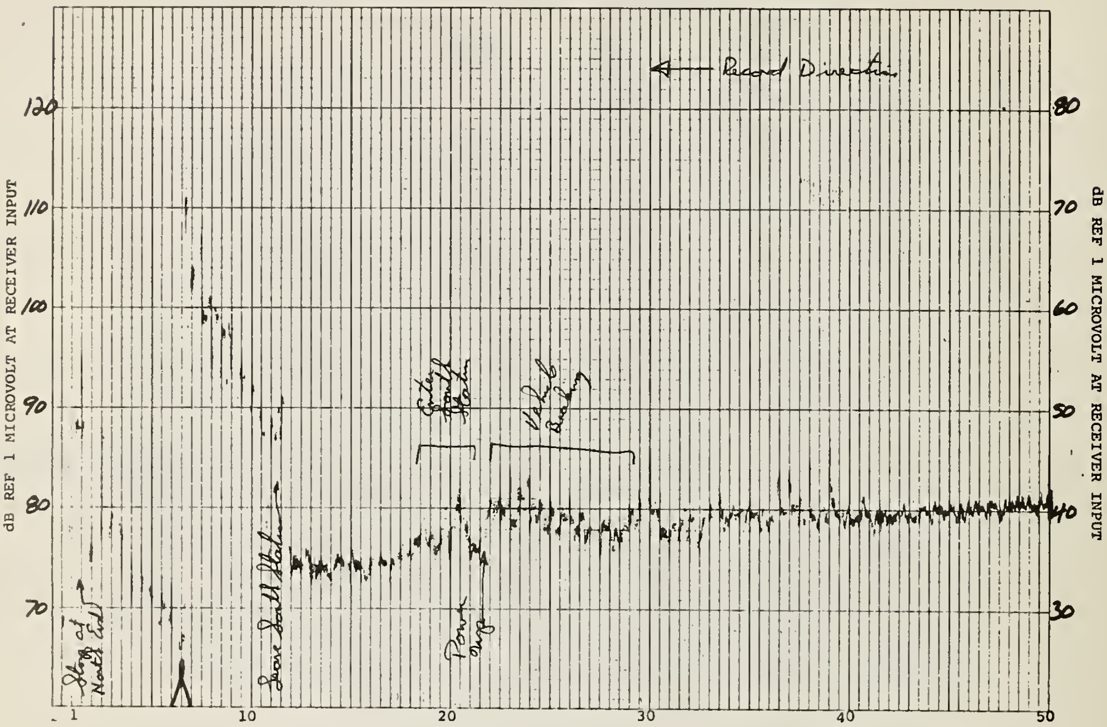
TEST NO. 430 TEST TYPE PLC BANDWIDTH 50 Hz 0926
TEST SPECIMEN ØA Ford TEST EQUIP. EMC-10 DATE 8-2-72 EEJ

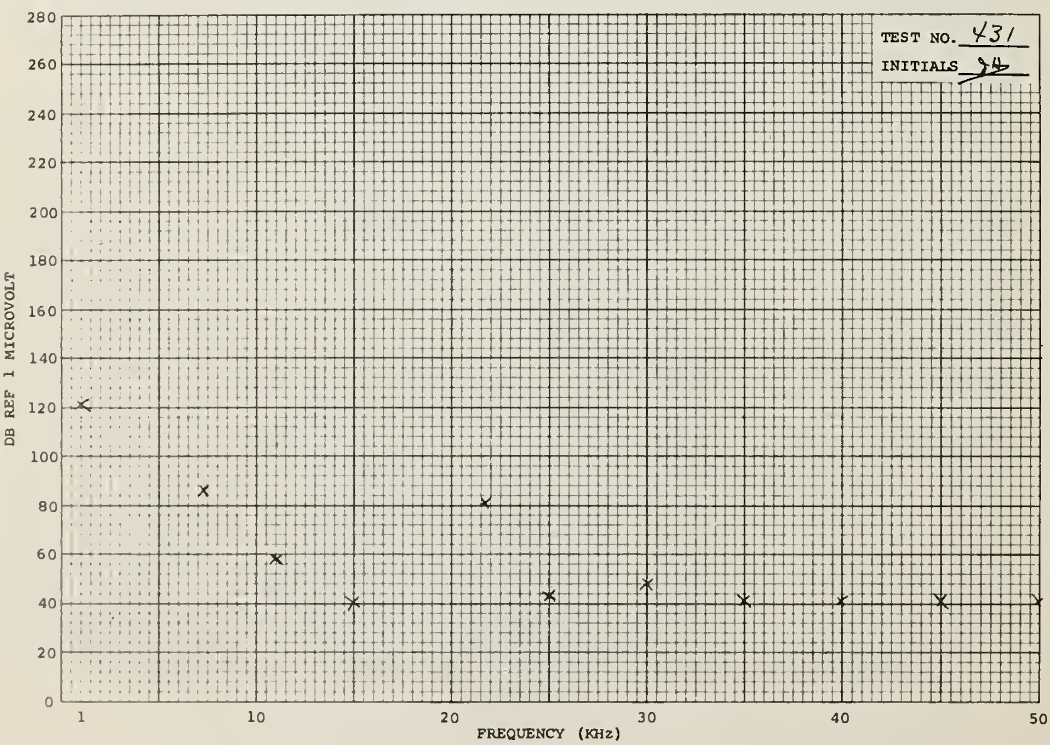




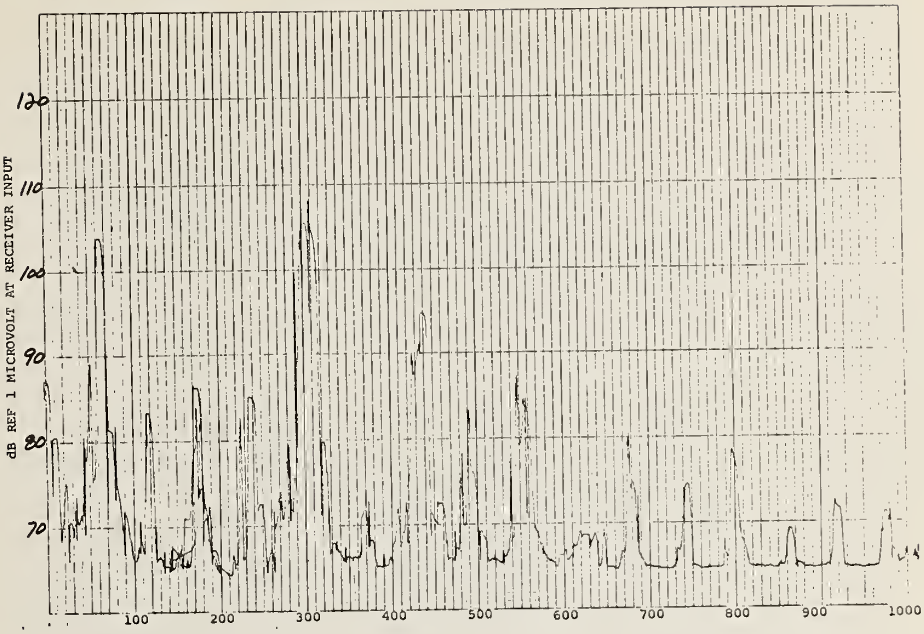
TEST NO. 431 TEST TYPE PLC BANDWIDTH 50 Hz 0933

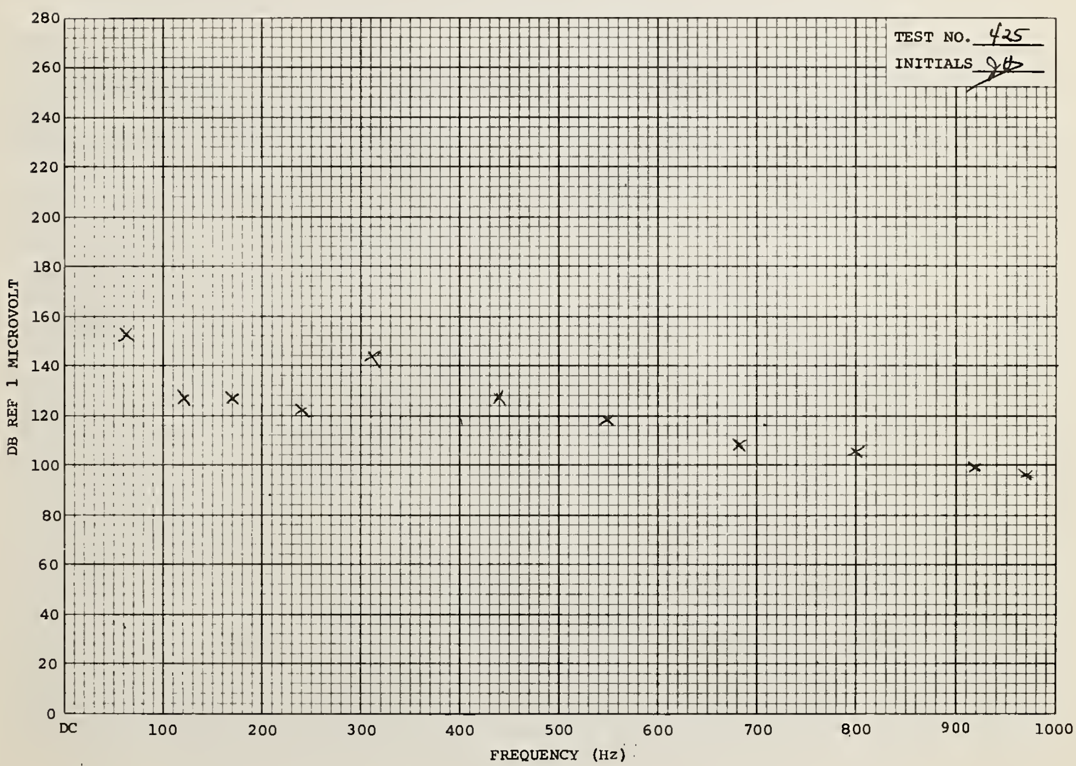
TEST SPECIMEN ØA Ford TEST EQUIP. EMC-10 DATE 8-2-72

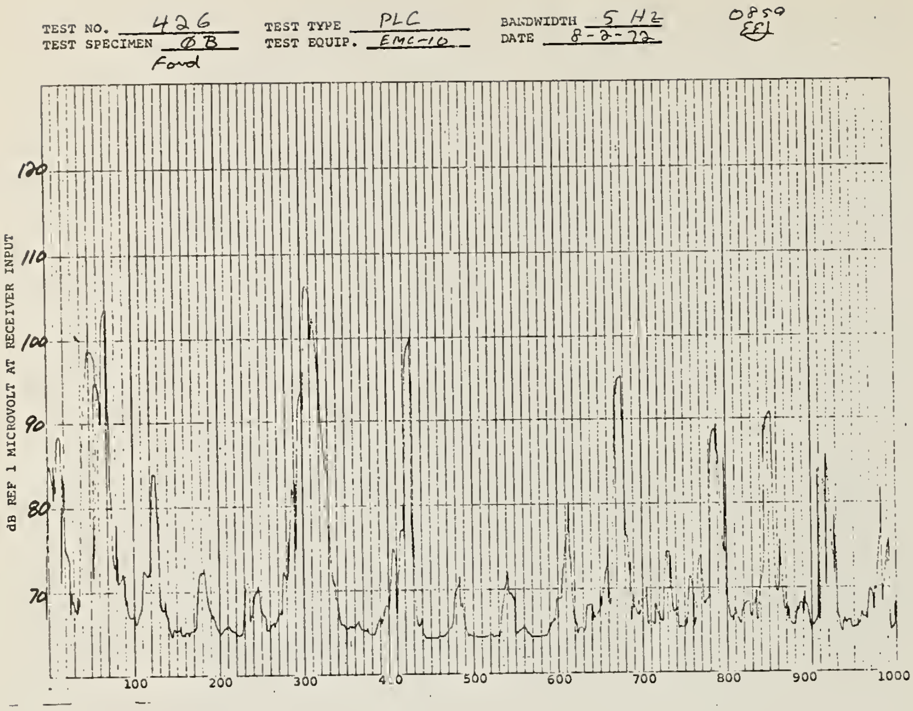




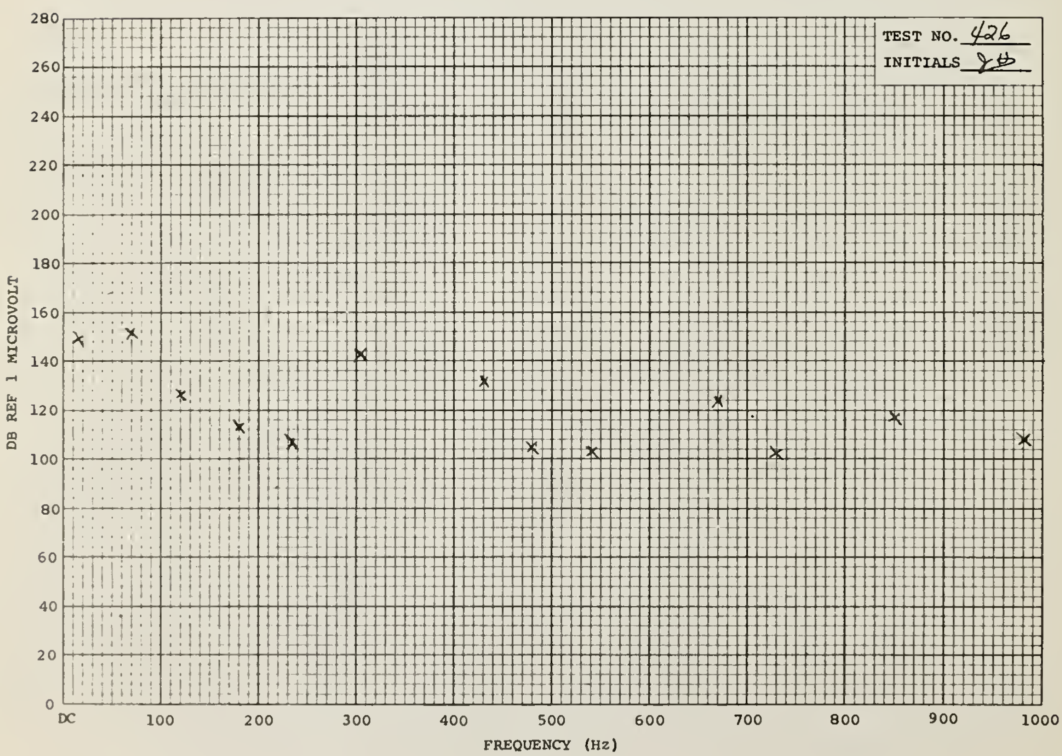
TEST NO. 425 TEST TYPE PLC BANDWIDTH 5 Hz 0855
TEST SPECIMEN ØB Ford TEST EQUIP. EMC-10 DATE 8-2-72





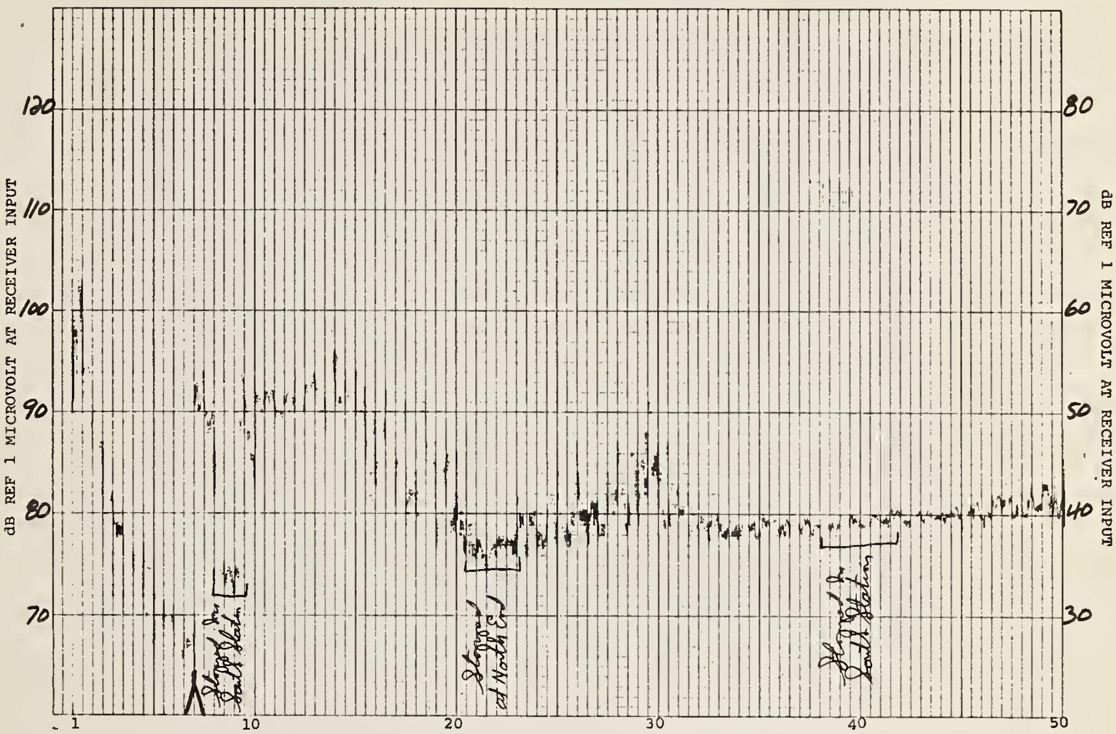


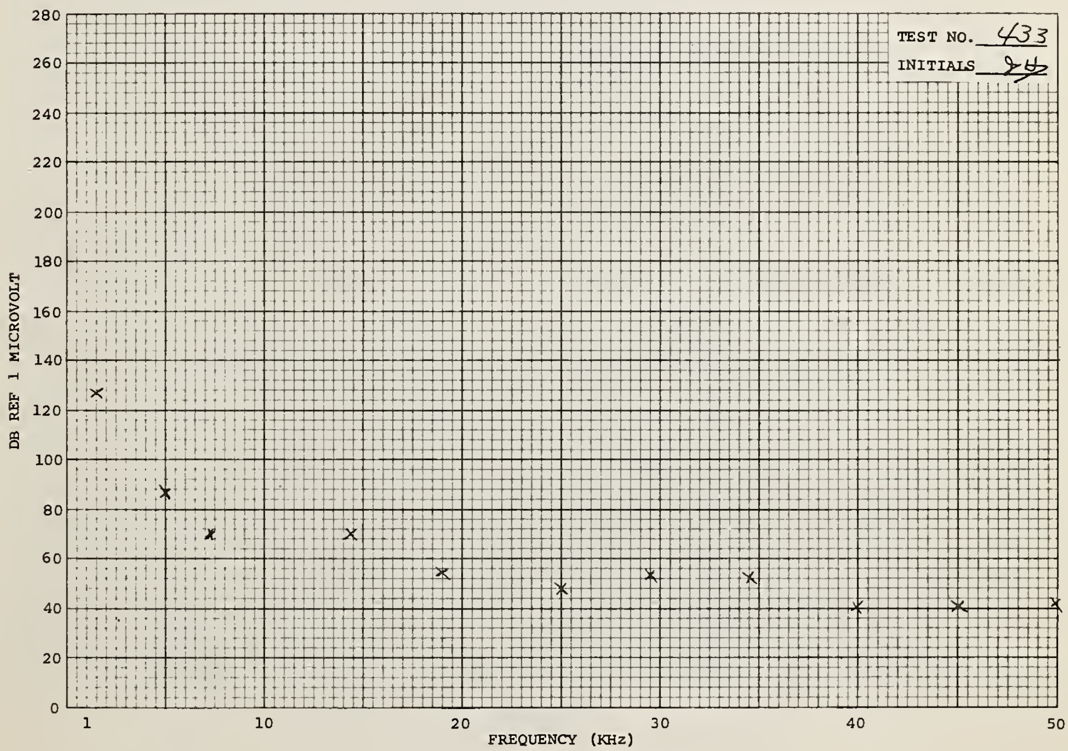
TEST NO. 426
TEST SPECIMEN ØB Ford
TEST TYPE PLC
TEST EQUIP. EMC-10
BANDWIDTH 5 Hz
DATE 8-2-72
0859
dB REF 1 MICROVOLT AT RECEIVER INPUT
120
110
100
90
80
70
100
200
300
400
500
600
700
800
900
1000

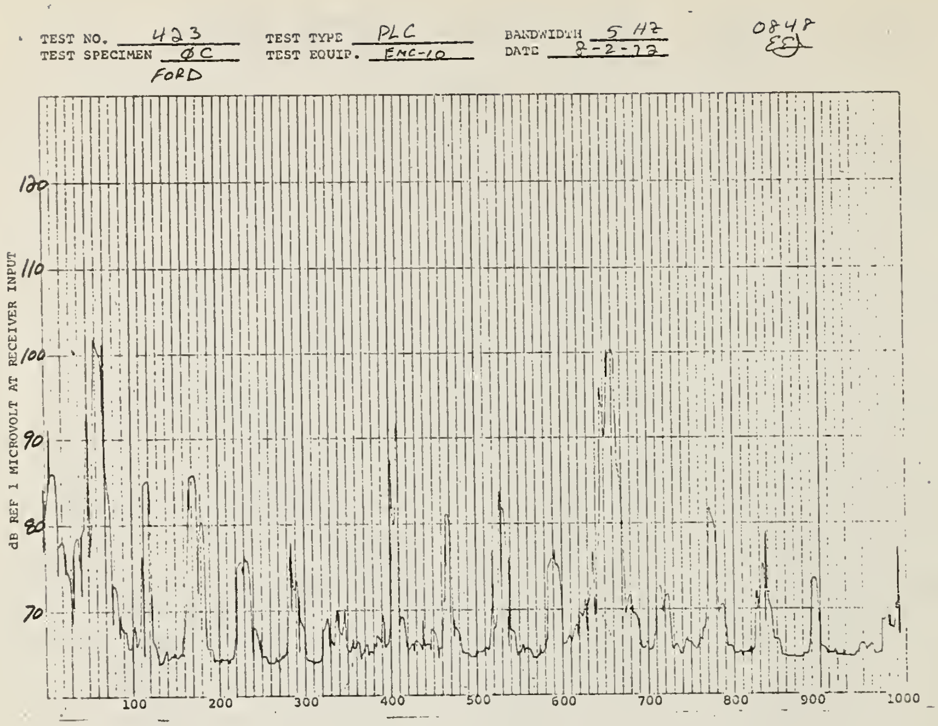


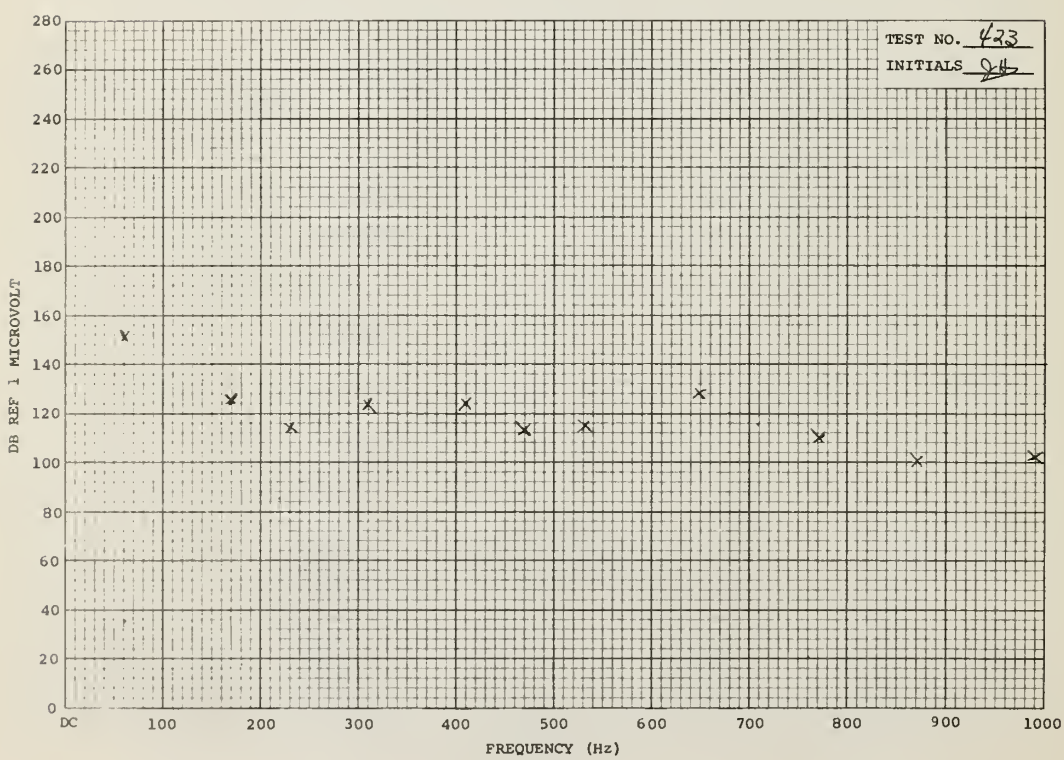
TEST NO. 426
INITIALS
DB REF 1 MICROVOLT
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
DC
100
200
300
400
500
600
700
800
900
1000
FREQUENCY (Hz)

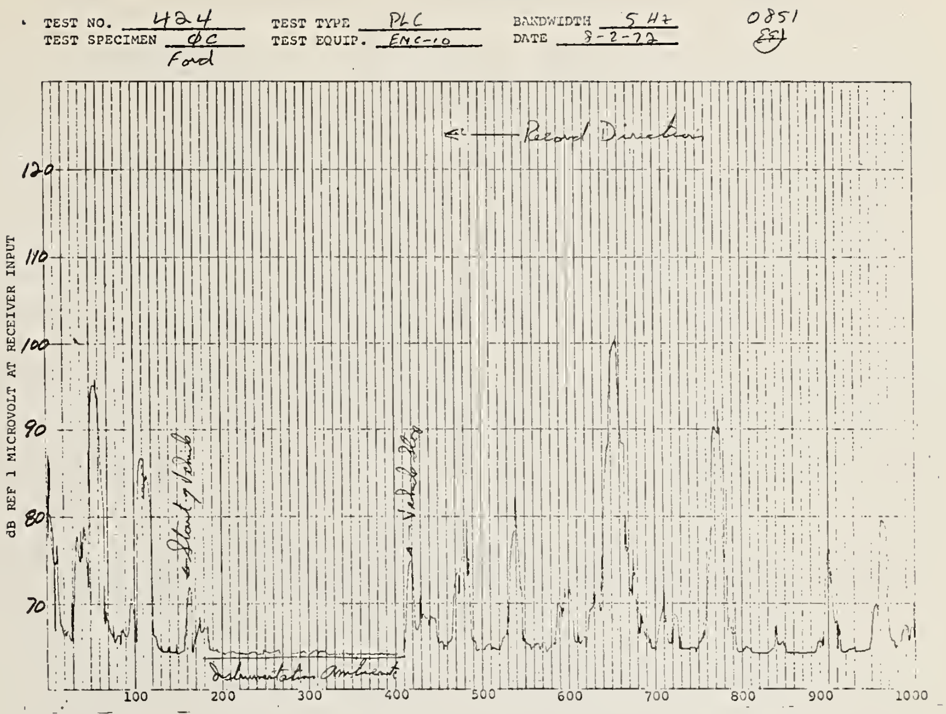
TEST NO. 433　　TEST TYPE PLC　　BANDWIDTH 50 Hz　　0947
TEST SPECIMEN ΦB Ford　　TEST EQUIP. EMC-10　　DATE 8-2-72

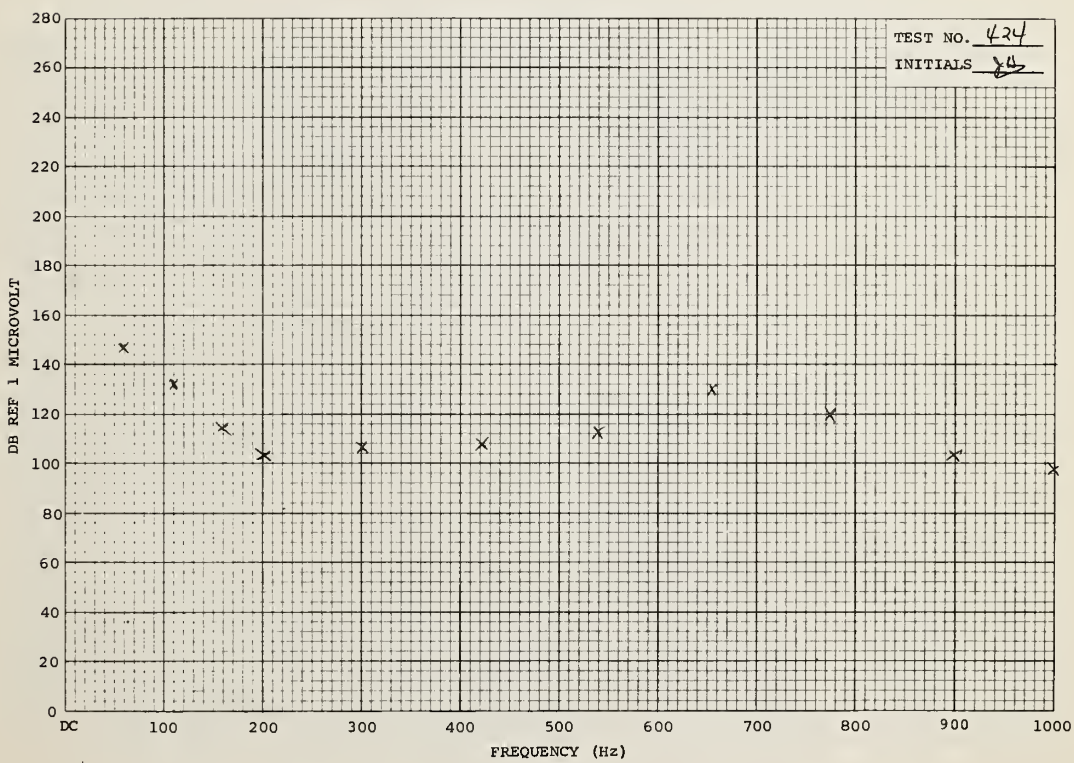





TEST NO. 423
TEST TYPE PLC
BANDWIDTH 5 Hz
0848
TEST SPECIMEN ØC FORD
TEST EQUIP. EMC-10
DATE 8-2-72
dB REF 1 MICROVOLT AT RECEIVER INPUT
120
110
100
90
80
70
100
200
300
400
500
600
700
800
900
1000

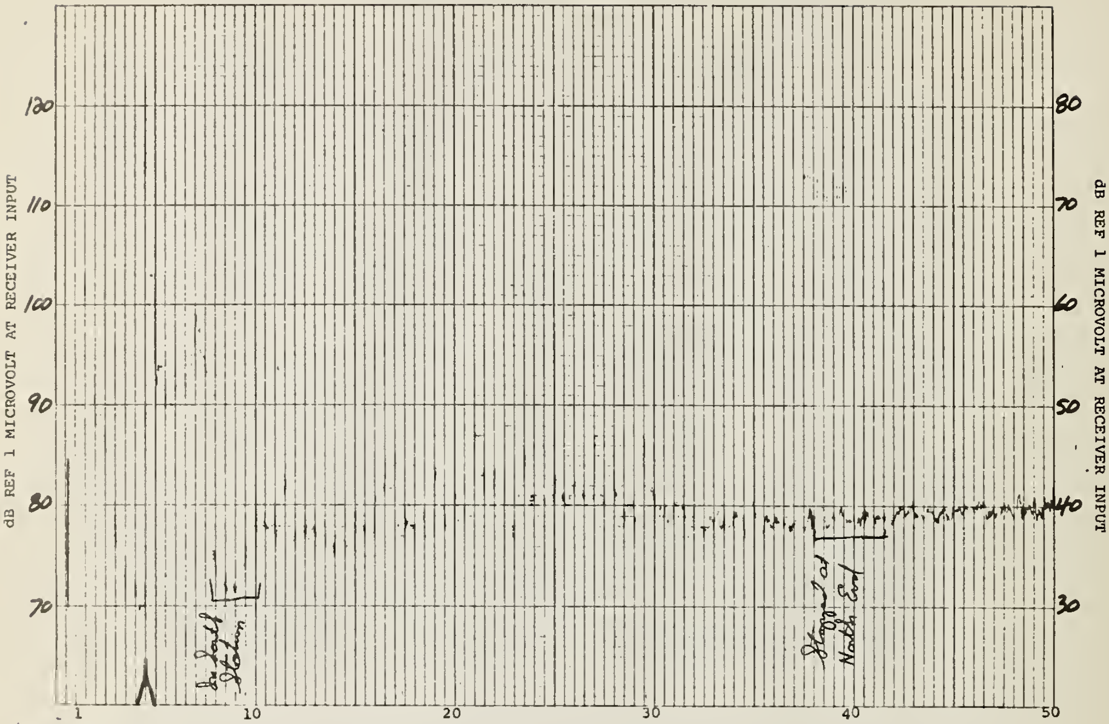

TEST NO. 423
INITIALS
DB REF 1 MICROVOLT
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
DC
100
200
300
400
500
600
700
800
900
1000
FREQUENCY (Hz)

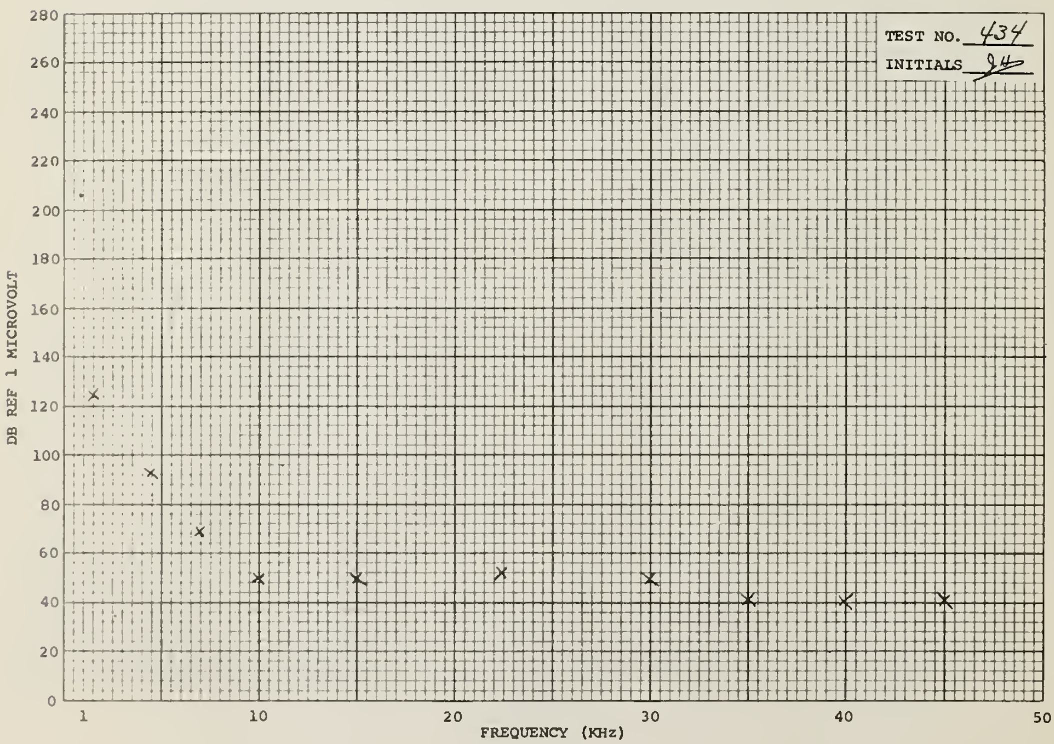

TEST NO. 424
TEST SPECIMEN ΦC Ford
TEST TYPE PLC
TEST EQUIP. EMC-10
BANDWIDTH 5 Hz
DATE 8-2-72
0851
Record Direction
dB REF 1 MICROVOLT AT RECEIVER INPUT
120
110
100
90
80
70
100
200
300
400
500
600
700
800
900
1000


TEST NO. 424
INITIALS
DB REF 1 MICROVOLT
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
DC
100
200
300
400
500
600
700
800
900
1000
FREQUENCY (Hz)

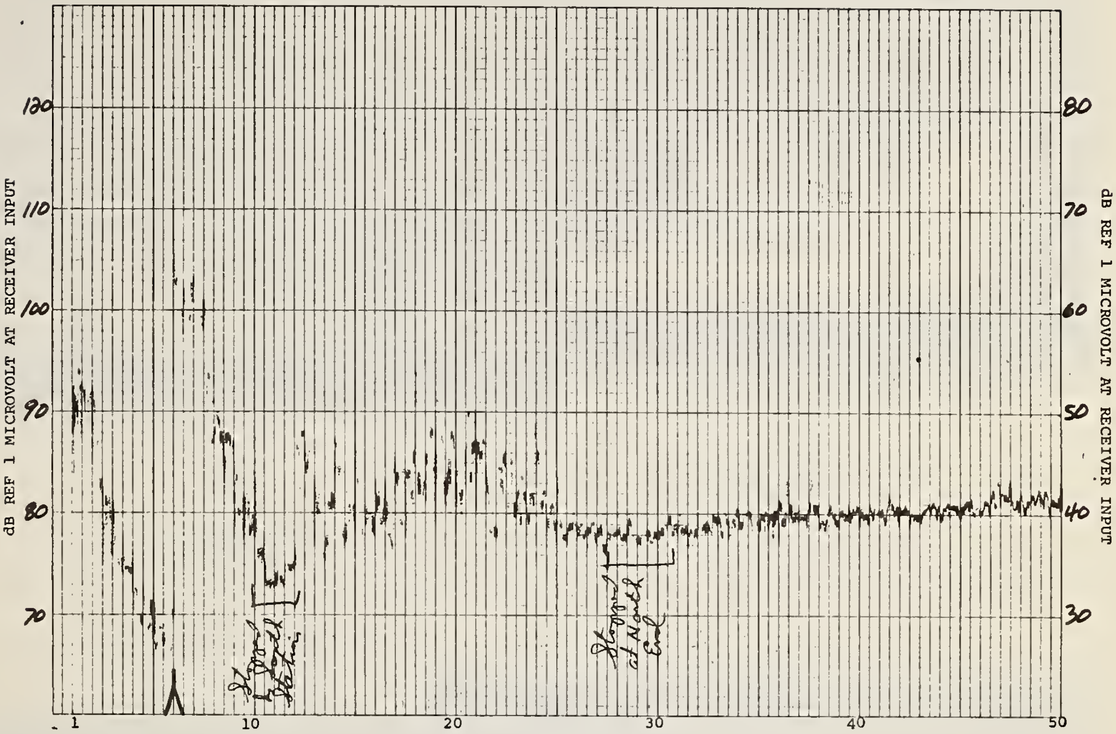
TEST NO. 434 TEST TYPE PLC BANDWIDTH 50 Hz 0950

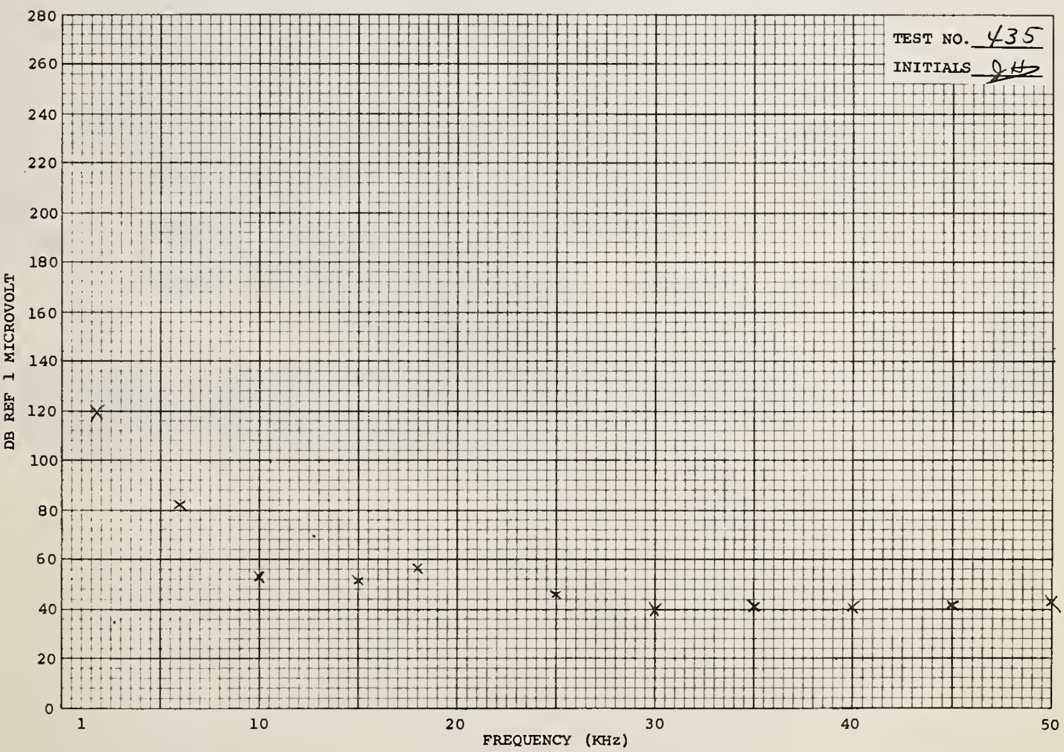
TEST SPECIMEN ØC Ford TEST EQUIP. EMC-10 DATE 8-2-72 EEJ

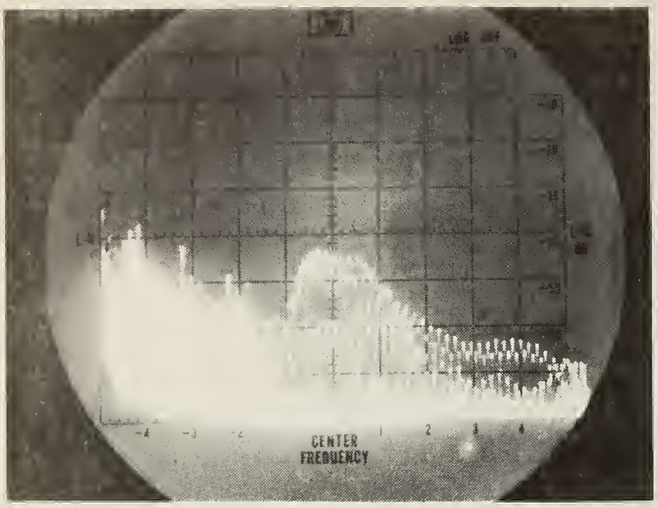




TEST NO. 435 TEST TYPE PLC BANDWIDTH 50 Hz 0956
TEST SPECIMEN ΦC Ford TEST EQUIP. EMC-10 DATE 8-2-72 EEJ







f_c

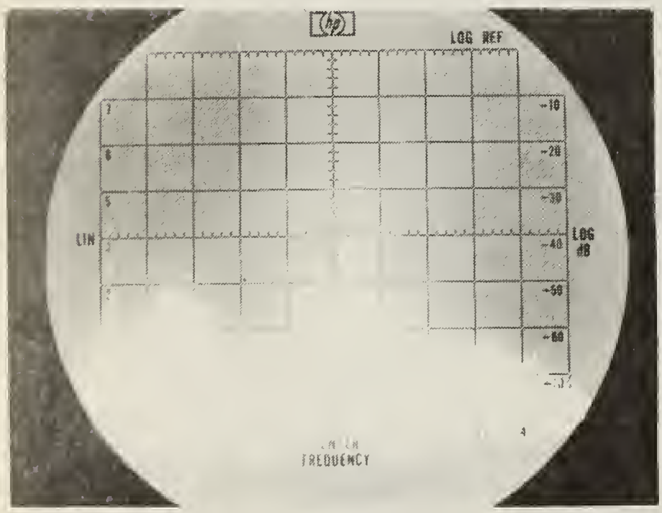
500 kHz

No. 436

FREQ. SCAN = 100 kHz/DIV.
TIME SCAN = 0.1 sec/DIV.
For frequencies above 50 kHz, -40 dB gradicule scale is 95 dBμV/MHz

POWER LINE: ØA

Vehicle slow down before entering station.



f_c

500 kHz

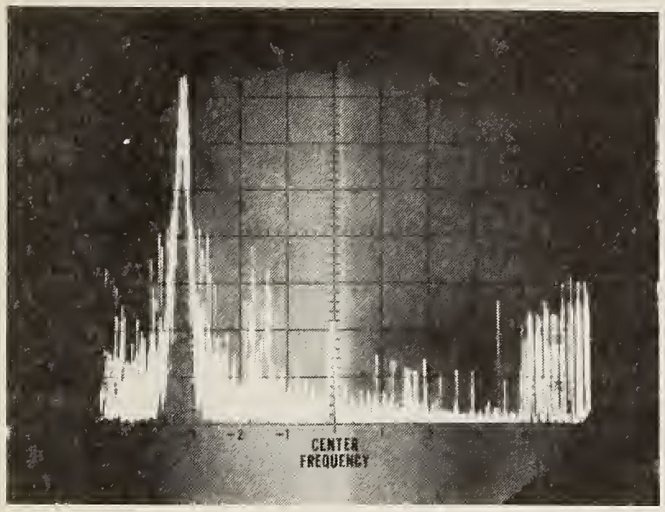
No. 438

FREQ. SCAN = 100 kHz/DIV.
TIME SCAN = 0.2 sec/DIV.

For frequencies above 50 kHz, -40 dB gradicule scale is 95 dBμV/MHz

Power Line: ØA

Vehicle parked in station.



f_c

150 kHz

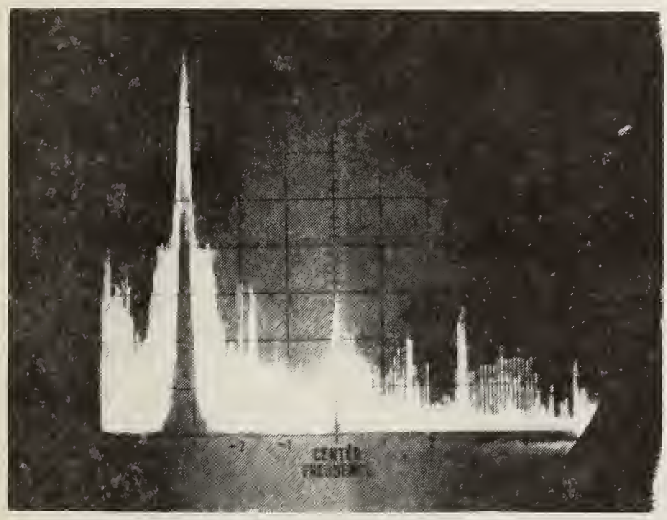
No. 440

FREQ. SCAN = 50 kHz/DIV.
TIME SCAN = 0.1 sec/DIV.

For frequencies above 50 kHz, -40 dB gradicule line (center) is 95 dBμV/MHz

POWER LINE: ØA

Vehicle parked in South Station



f_c

150 kHz

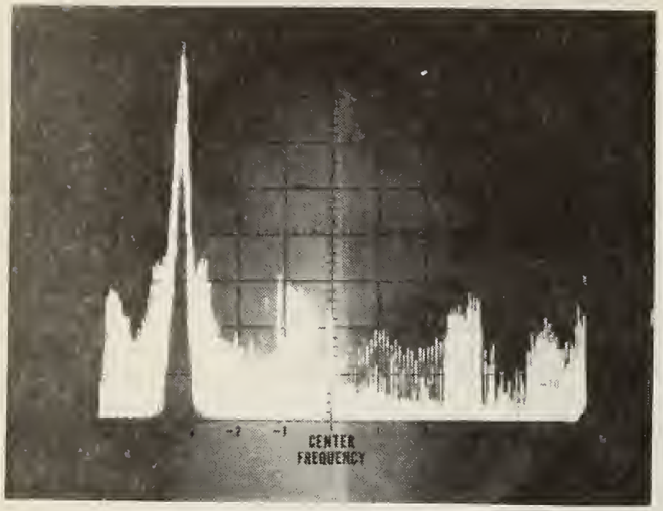
No. 442

FREQ. SCAN = 50 kHz/DIV.
TIME SCAN = 0.1 sec/DIV.

For frequencies above 50 kHz, -40 dB gradicule line (center) is 95 dBμV/MHz

POWER LINE: ØA

Vehicle stopped at North end of guideway.



f_c

150 kHz

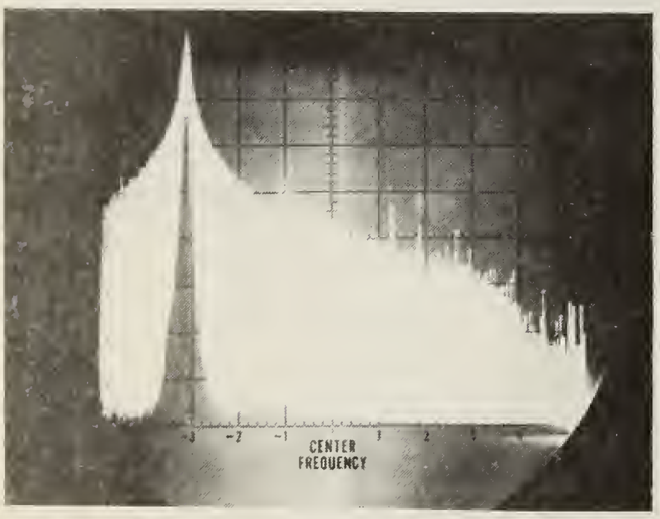
No. 441

FREQ. SCAN = 50 kHz/DIV.
TIME SCAN = 0.1 SEC/DIV.

For frequencies above 50 kHz, -40 dB gradicule line (center) is 90 dBμ/MHz

POWER LINE: ØA

Vehicle stopped (unscheduled) on guideway



f_c

150 kHz

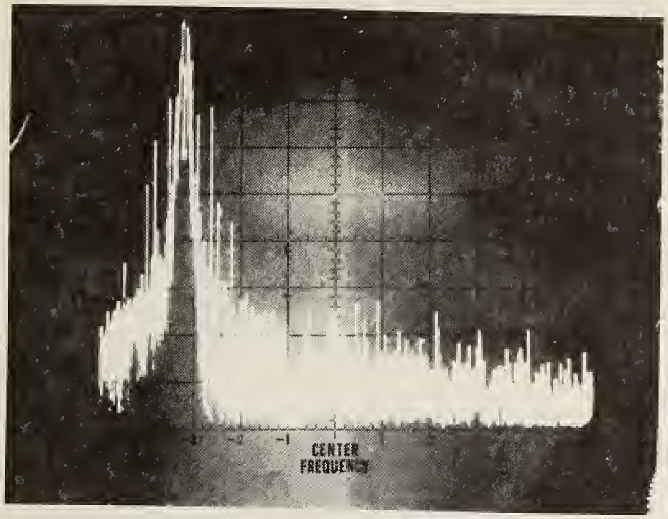
No. 443

FREQ. SCAN = 50 kHz/DIV.
TIME SCAN = 0.1 SEC/DIV.

For frequencies above 50 kHz, -40 dB gradicule line (center) is 95 dBμV/MHz

POWER LINE: ØA

Vehicle travelling from North to South on guideway



f_c

150 kHz

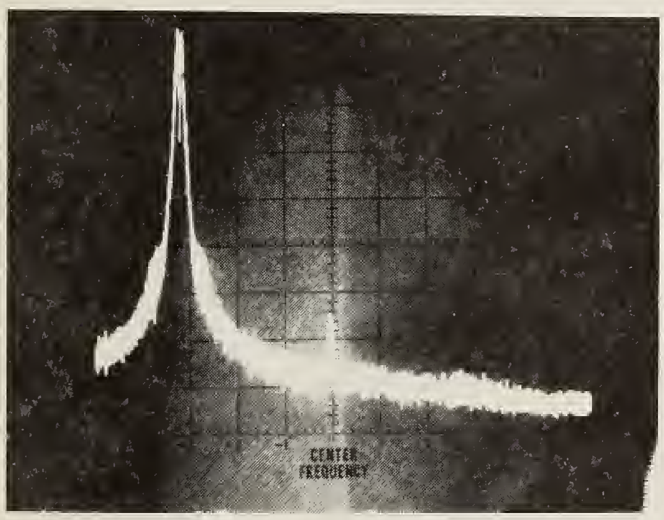
No. 444

FREQ. SCAN = 50 kHz/DIV.
TIME SCAN = 0.5 SEC/DIV.

For frequencies above 50 kHz, -40 dB gradicule line (center) is 75 dBμV/MHz

POWER LINE: ØB

Vehicle parked on guideway during noon lunch hour.



No. 444
(Special)

Same as 444 above except:

TIME SCAN = 5 SEC/DIV., and Display Video Frequencies limited to 100 Hz.

AL
TRANSPORTATION
SYSTEMS - SPVO

Ford

LOG SHEET

PAGE 1 OF

ransportation

DULLES SYSTEM

OPERATOR ________ O.D. READING ✓ MILES

VEHICLE Rachel HOUR METER READING ✓ HOURS

DATE 8-2-72

Test or Subject: Activity Record for EMI Test

Observations:

806 Begin 1st cycle on Rachel
810 " 2nd " " "
815 " 3rd " " "
818 " 4th " " "
821 " 5th " " "
824 " 6th " " "
829 " 7th " " "
831 " 8th " " "
834 " 9th " " "
836 " 10th " " "
839 " 11th " " "
841 " 12th " " "
843 " 13th " " "
845 " 14th " " "
848 " 15 " " "
850 TRIPPED POWER AS OF SPEED TRAP
851 BEGIN 16th cycle on RACHEL
854 " 17th " " "
857 " 18th " " "
859 " 19th " " "
902 " 20th " " "
903 POWER OFF
905 " BACK ON
9:10 Returning to Sta A stopped ~100 ft N of Sta A
915 Begin 21st cycle on Rachel
9:18 " 22" " " "
9:21 " 23" " " "
9:23 " 24" " " "
9:25 " 25" " " "
9:28 " 26" " " "
9:30 " 27" " " "
9:31 Speed trap shutdown (S end guideway)
9:33 Reset speed
9:34 Begin 28" " " "
9:36 Circuit Breaker out - go aboard vehicle (N switchover)

Form STS 5

AL
NSPORTATION
YSTEMS - SPVO

Ford

PAGE 2 OF

ranspo

DULLES SYSTEM

NATOR

O.D. READING ______ MILES

LE

HOUR METER READING ______ HOURS

8-2-72

or Subject:

nations:

9:44	Begin	29 th	Cycle	on	Rachel	
9:46	"	30 "	"	"	"	
9:49	"	31 "	"	"	"	
9:51	"	32 "	"	"	"	
9:54	"	33 "	"	"	"	
9:56	"	34 "	"	"	"	
9:58	"	35 "	"	"	"	
10:01	"	36 "	"	"	"	
10:03	"	37 "	"	"	"	
10:06	"	38 "	"	"	"	
10:08	"	39 "	"	"	"	
10:10	"	40 "	"	"	"	
10:12	Speedtrap outage (S end guideway)					
10:13	Restart toward Sta A					
10:14	Begin	41 st	"	"	"	
10:16	"	42 "	"	"	"	
10:18	"	43 "	"	"	"	
1022	"	44 "	"	"	"	
1024	"	45 "	"	"	"	
1026	"	46 "	"	"	"	
1029	"	47 "	"	"	"	
1031	"	48 "	"	"	"	
1034	"	49 "	"	"	"	
1036	"	50 "	"	"	"	
1040	"	51 "	"	"	"	
1042	"	52 "	"	"	"	
1044	"	53 "	"	"	"	
1046	"	54 "	"	"	"	
1049	"	55 "	"	"	"	
1051	POWER OFF SPEED TRAP					
1052	Begin	56 "	"	"	"	

Form STS 5

AL
ESPORTATION
YSTEMS - SPVO

PAGE 3 OF

ranspo

DULLES SYSTEM

MATOR

O.D. READING ______ MILES

HOUR METER READING ______ HOURS

LE
8-2-72

or Subject: Activity Record for EMI test

nations:

1055	Begin	57 th	cycle	on	Rachel
1057	"	58 "	"	"	"
1100	"	59 "	"	"	"
1105	"	60 "	"	"	"
1107	"	61 "	"	"	"
1110	"	62 "	"	"	"
1112	"	63 "	"	"	"
1115	"	64 "	"	"	"
1117	"	65 "	"	"	"
1119	"	66 "	"	"	"
1122	"	67 "	"	"	"
1124	"	68 "	"	"	"
11:27	"	69 "	"	"	"
1129	"	70 "	"	"	"
1132	"	71 "	"	"	"
1134	"	72 "	"	"	"
1136	"	73 "	"	"	"
11:39	"	74 "	"	"	"
11:41	"	75 "	"	"	"
11:44	"	76 "	"	"	"
11:46	"	77 "	"	"	"
11:48	"	78 "	"	"	"

11:49 Stop in S switch area move to Sta A 11:51

11:51	Begin	79 th	cycle	
11:54	"	80 "	"	
11:56	"	81 "	"	
11:59	"	82 "	"	
12:01	"	83 "	"	
12:04	"	84 "	"	

Form STS 5