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

Earl E. Jamison

JANUARY 1974

FINAL REPORT

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16. Abstract

An X-Y plot is made of the radiated Electromagnetic signals and noise between 1KHz and 50KHz at each of the four Personalized Rapid Transit (PRT) sites at Dulles International Airport. The PRT systems were operated individually to establish the signal characteristics of each system. A spectrum analyzer was used to view the frequency spectrum broadband prior to recording and a Polaroid scope camera was used in conjunction with the spectrum analyzer to photograph signals between 50KHz and 50MHz. This frequency range was sufficiently broad to cover all command and control frequencies of the four PRT systems.

The purpose of the measurements program was to establish some base line information on the electromagnetic signal characteristics in the Dulles area in the event there was an interaction between the PRT Command and Control systems and the Federal Aviation Administration Air Traffic Control equipment.

The measurements obtained during this series of tests will be used for a comparison with data obtained with no PRT systems operating and later with all four 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.

RADIATED FIELD NOISE MEASUREMENTS

FORD SYSTEM - TRANSPO® '72

1. INTRODUCTION

This technical report presents the data obtained in the performance of tests for radiated field 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 2 of Contract DOT-TSC-375, and as performed by National Scientific Laboratories.

Item 2 calls for the performance of radiated field noise measurements from each PRT system in the frequency range from 1 KHz to at least 50 MHz with one PRT system on. The objective of the test was to gather operational data for each of the PRT systems. Such data will enable characterization of the noise increase attributable to system operation, 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 1, 1972.

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* Technical Report, Item 1, Ambient Radiated Field Noise Survey, PRT Systems - TRANSPO®'72, March 1972, Contract DOT-TSC-375 Department of Transportation, Transportation Systems Center, 55 Broadway, Cambridge, Massachusetts 02142

2. METHOD OF MEASUREMENT

All measurements were made using test setups and instruments as nearly identical as possible to those used during ambient testing.

2.1 Instruments

The measurements made in the frequency range from 1 KHz to 50 KHz 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 from 1 KHz to 50 KHz. The receiver 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.

Signals were obtained from the electro-magnetic environment by use of either a Fairchild PEF-10 Electric Field Antenna or a Fairchild ALP-10 Magnetic Field Antenna. Both of these antennas are directional in the horizontal plane, therefore, measurements were made for North/South and East/West orientations.

The measurements made in the 50 KHz to 60 MHz frequency range were performed using Hewlett Packard Model 8552/8553A

Spectrum Analyzer. 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. The analyzer was used in four frequency bands 50 KHz to 100 KHz, 100 KHz to 1.1 MHz, 1 MHz to 21 MHz, and 10 MHz to 60 MHz. Data was recorded photographically with a Hewlett Packard Model 198A oscilloscope camera.

Signals were obtained from the electro-magnetic environment in the 50 KHz to 21 MHz frequency range by using an NSL verticle top loaded whip electric field antenna mounted on a cathode follower. This antenna is non-directional in the horizontal plane. In the 20 MHz to 60 MHz frequency range, an EMCO Model 3104 biconical electric field antenna was utilized. This antenna is directional in the horizontal plane, therefore, measurements were made in the North/South and East/West orientations.

During the tests, the various antennas were attached to the top of a mast mounted on the NSL instrumentation van. An antenna rotator was incorporated in the antenna mast to enable rotation in azimuth. The antenna height was approximately 12 feet above ground.

The various instruments received a.c. power from a motor generator positioned 150 feet from the van.

2.2 Test Sites

The test sites used during the performance of the measurements were the same locations as denoted in the Item 1 report

for the ambient noise tests. The sites are numbered 1 through 11 for the entire PRT area. Sites 1, 3 and 4 are located at the FORD system as shown in the map, Figure 1. A complete set of measurements was obtained at each site - magnetic field, 1 KHz to 50 KHz, and electric field, 1 KHz to 60 MHz.

2.3 Measurement Technique

Data were obtained in the 1 KHz to 50 KHz frequency range by scanning manually the EMC-10 receiver, using a 50 Hz bandwidth setting. Two recordings have been made for each antenna (magnetic field, electric field) in two orientations (North/South, East/West). The scanning time per recording averaged four to six minutes.

The magnetic field recordings, denoted as MSR type test on the charts, are reproduced in the Appendix as the upper half of pages A-2 to A-5, A-15 to A-18 and A-28 to A-31. The dB scale refers to the level at the instruments 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 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 antenna (antenna amplitude response is non-linear with frequency) has been included in the levels plotted in the lower graphs. In the upper

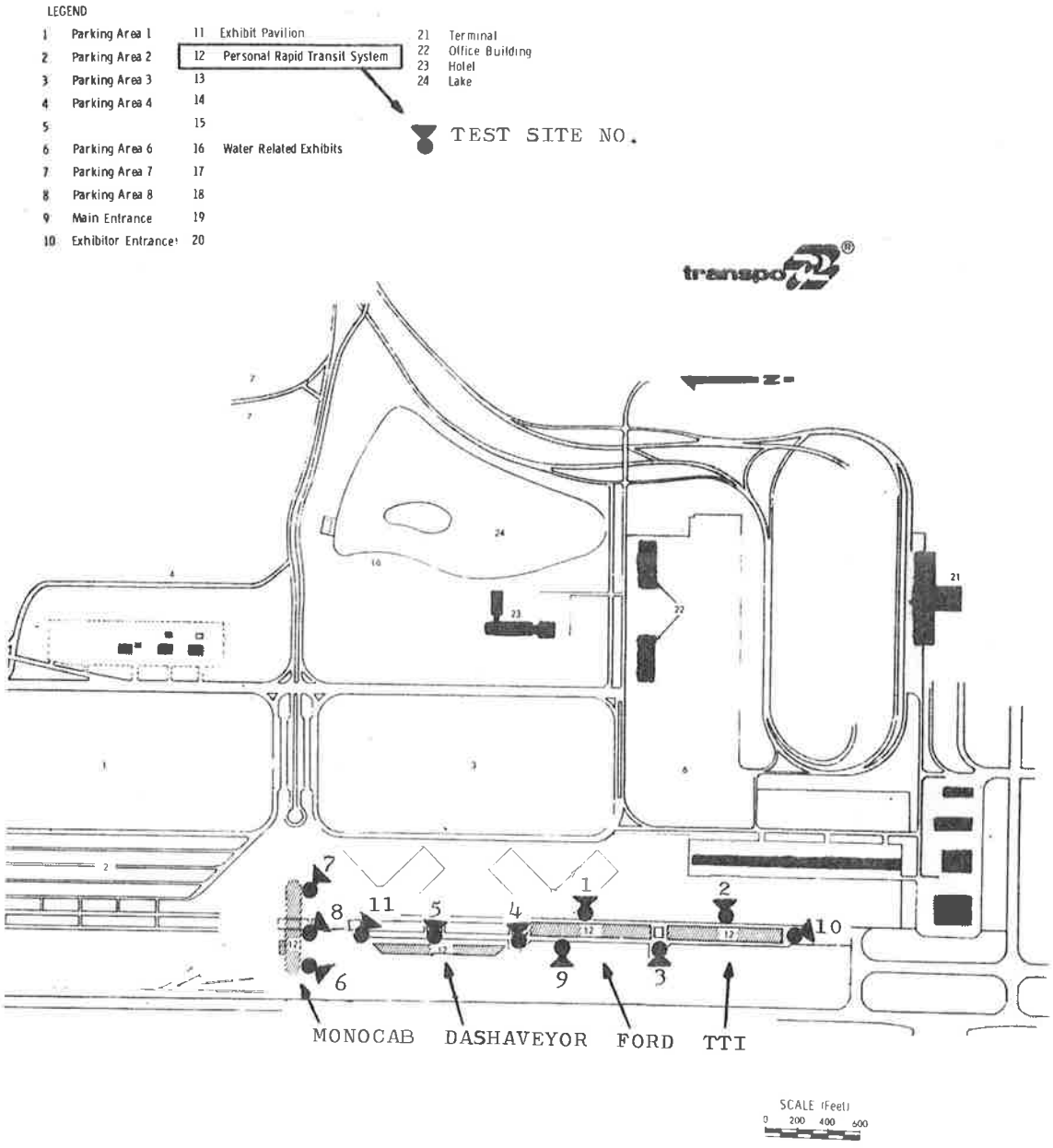


FIGURE 1. PRT TEST SITE LOCATIONS

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.

The electric field chart recordings, denoted as ESR type test on the charts, are reproduced in the Appendix on Pages A-6 to A-9, A-19,to A-22, and A-32 to A-35. Some of these charts also have two amplitude scales, and they are used in the same manner as described for the magnetic field recordings. In addition, noise peaks recorded in the top major amplitude division are out of the calibrated range of the system.

Electric field data for the 50 KHz to 60 MHz frequency range were obtained as photographic recordings of spectrum analyzer amplitude/frequency CRT displays. Two recordings have been made for each frequency band - 50 KHz to 100 KHz, 100 KHz to 1.1 MHz, and 1 MHz to 21 MHz. A non-directional antenna was used for the above frequencies. Four recordings were obtained for the 10 MHz to 60 MHz frequency band for which a directional antenna was employed, therfore, two recordings were made for North/South orientation, and two recordings for East/West orientation. The antenna employed for the first three frequency bands has a constant correction factor for all frequencies, and this is included in the amplitude designations for the recorded data. The antenna employed for the high frequency

band has a nearly constant correction factor above 20 MHz, and this factor has been included in the amplitude designations for the recorded data. Thus, the calibration levels given by the side of the photograph do not apply to frequencies from 10-20 MHz. The photographic recordings are reproduced in the Appendix on Pages A-10 to A-14, A-23 to A-27, and A-36 to A-40.

3. INTERPRETATION OF DATA

Radiated field measurements have been made at three test sites at the FORD installation. The data are contained in Appendix A. No notations are given with the data as no vehicle functions could be directly correlated with any signal peaks. Thus, the data can be compared with the ambient data to determine and increase its radiation levels.

4. TIME LOG

FORD has only one vehicle running during the test period of 0800 to 1200. The log of events is contained in the Appendix on pages A-41 to A-43.

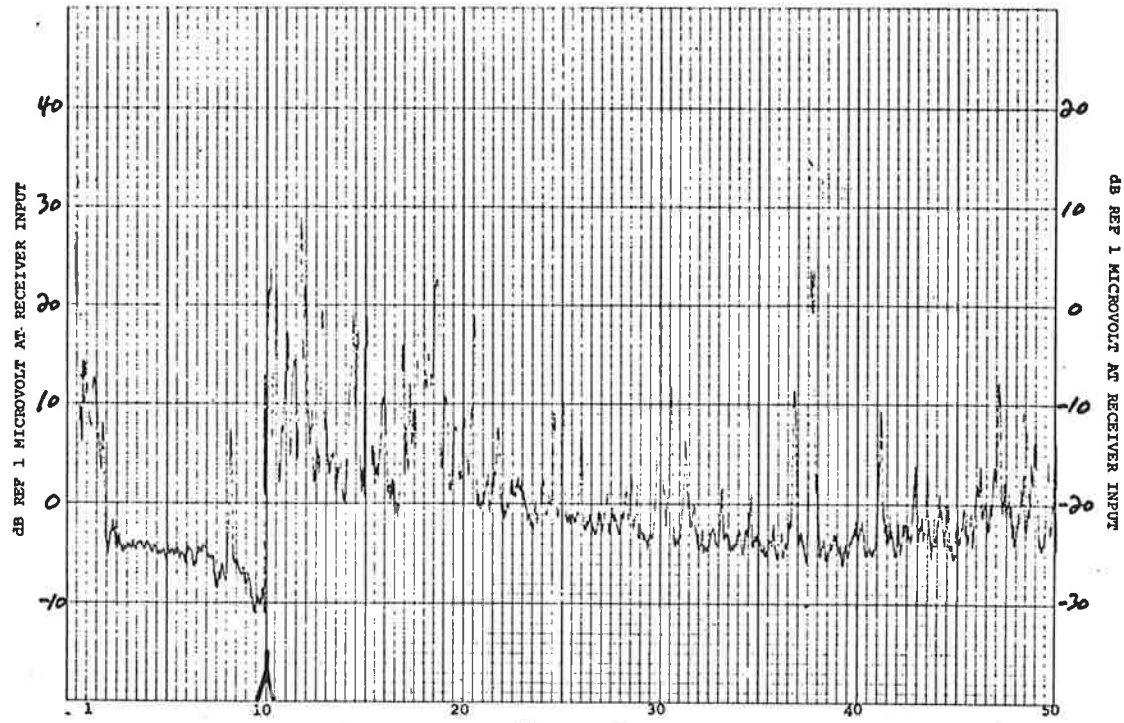
APPENDIX A

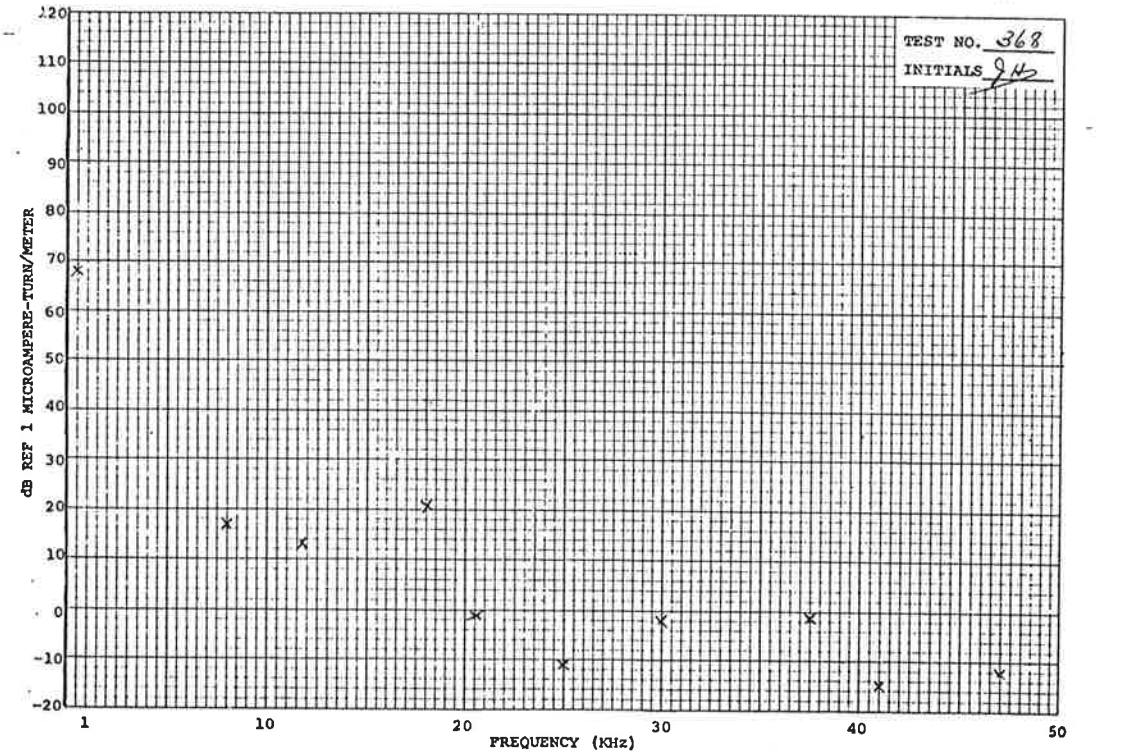
RADIATED FIELD MEASUREMENTS DATA

This appendix contains the data obtained during the various tests performed. The data is not presented in numerical sequence as the tests were performed, but rather by site location number from south to north - Site No. 3, 1 and 4. Further, the data are arranged in the following manner - first, magnetic field charts, then electric field charts and photographs in order of frequency progression. Data is contained herein for Test No's. 366 to 378, 351 to 363 and 379 to 391.

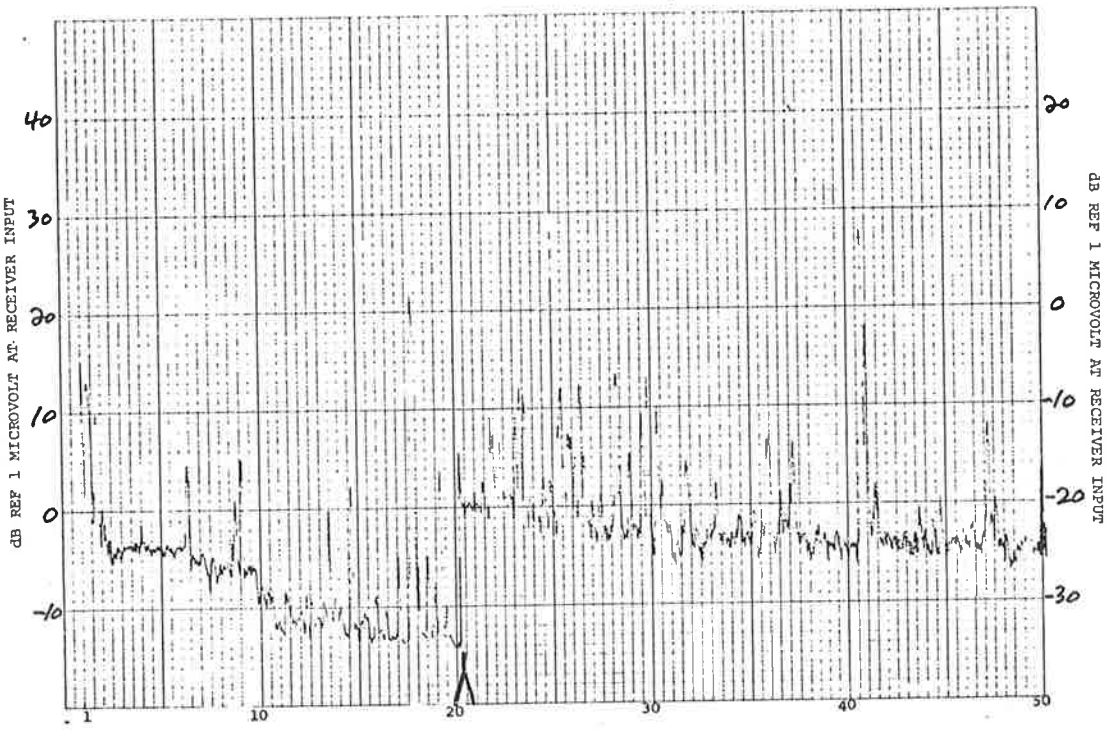
A Time Log of events for PRT vehicle operations is contained on pages A-41 to A-43.

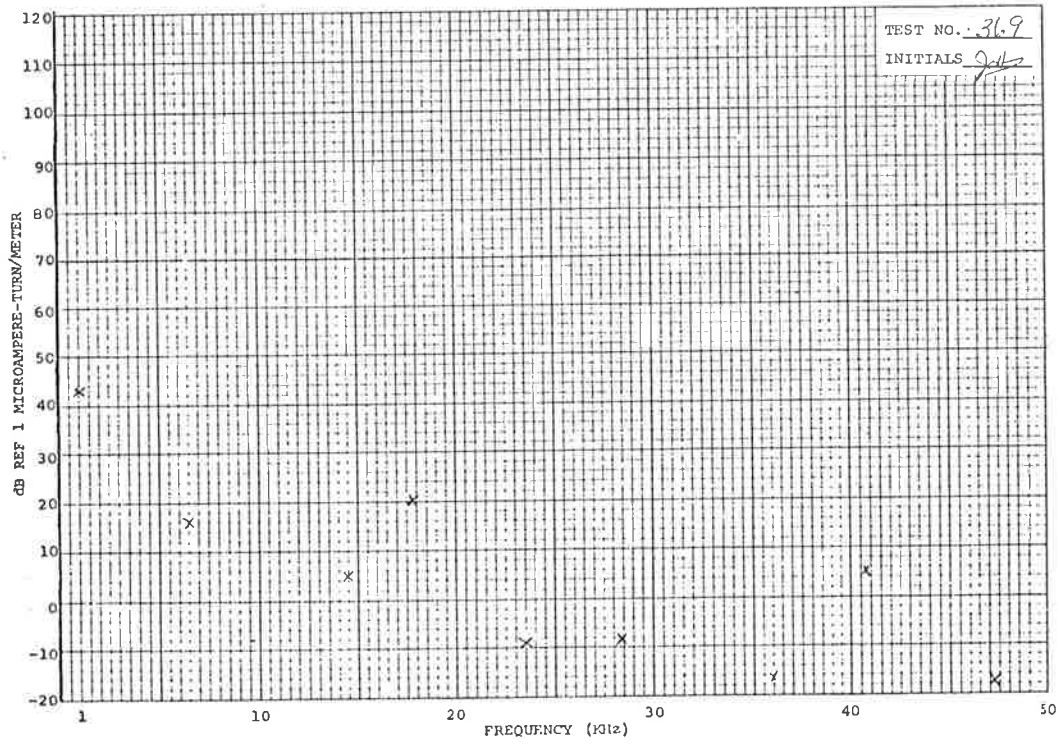
TEST NO. 368 TEST TYPE MSR F/W BANDWIDTH 50 Hz 1000
TEST SPECIMEN Sub 3 TEST EQUIP. LMC 10 DATE 8-1-72 EJ



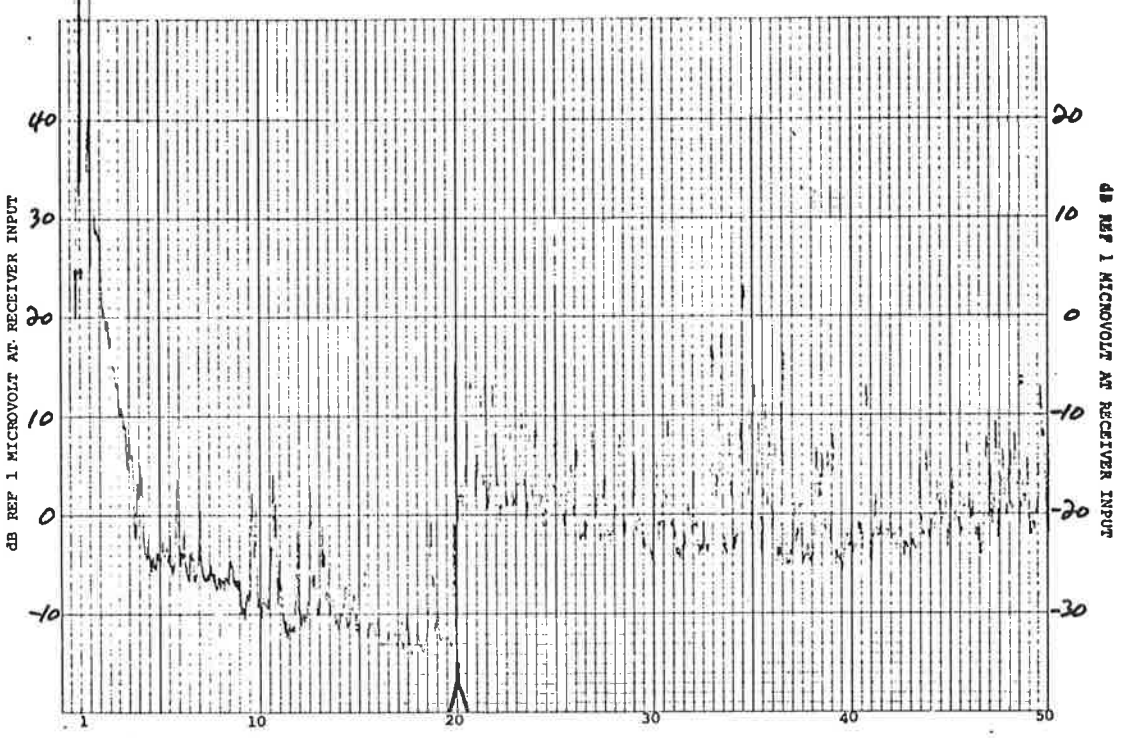


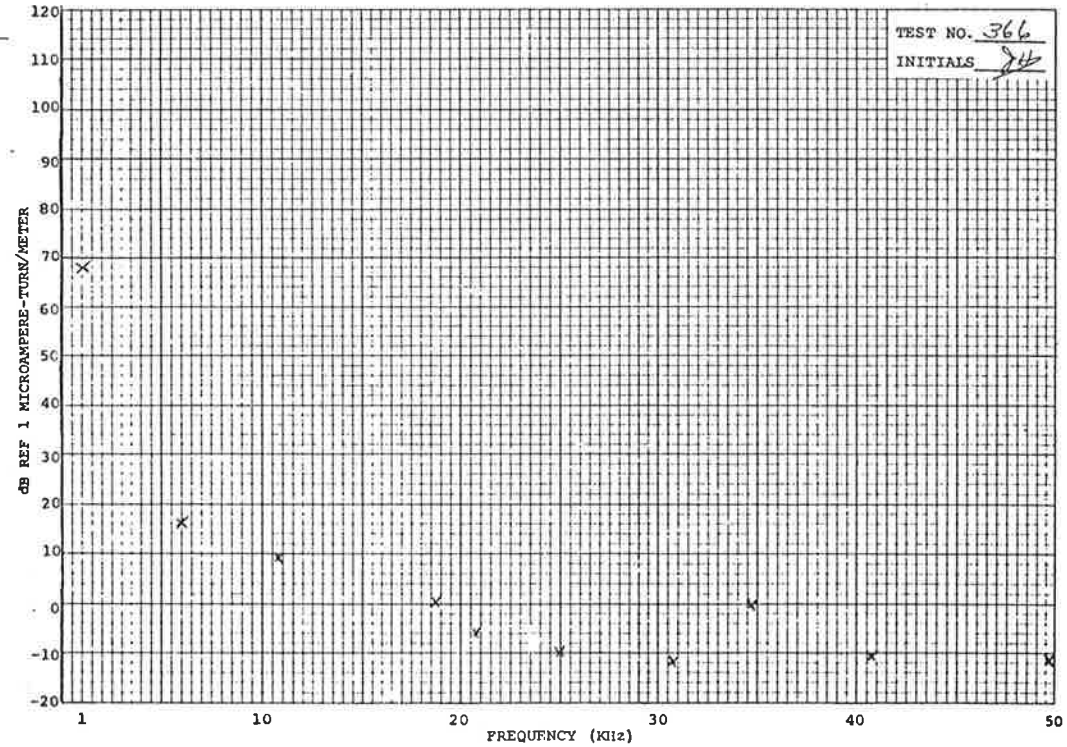
TEST NO. 369 TEST TYPE MSR E/H BANDWIDTH 50 Hz 1003
TEST SPECIMEN S/C 5 TEST EQUIP. FMC-16 DATE 8-1-12 EJ



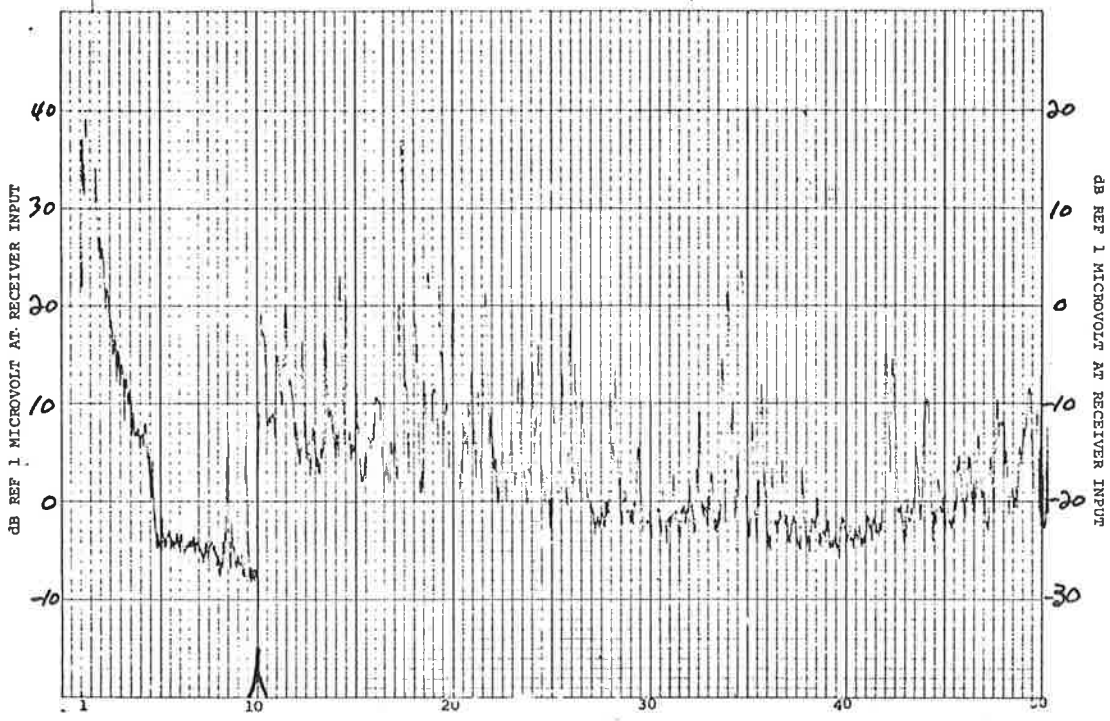


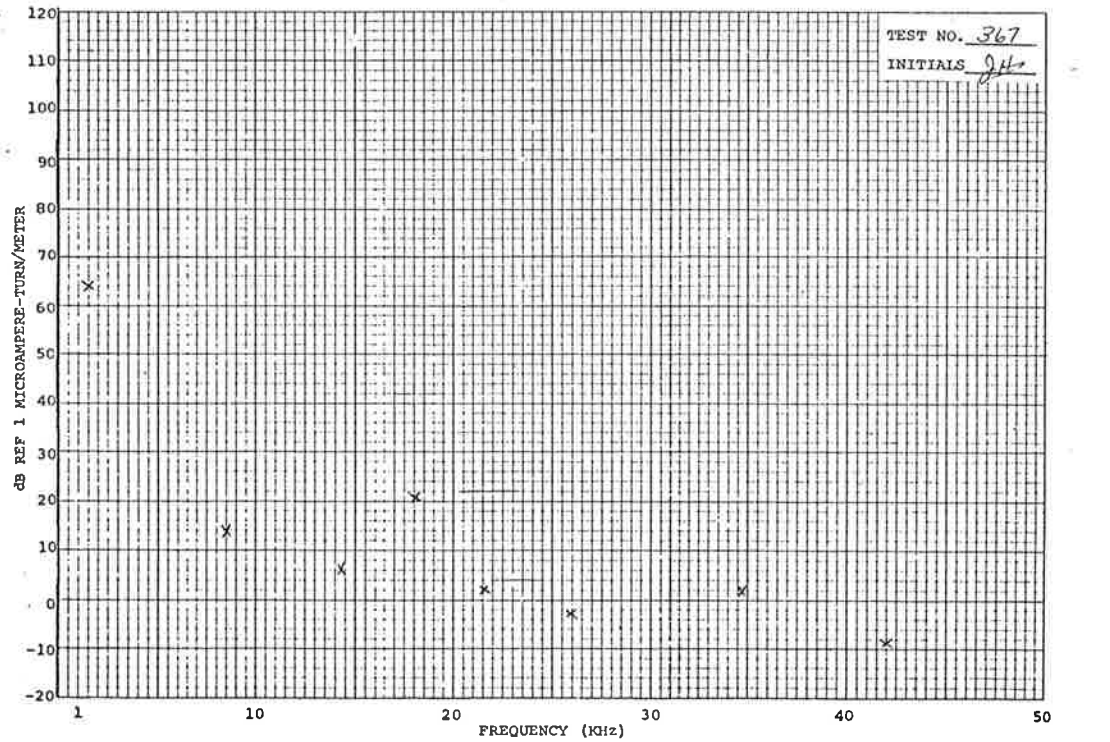
TEST NO. 366 TEST TYPE MSR N/S BANDWIDTH 50 Hz 0954
TEST SPECIMEN- S/C 3 TEST EQUIP. EMC-10 DATE 8-1-12



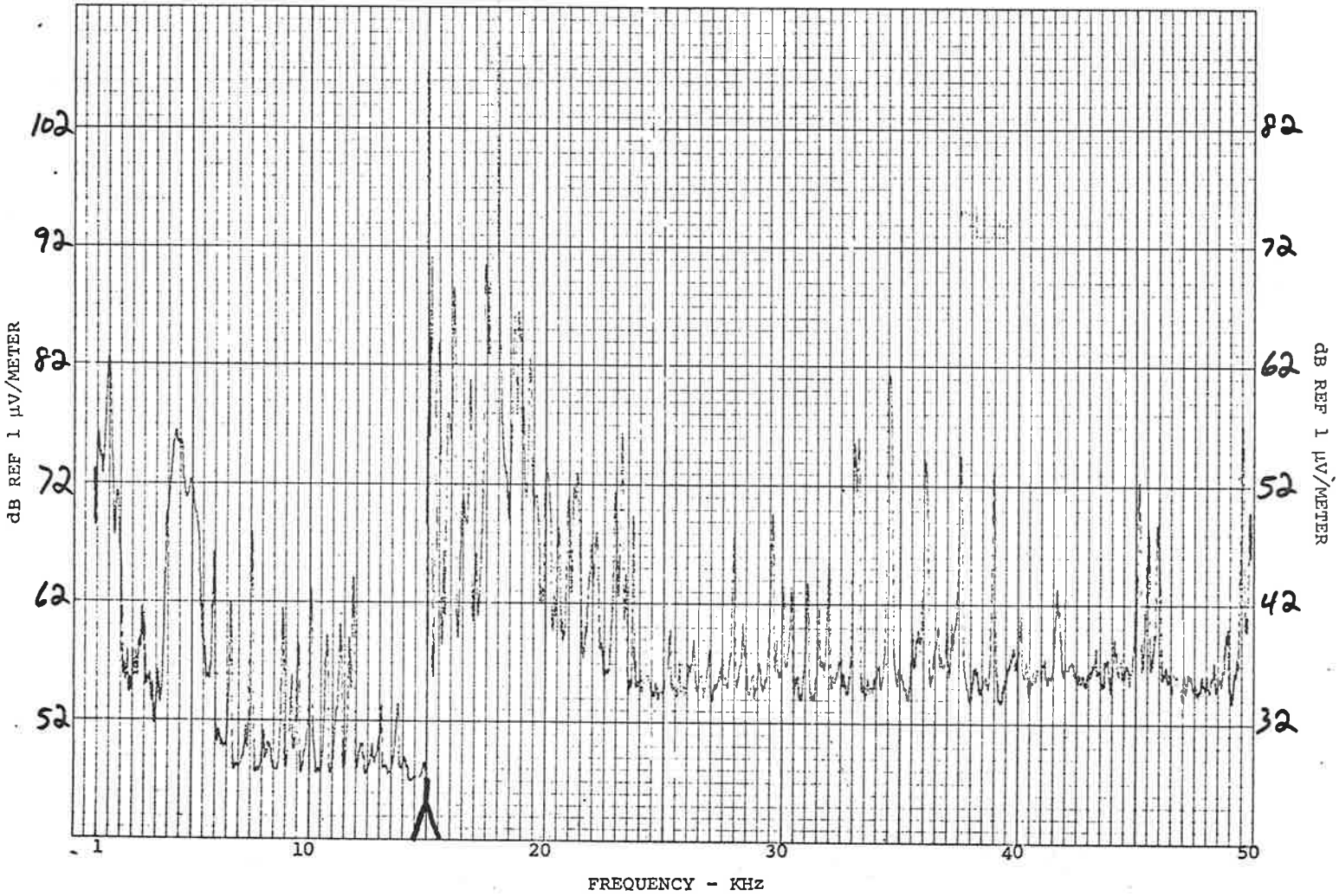


TEST NO. 367 TEST TYPE MSR N/S BANDWIDTH 50Hz 0956
TEST SPECIMEN 363 TEST EQUIP. EMC-10 DATE 8-1-12 ESI

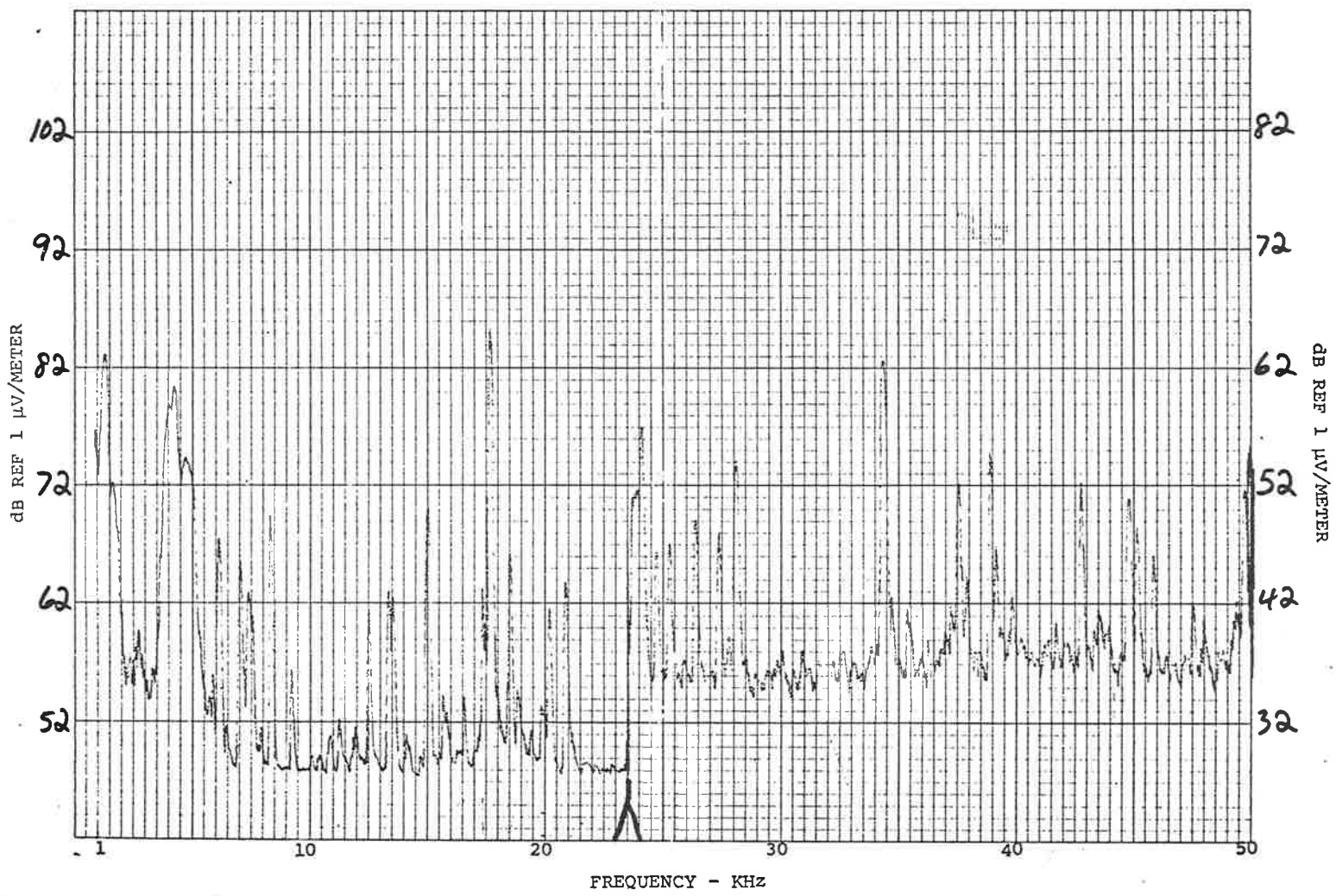




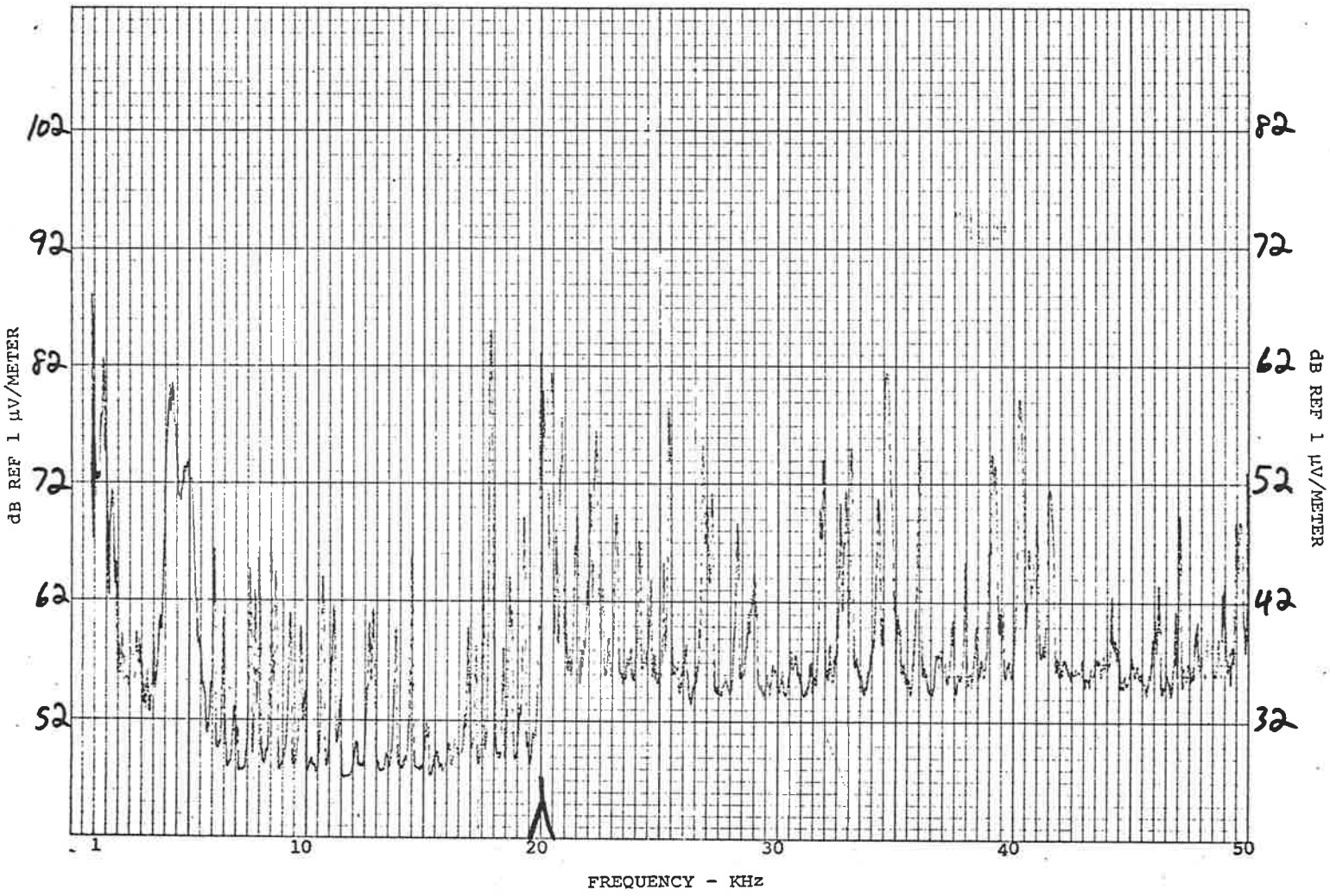
TEST NO. 370 TEST TYPE ESR E/W BANDWIDTH 50 Hz 1009
TEST SPECIMEN Sub 3 TEST EQUIP. EMC-10 DATE 8-1-72 ESJ



TEST NO. 371 TEST TYPE ESR E/W BANDWIDTH 50 Hz 1012
TEST SPECIMEN 863 TEST EQUIP. EMC-10 DATE 8-1-72 ES1

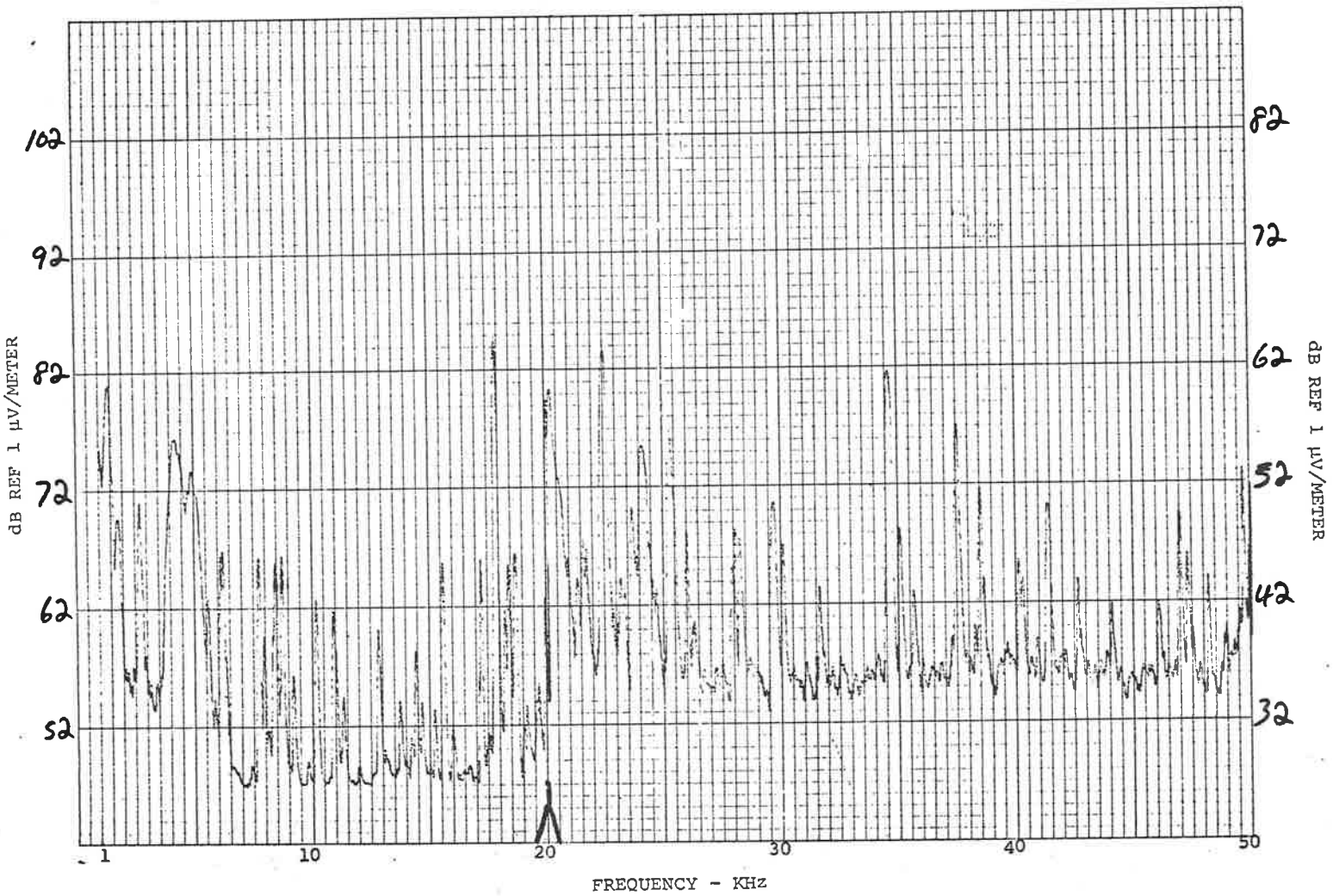


TEST NO. 372 TEST TYPE ESR N/S BANDWIDTH 50 Hz 1015
TEST SPECIMEN Sub 3 TEST EQUIP. EMC-10 DATE 8-1-72 EB

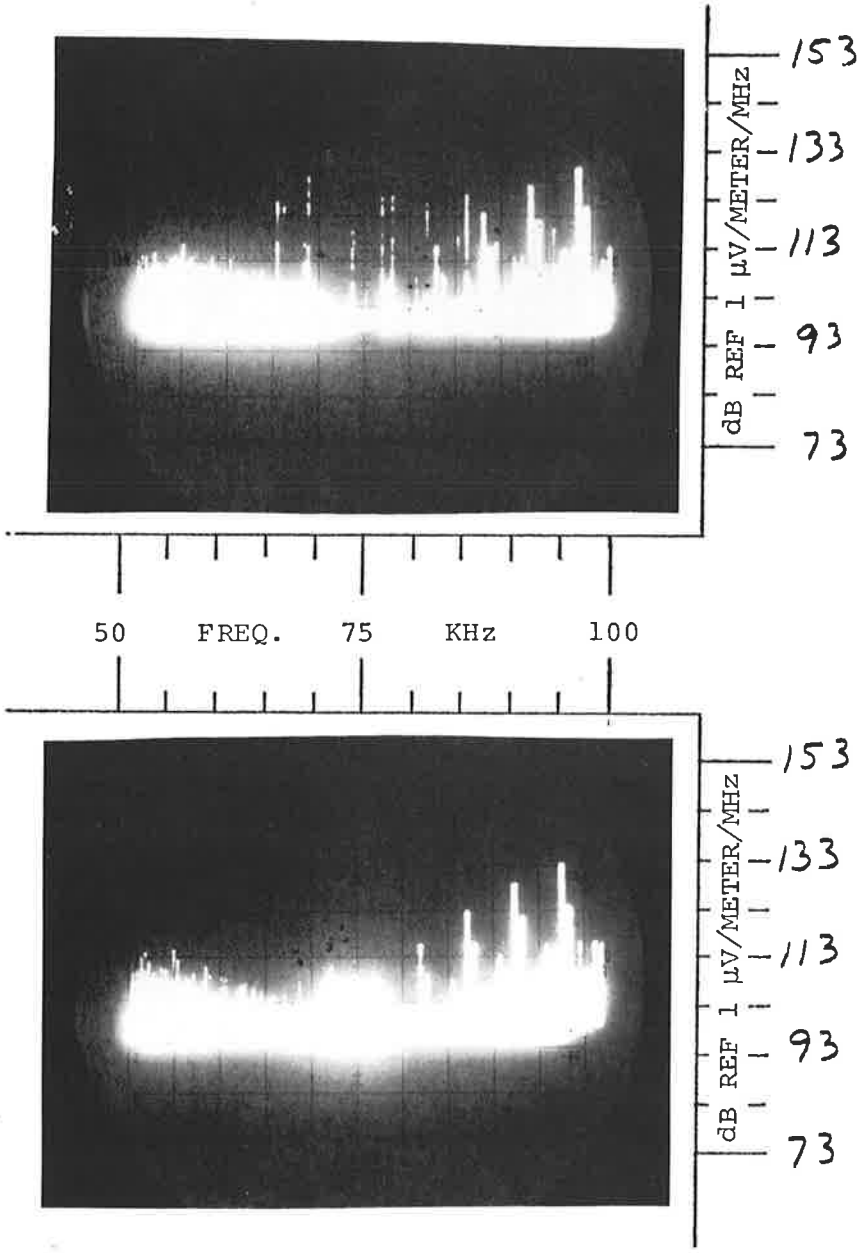


TEST NO. 373
TEST SPECIMEN Site 3
TEST TYPE ESR N/S
TEST EQUIP. EMC-10
BANDWIDTH 50Hz
DATE 8-1-72

1018
ESJ



LOCATION: SITE 3 TYPE TEST ESR DATE 8-1-72

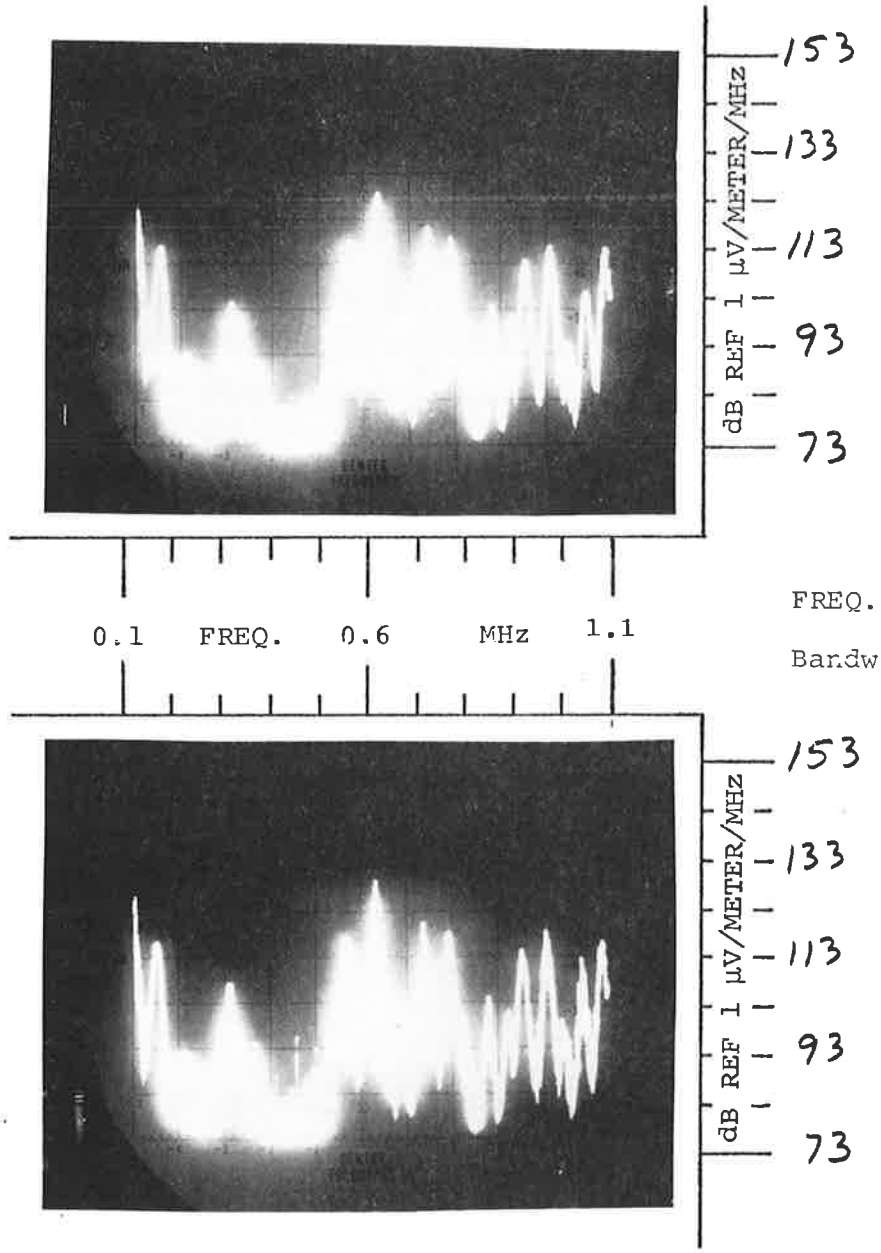


TEST 374
TIME 1027

FREQ. SCAN: 5 KHz/Div.
Bandwidth: 10 KHz

TEST 374
TIME 1027.5

LOCATION: SITE 3 TYPE TEST ESR DATE 8-1-72

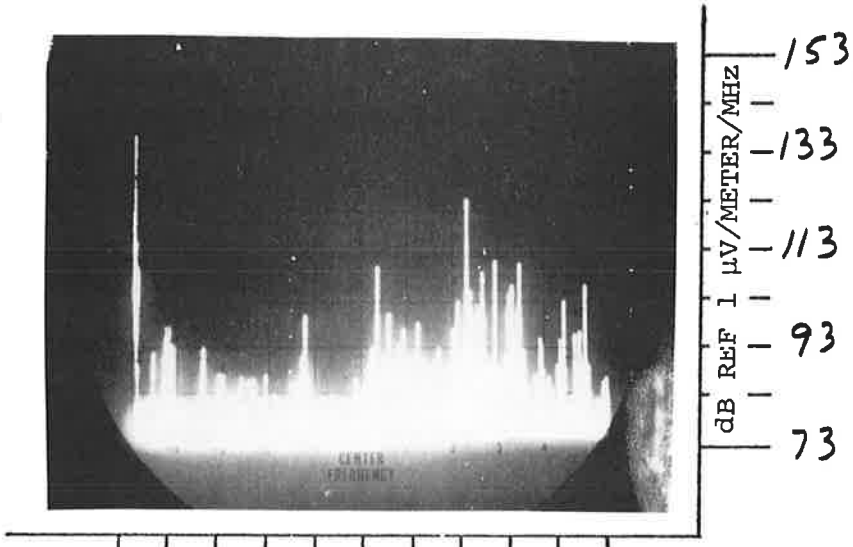


TEST 375
TIME 1029

FREQ. SCAN: 0.1 MHz/Div.
Bandwidth. 10 KHz

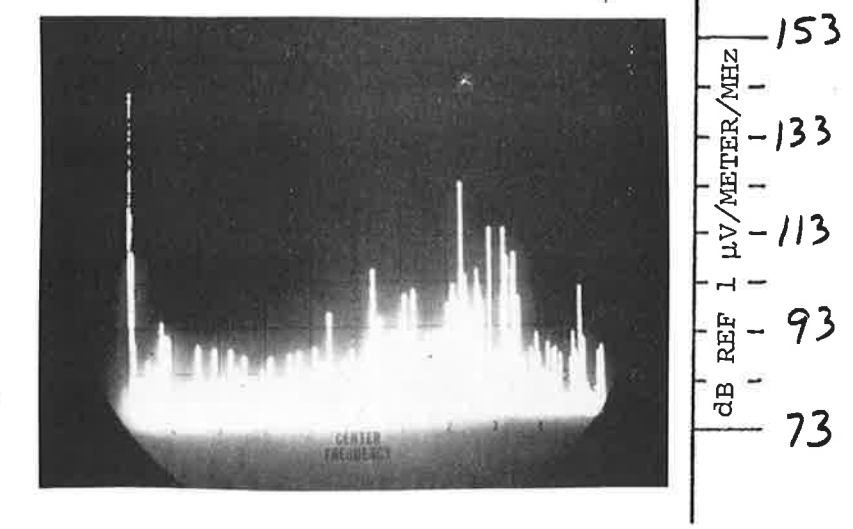
TEST 375
TIME 1029.5

LOCATION: SITE 3 TYPE TEST ESR DATE 8-1-72



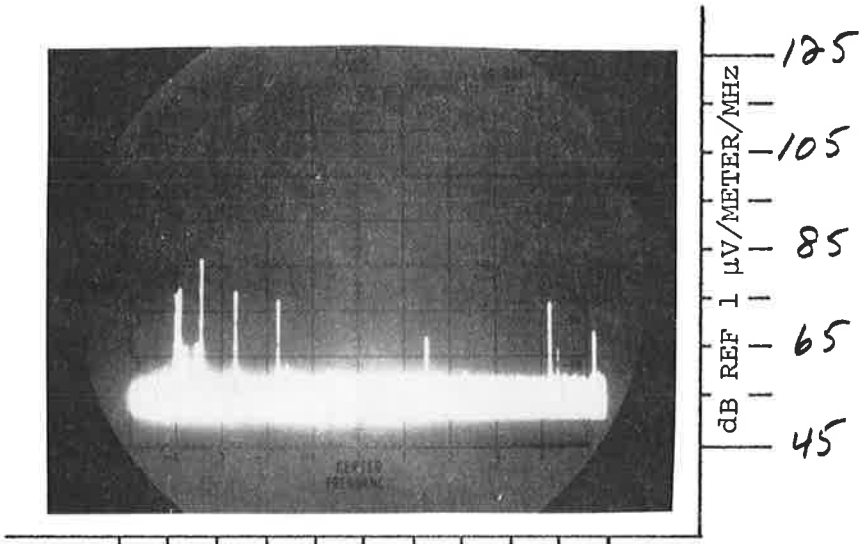
TEST 376
TIME 1033

FREQ. SCAN: 2MHz/Div.
Bandwidth: 10 KHz



TEST 376
TIME 1033.5

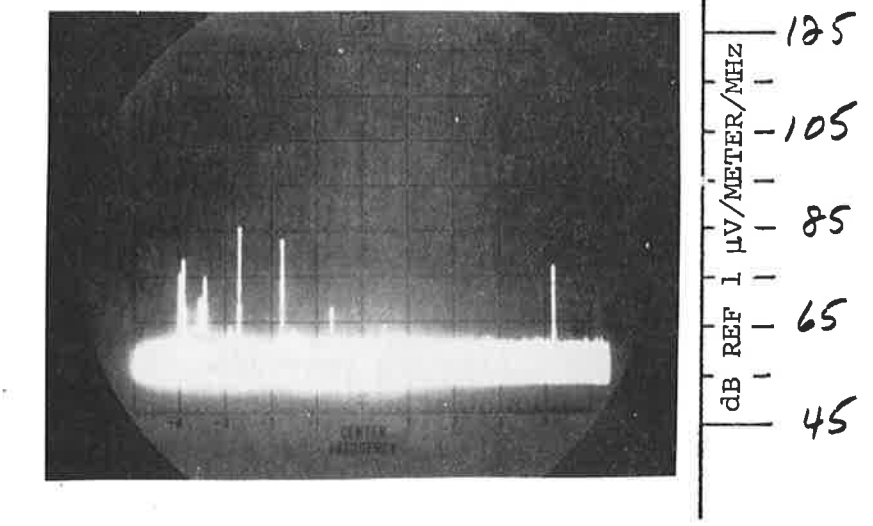
LOCATION: SITE 3 TYPE TEST ESR E/W DATE 8-1-72



TEST 378
TIME 1039.5

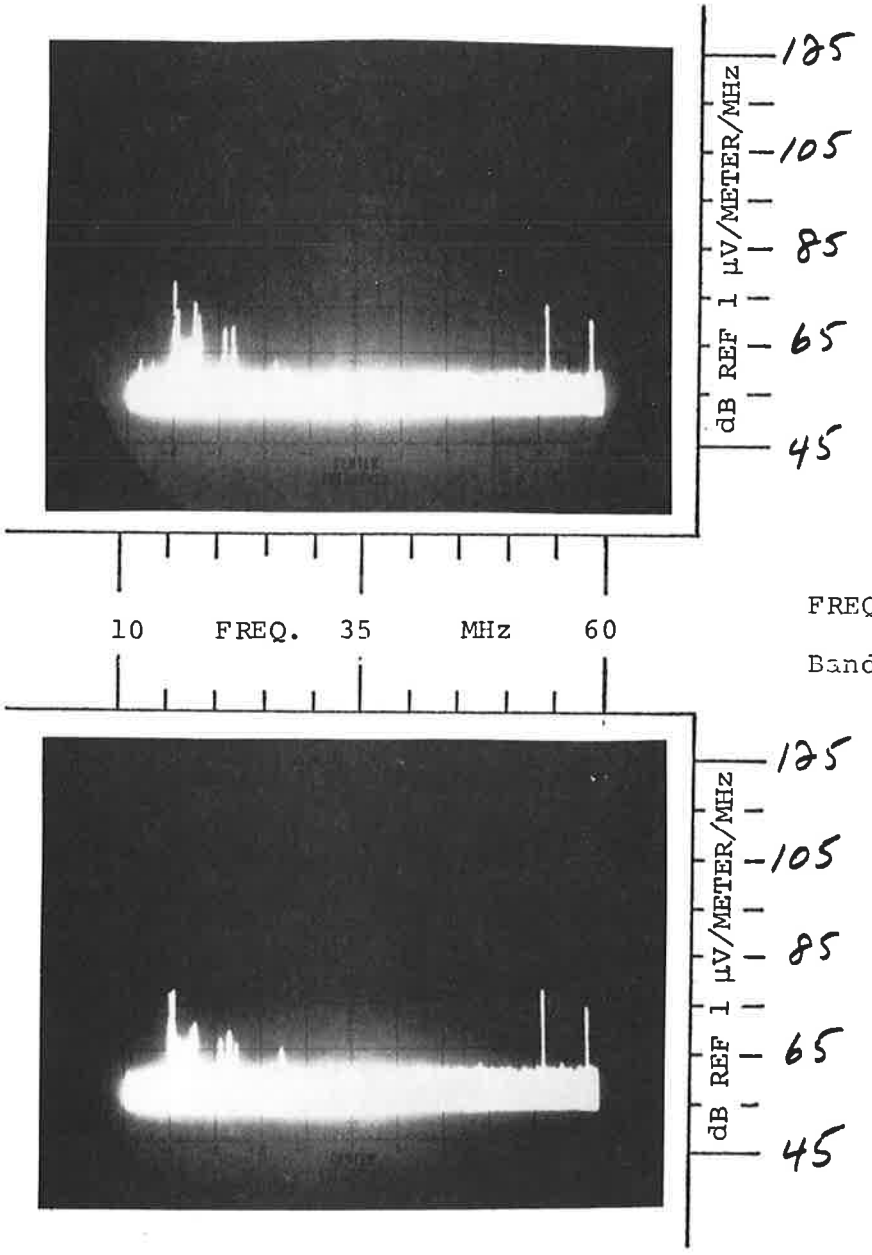
10 FREQ. 35 MHz 60

FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz



TEST 378
TIME 1040

LOCATION: SITE 3 TYPE TEST ESR N/S DATE 8-1-72



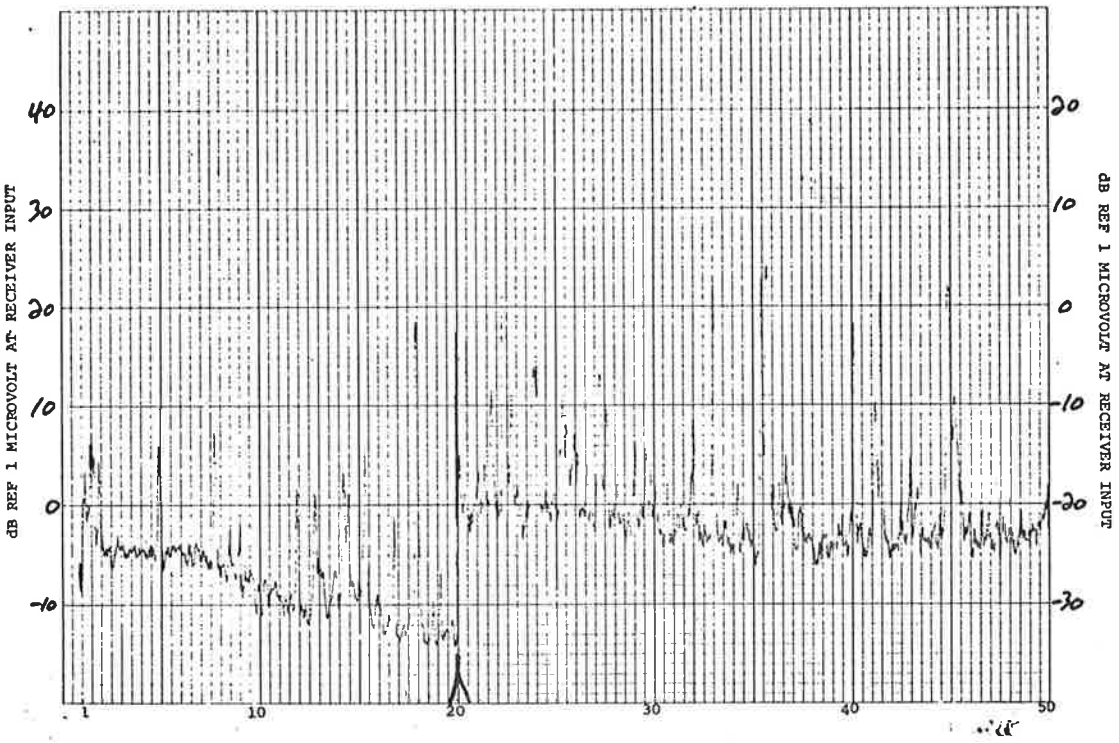
TEST 377
TIME 1038

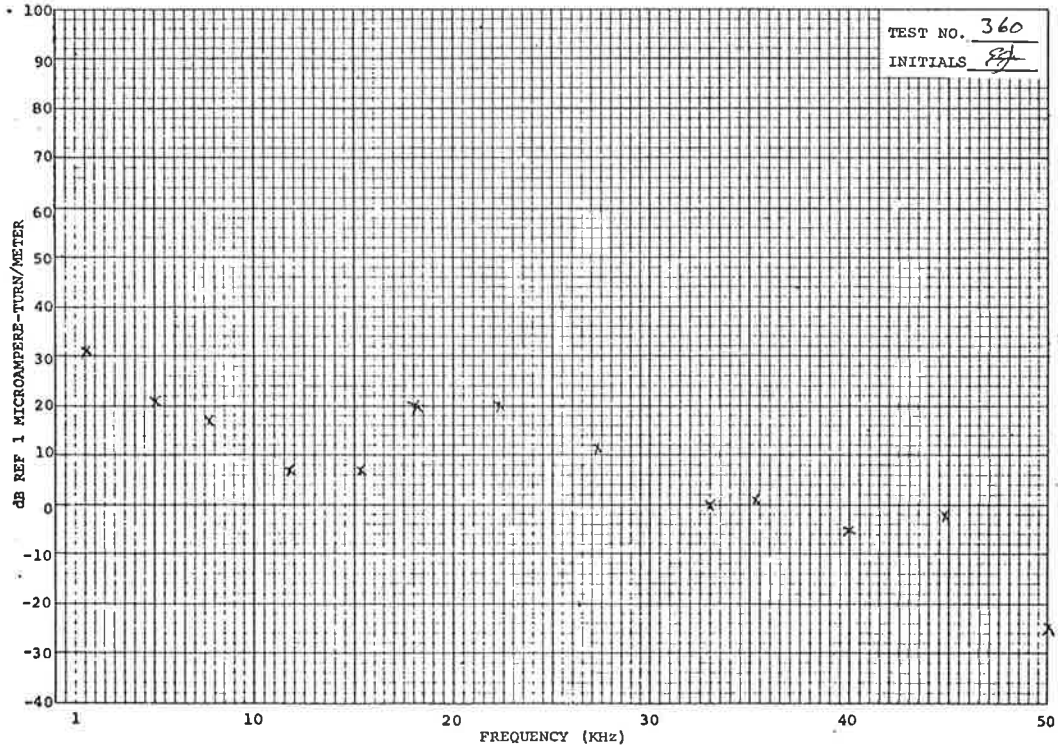
FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz

TEST 377
TIME 1038.5

TEST NO. 360 TEST TYPE MSL E/L BANDWIDTH 50Hz
TEST SPECIMEN S.C.1 TEST EQUIP. EMCL-10 DATE 8-1-72

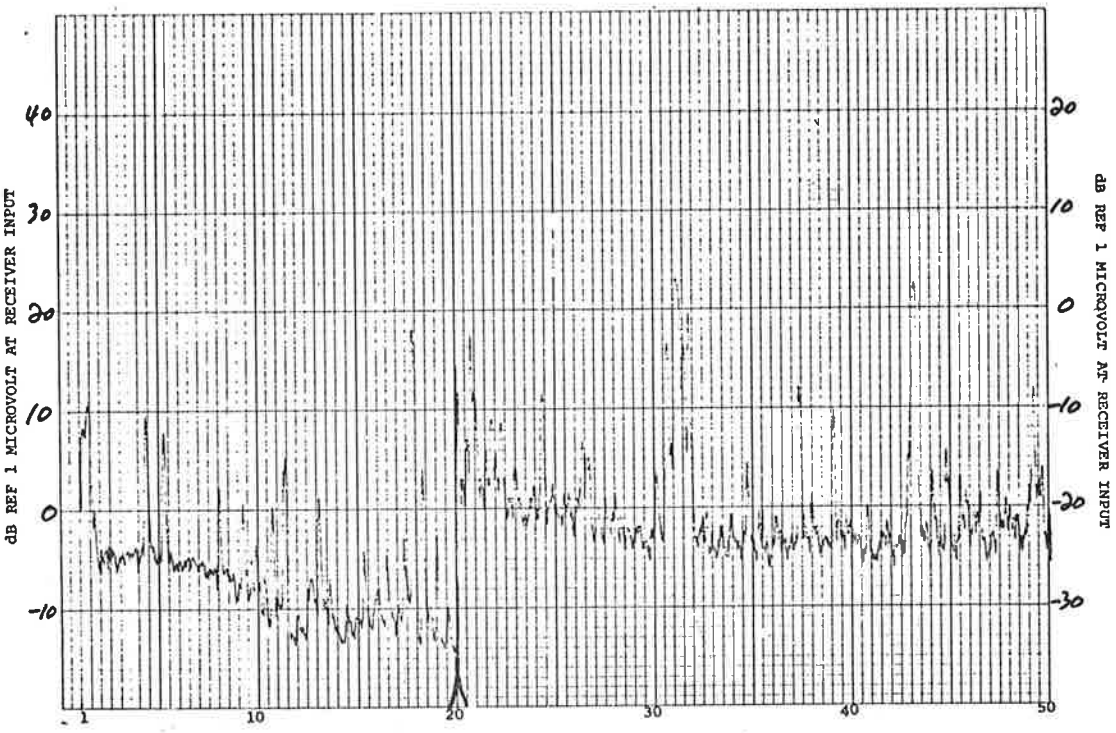
0908
EEJ

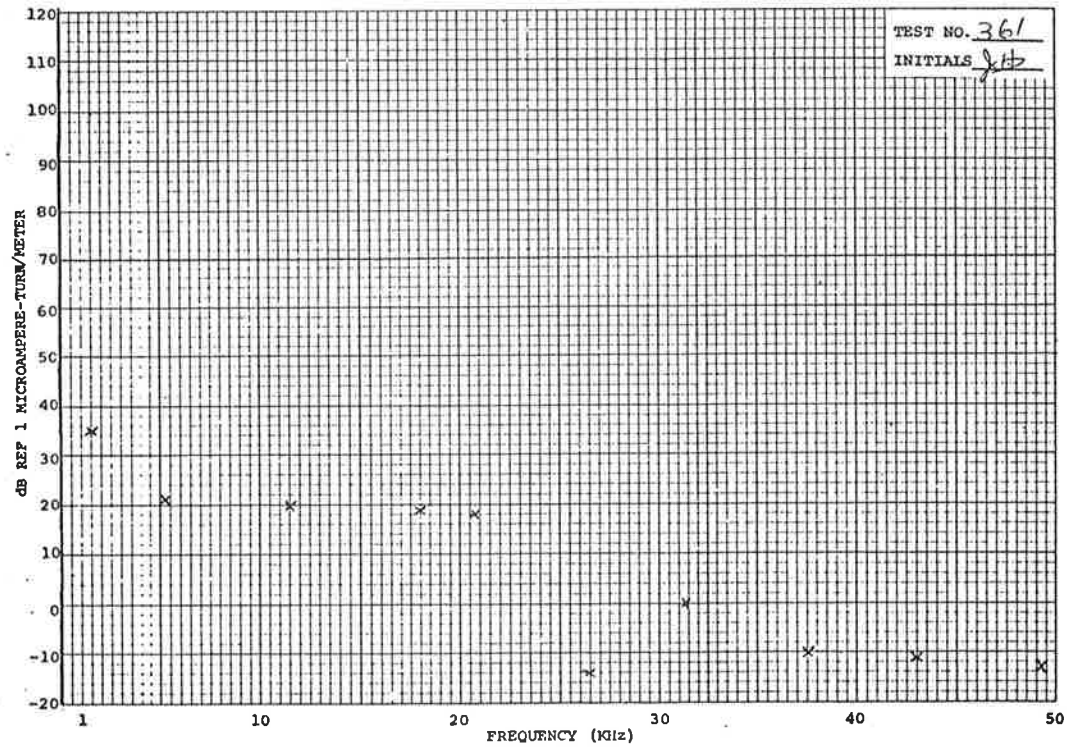




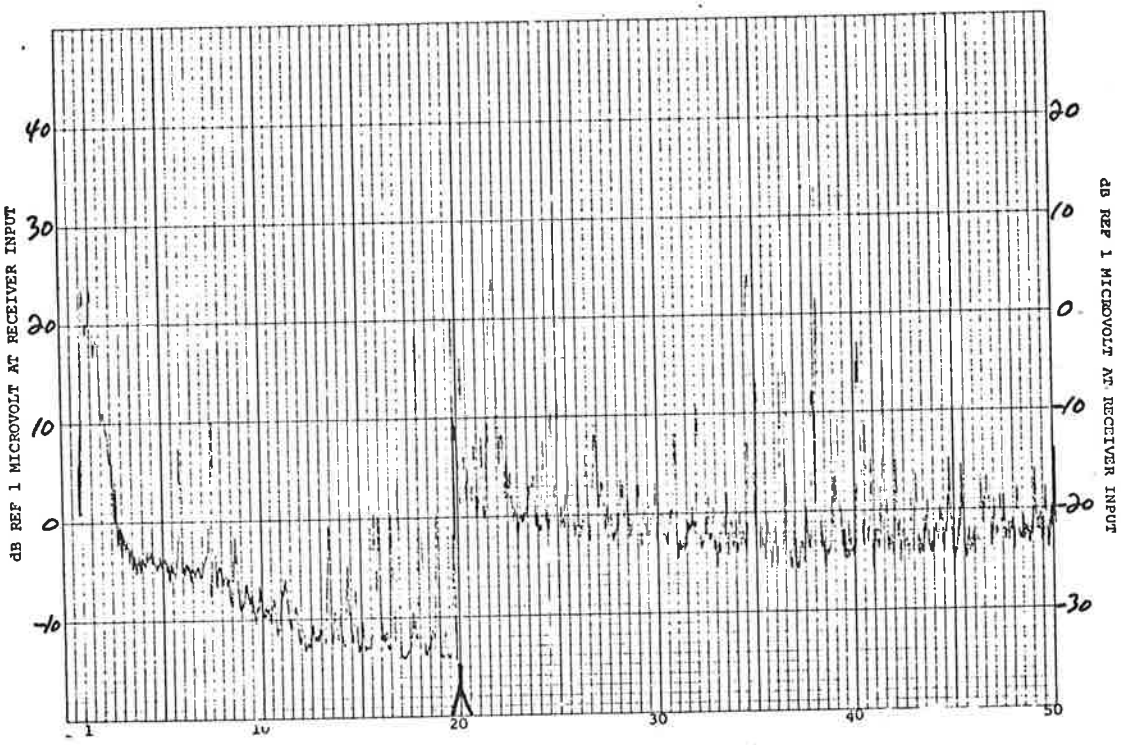
TEST NO. 361 TEST TYPE MSP E/H BANDWIDTH 50 Hz
TEST SPECIMEN Sub 1 TEST EQUIP. EMC-10 DATE 8-1-78

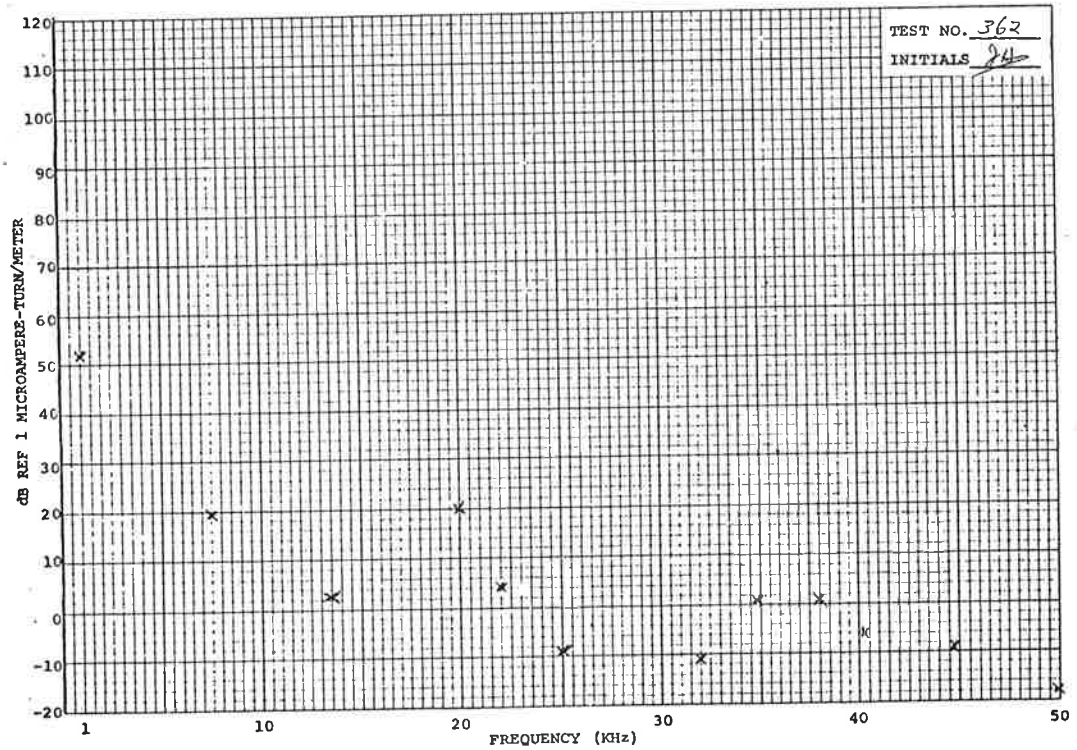
0912





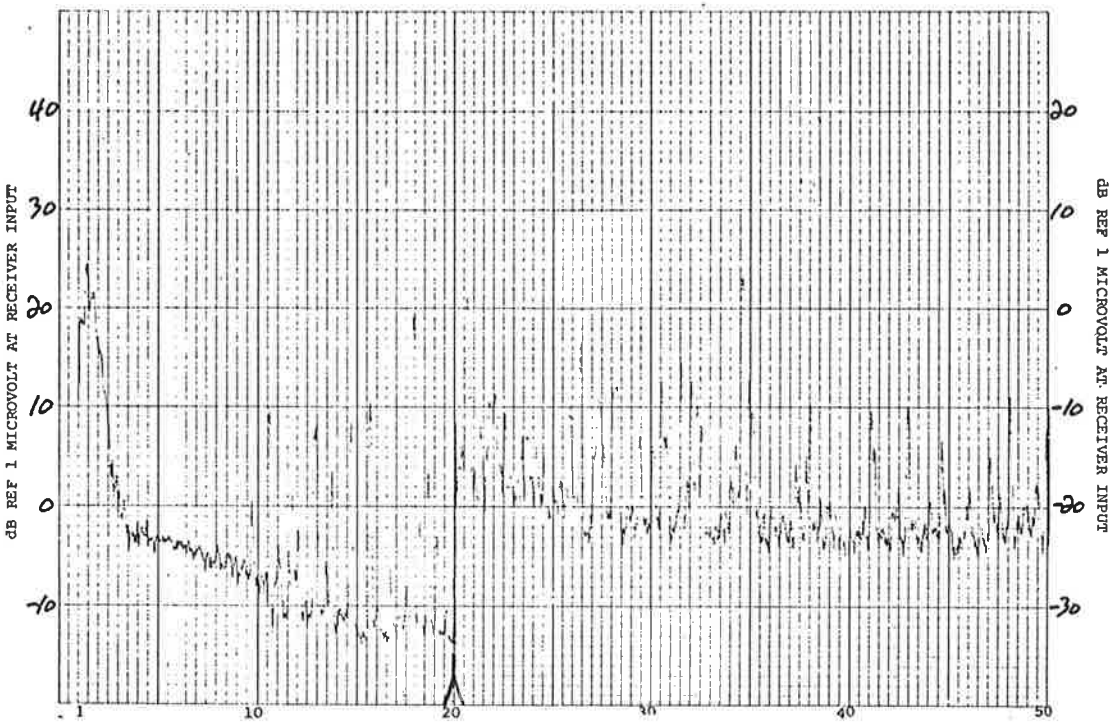
TEST NO. 362 TEST TYPE MSR N/S BANDWIDTH 50Hz 0915
TEST SPECIMEN S.A.1 TEST EQUIP. EMC-10 DATE 8-1-72

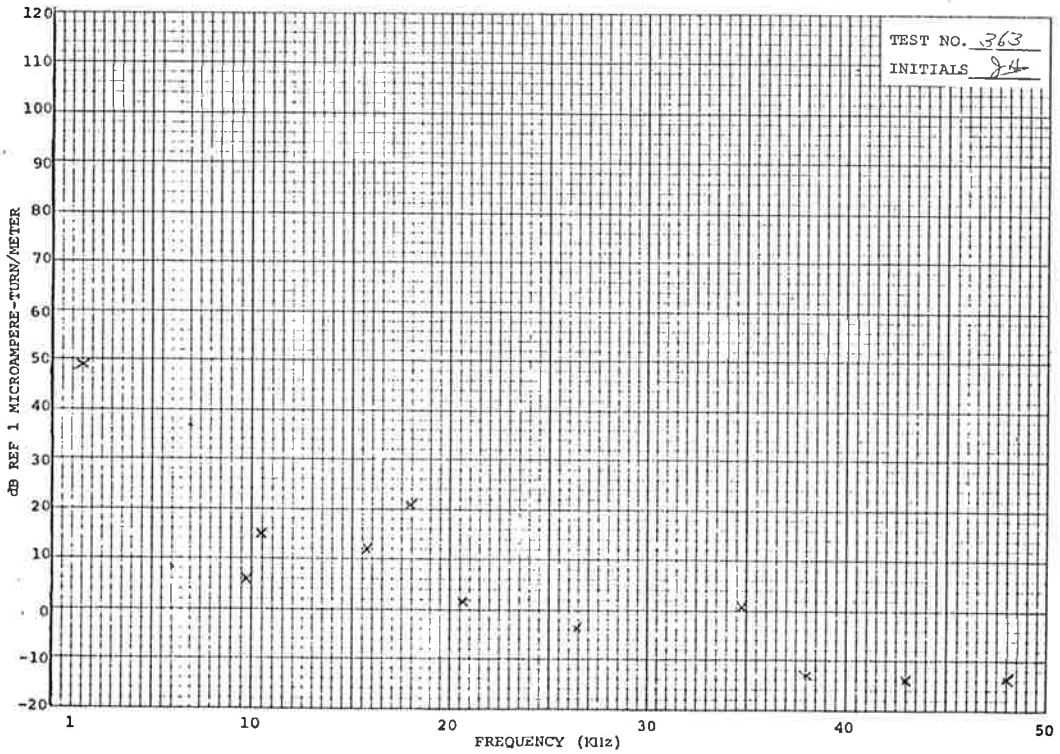




TEST NO. 363 TEST TYPE MS1' N/S BANDWIDTH 30 Hz
TEST SPECIMEN Side 1 TEST EQUIP. FMC 10 DATE 8-1-12

09/19
VRC



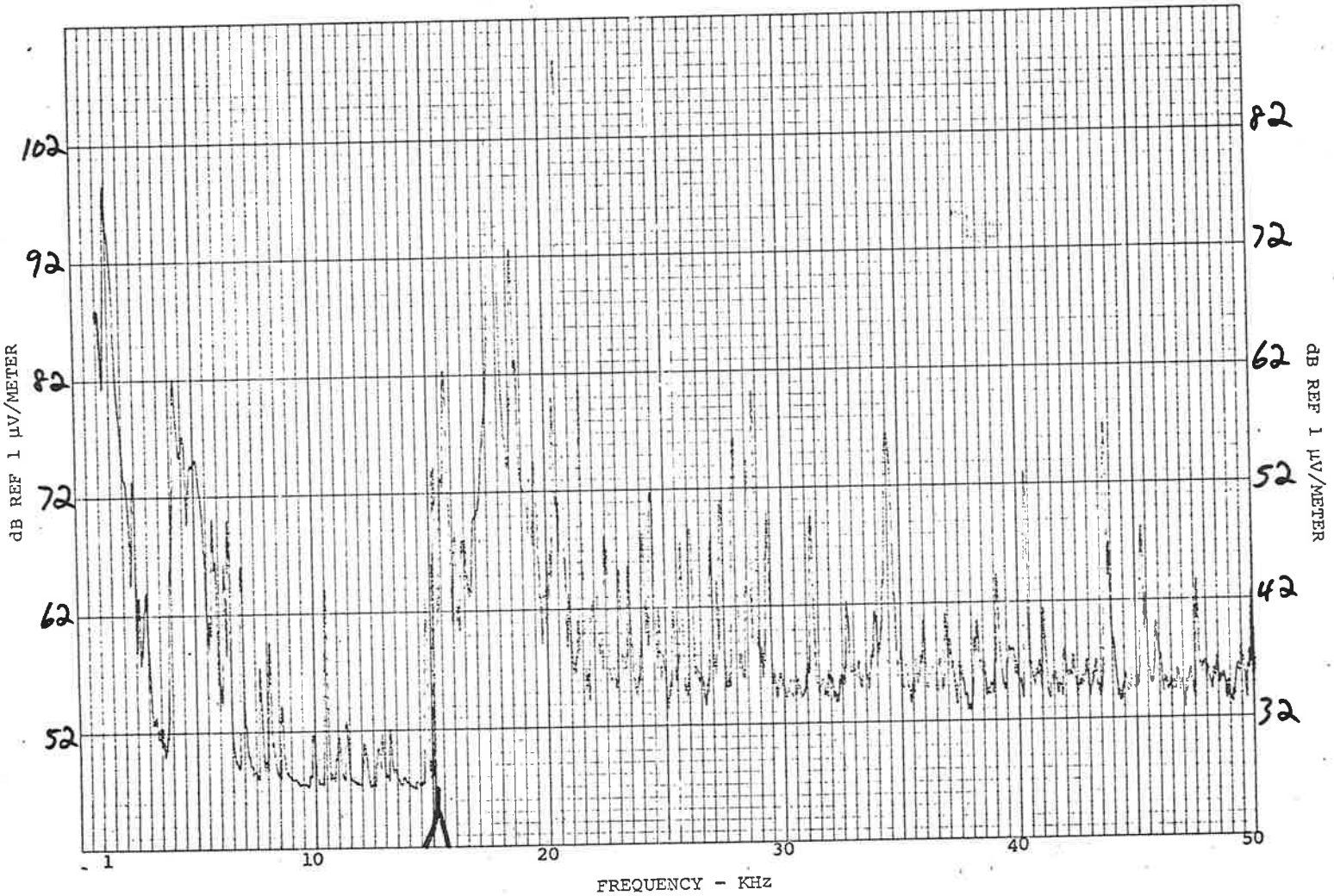


TEST NO. 356
TEST SPECIMEN Site 1

TEST TYPE ESR E/W
TEST EQUIP. EMC-10

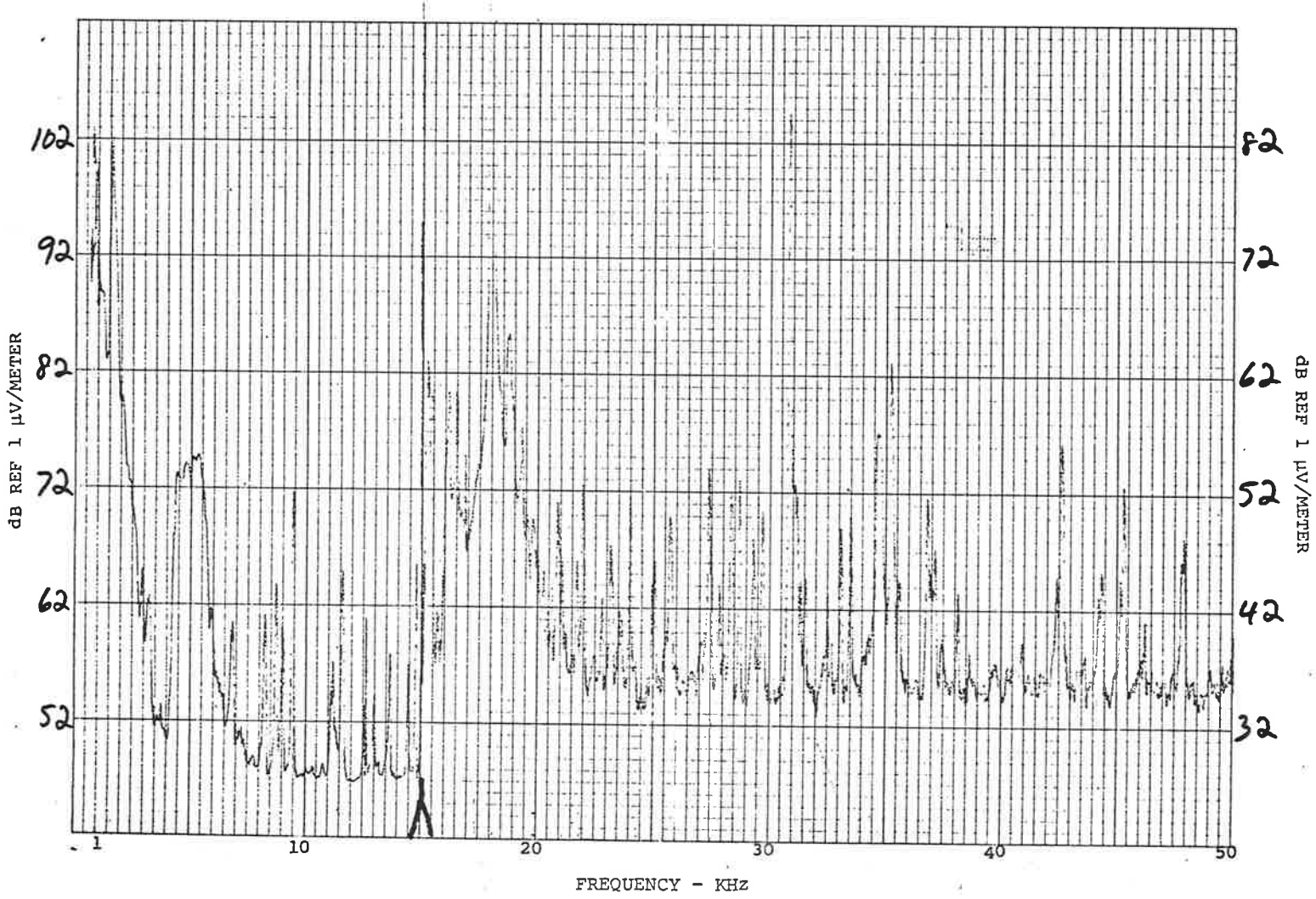
BANDWIDTH 50 Hz
DATE 8-1-72

0849
EEJ

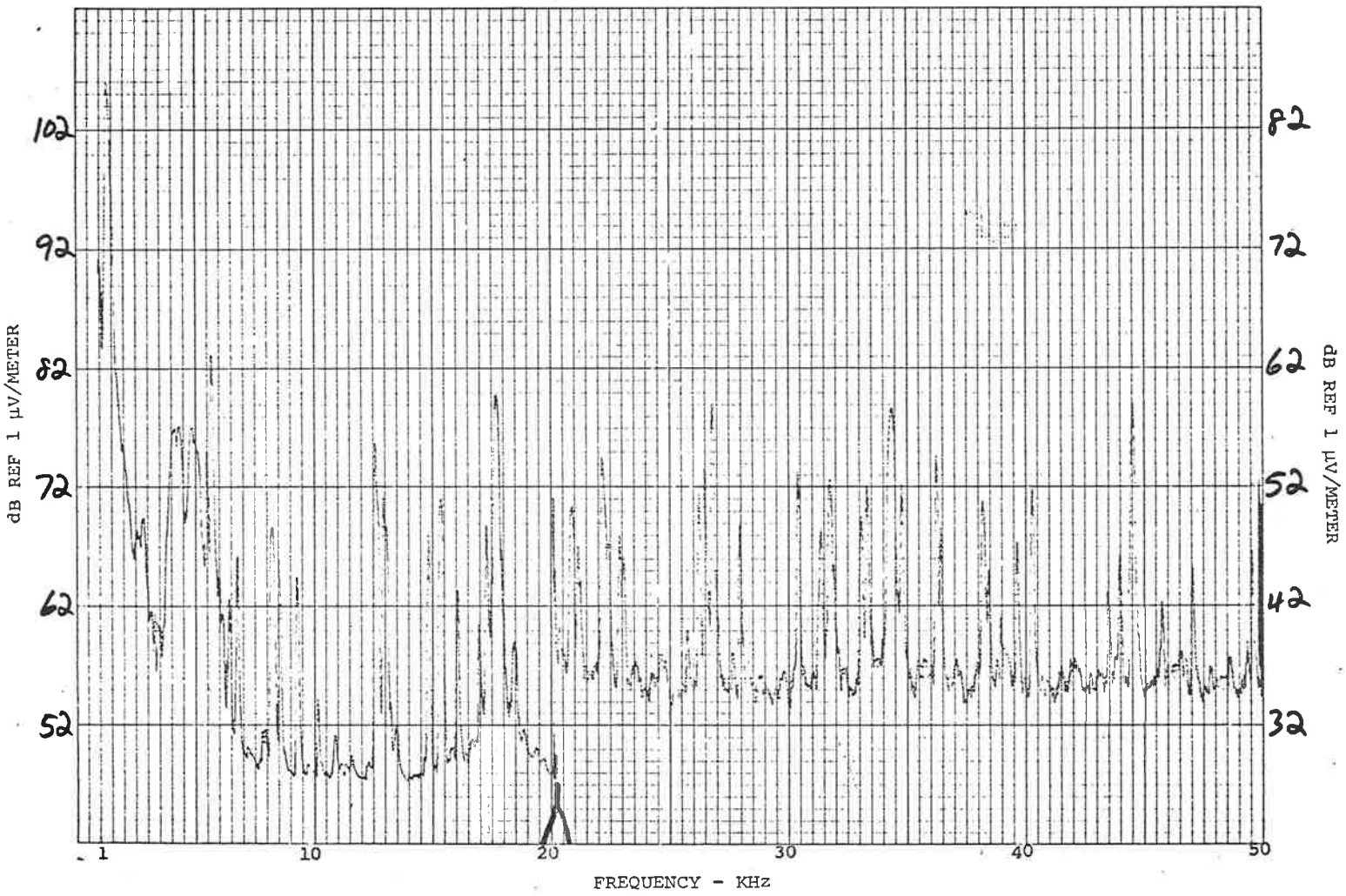


TEST NO. 357
TEST SPECIMEN 261
TEST TYPE ESR E/W
TEST EQUIP. EMC-10
BANDWIDTH 50 Hz
DATE 8-1-72

0852
EST



TEST NO. 358 TEST TYPE ESR N/S BANDWIDTH 50 Hz 0856
TEST SPECIMEN Site 1 TEST EQUIP. EMC-10 DATE 8-1-72 ESI



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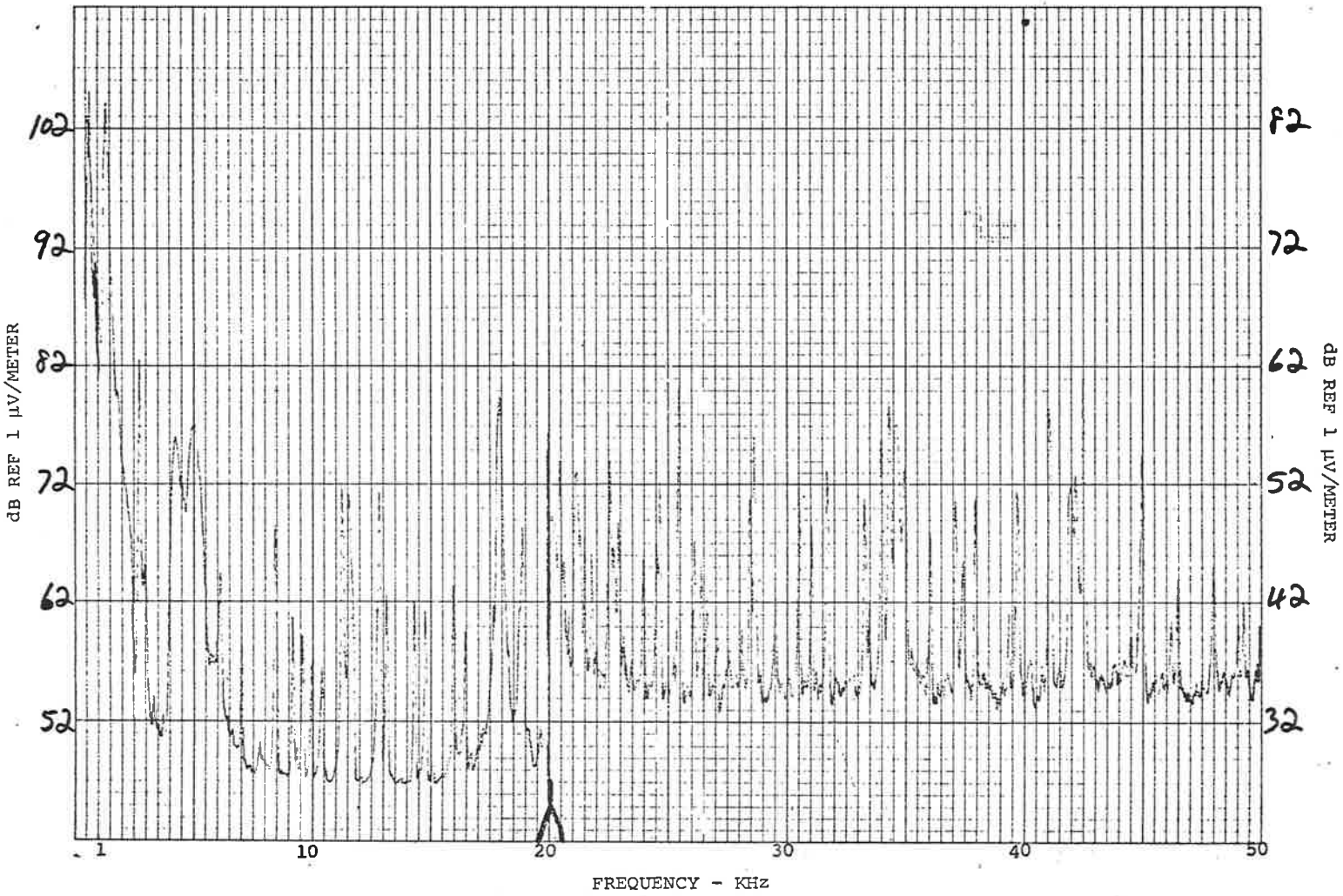
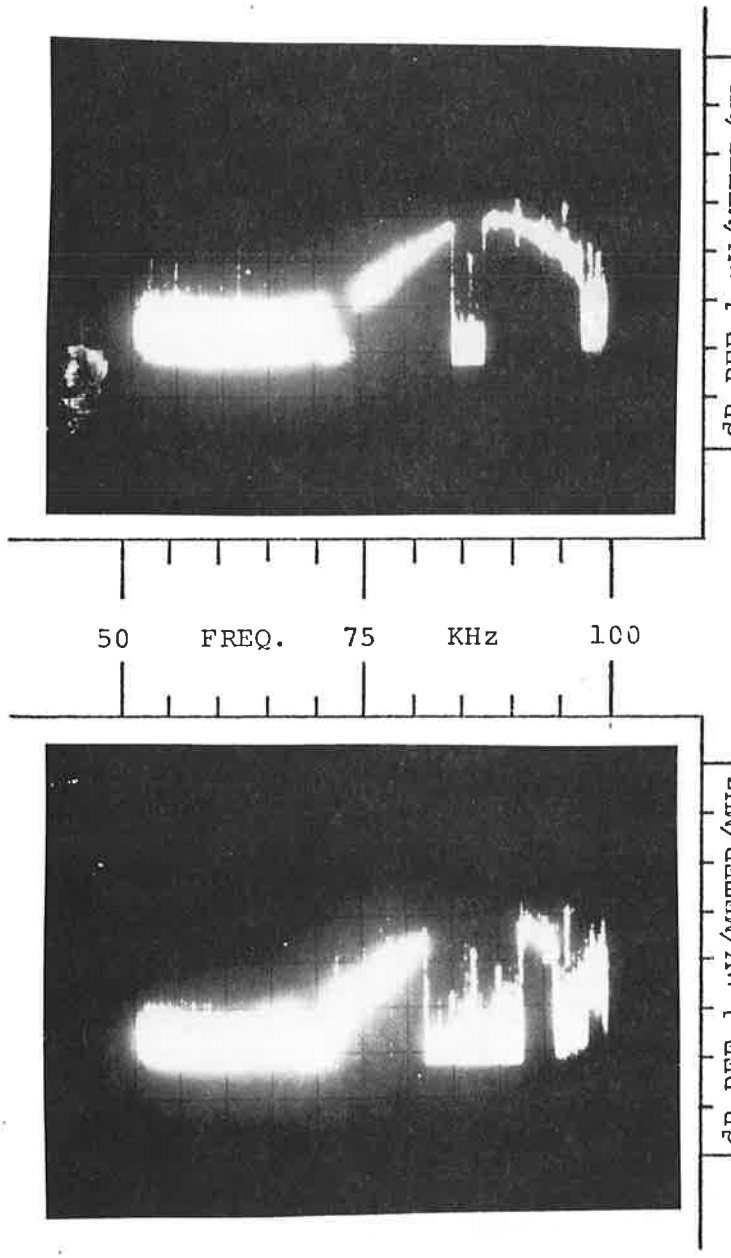


LOCATION: SITE 1 TYPE TEST ESR DATE 8-1-72



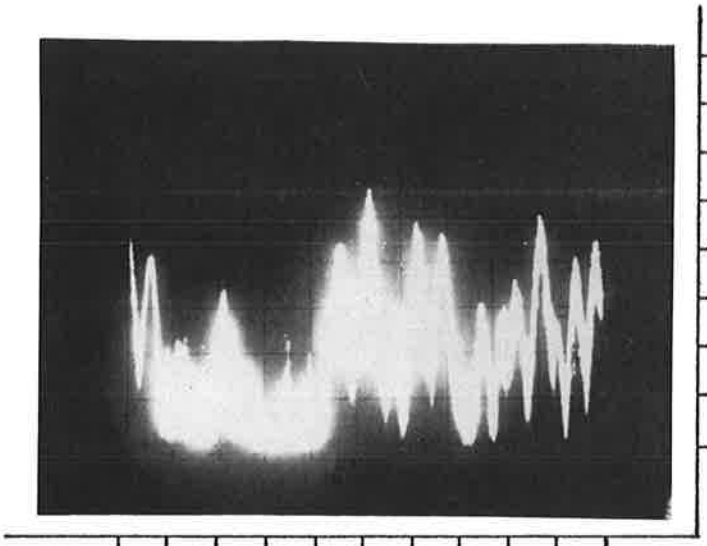
TEST 355
TIME 0838

FREQ. SCAN: 5 KHz/Div.

Bandwidth: 10 KHz

TEST 355
TIME 0839

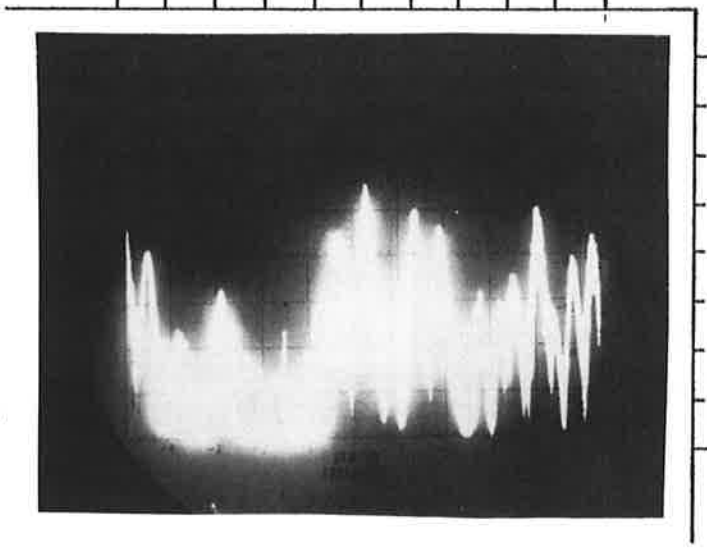
LOCATION: SITE 1 TYPE TEST ESR DATE 8-1-72



TEST 354
TIME 0836

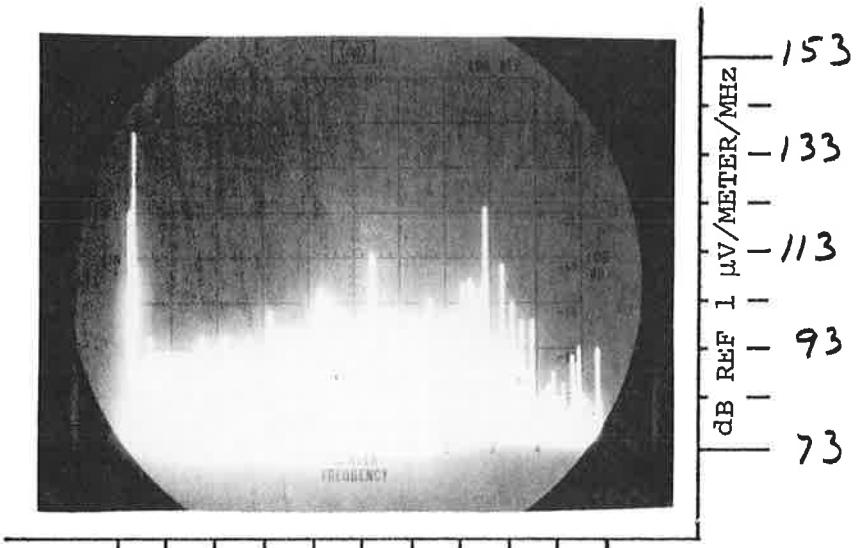
FREQ. SCAN: 0.1 MHz/Div.

Bandwidth: 10 KHz



TEST 354
TIME 0836.5

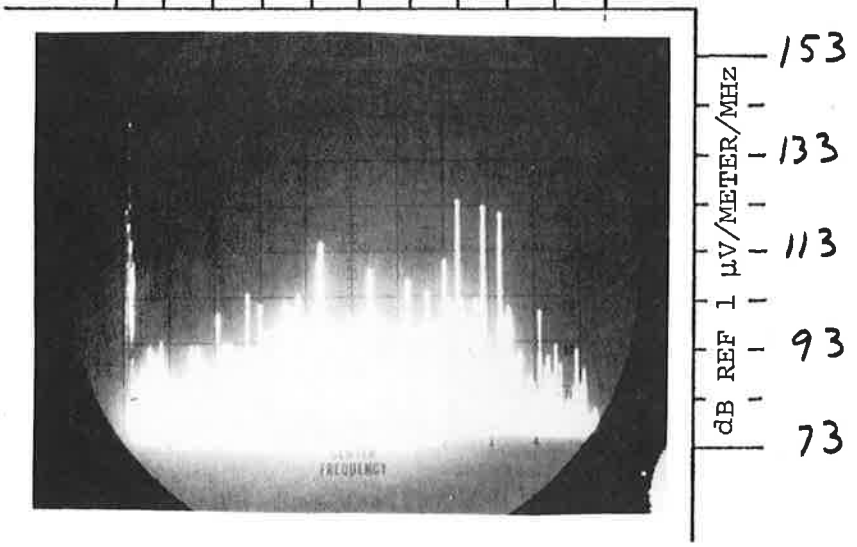
LOCATION: SITE 1 TYPE TEST ESR DATE 8-1-72



TEST 353
TIME 0833

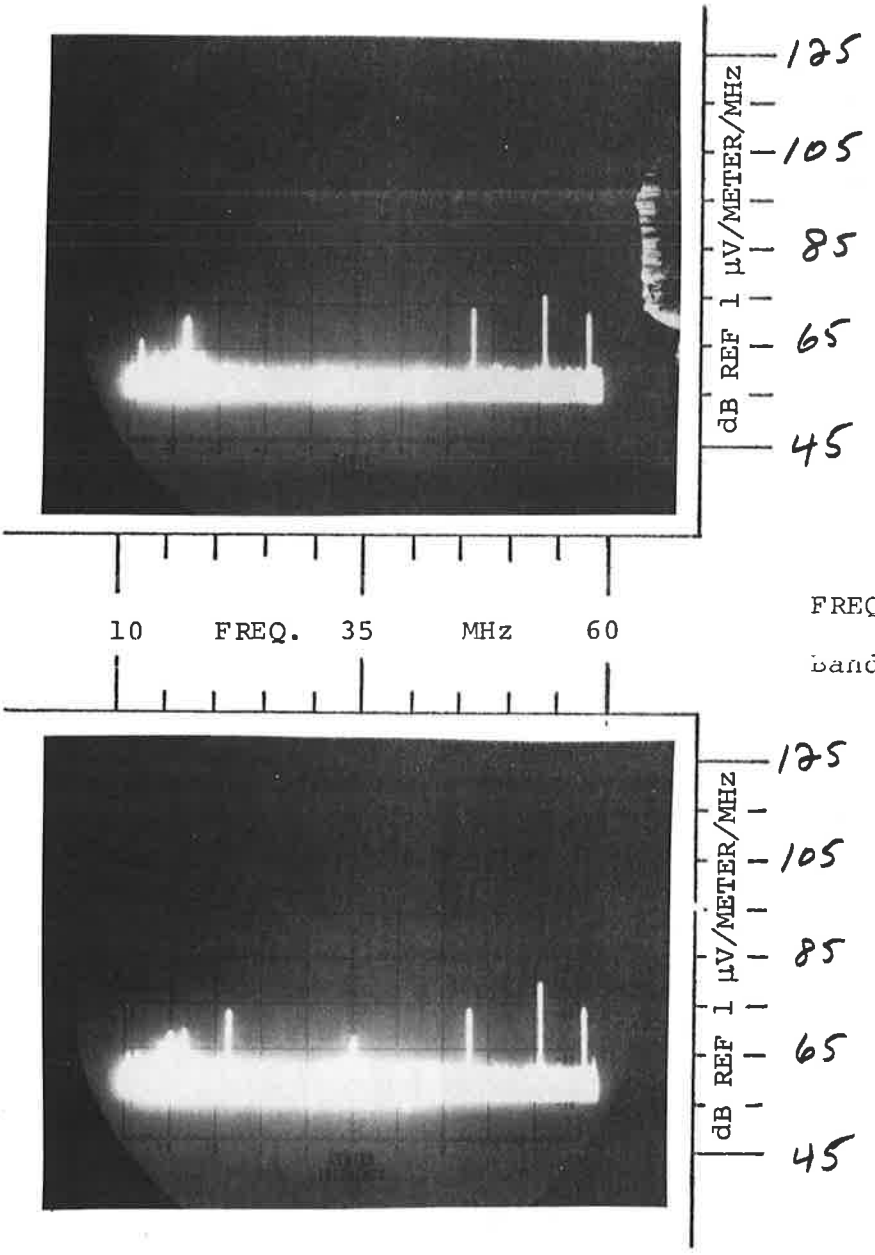
1 FREQ. 11 MHz 21

FREQ. SCAN: 2MHz/Div.
Bandwidth: 10 KHz



TEST 353
TIME 0834

LOCATION: SITE 1 TYPE TEST ESR E/W DATE 8-1-72

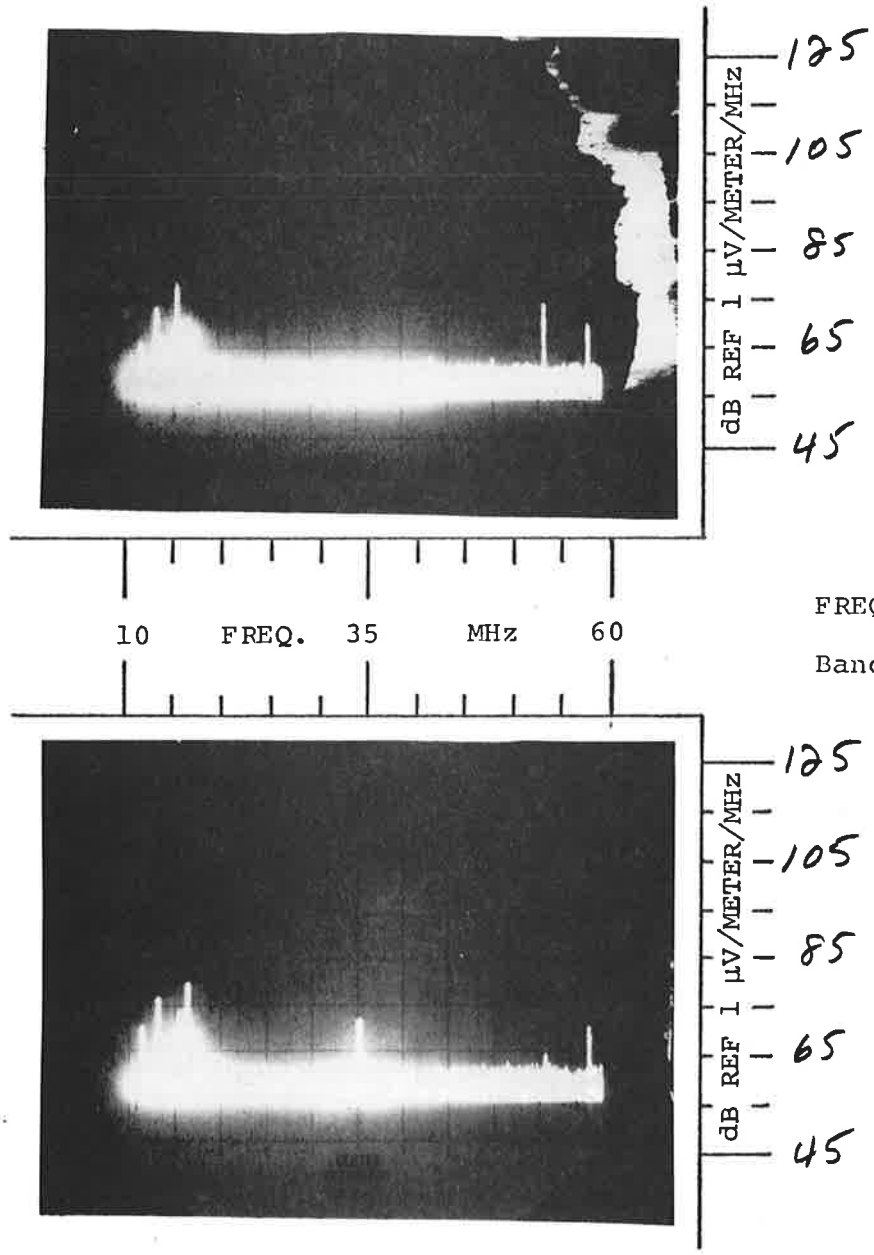


TEST 351
TIME 0825

FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz

TEST 351
TIME 0826

LOCATION: SITE 1 TYPE TEST ESR N/S DATE 8-1-72

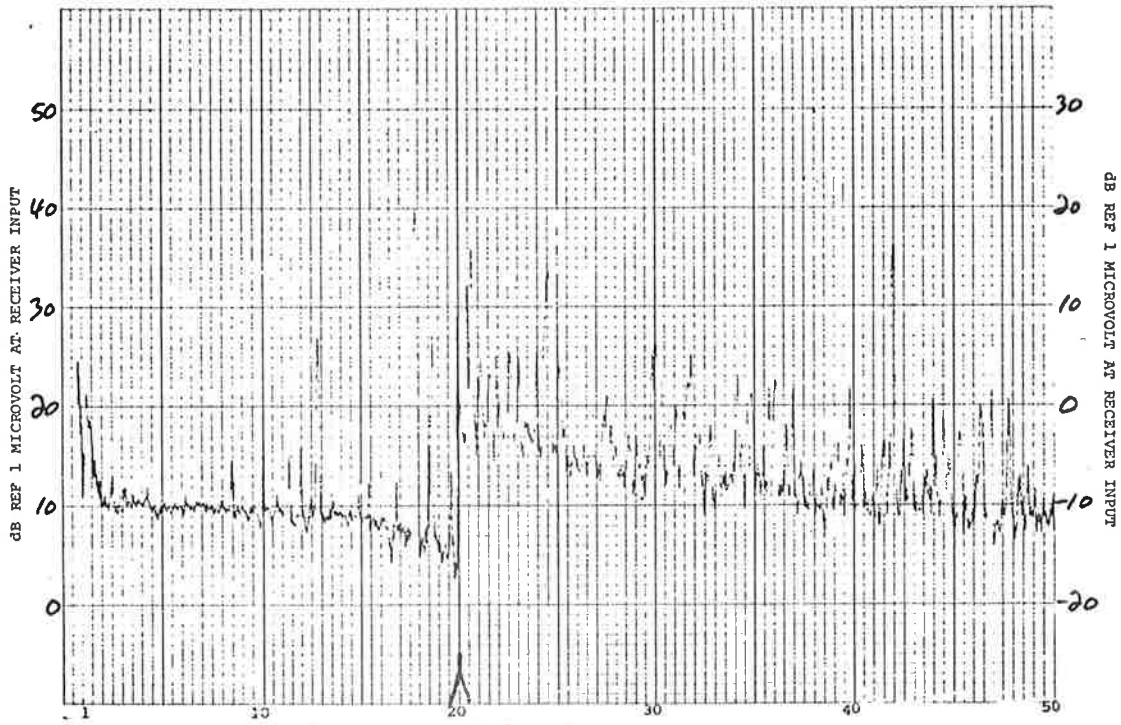


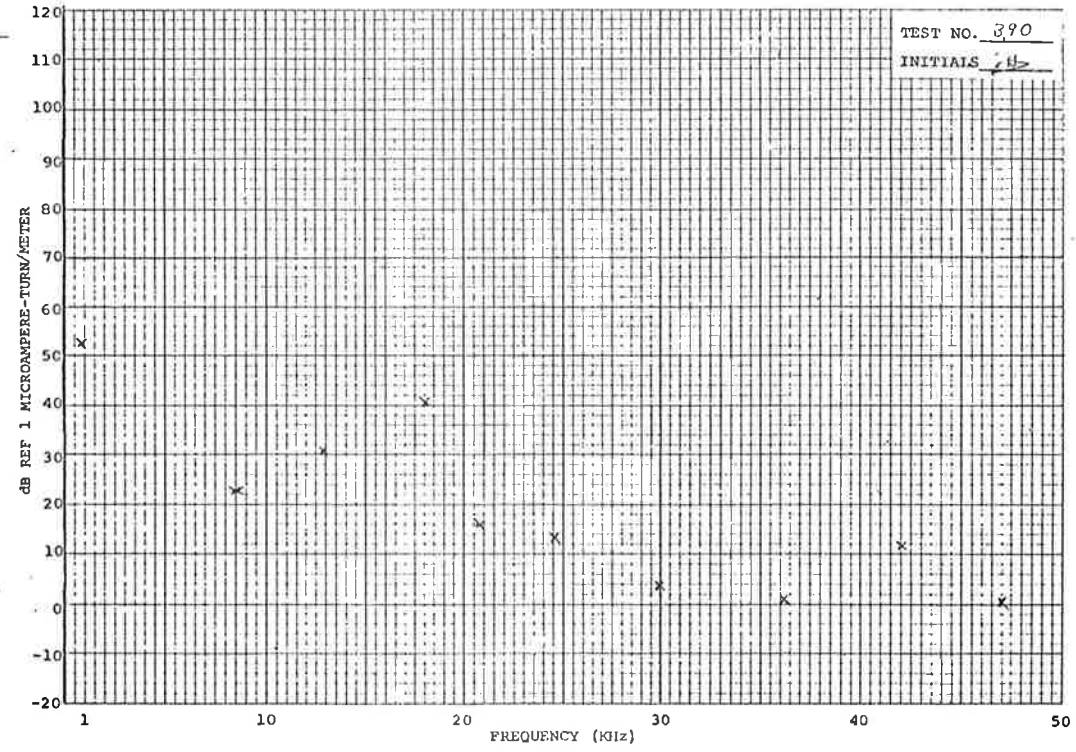
TEST 352
TIME 0827

FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz

TEST 352
TIME 0829

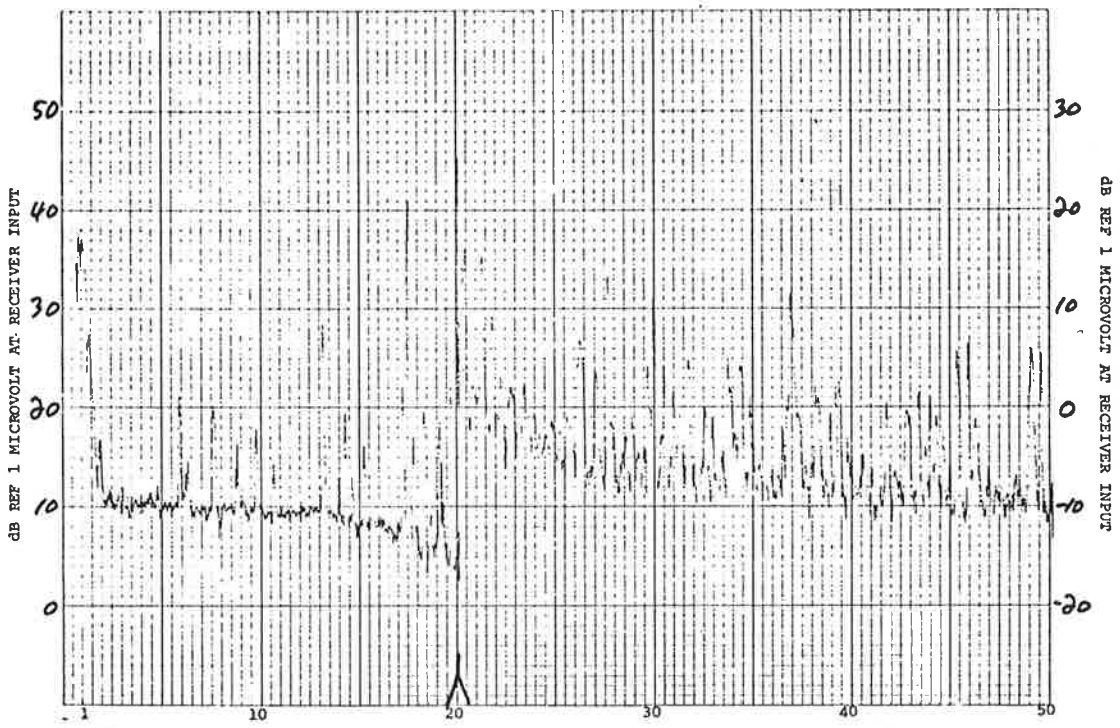
TEST NO. 390 TEST TYPE MSP F/N BANDWIDTH 50Hz 1139
TEST SPECIMEN Site 4 TEST EQUIP. EMC 10 DATE 8-1-72

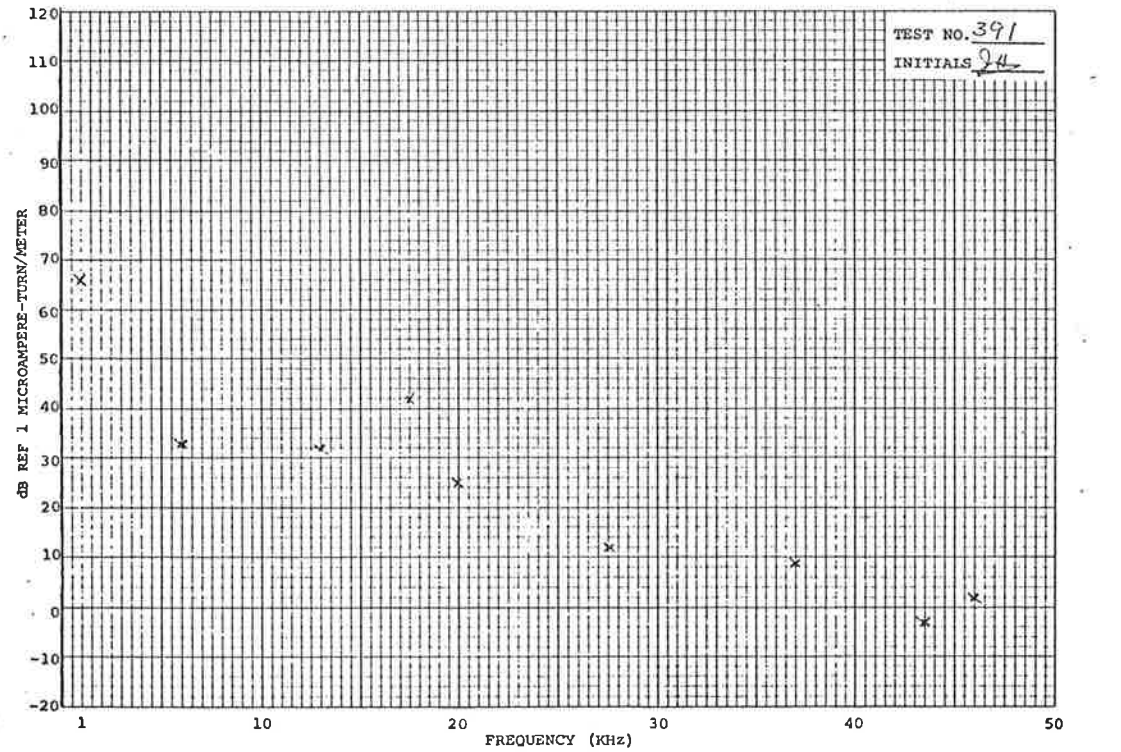




TEST NO. 391 TEST TYPE MSR F/W BANDWIDTH 50 Hz
TEST SPECIMEN 2.6 4 TEST EQUIP. EMC 10 DATE 8-1-12

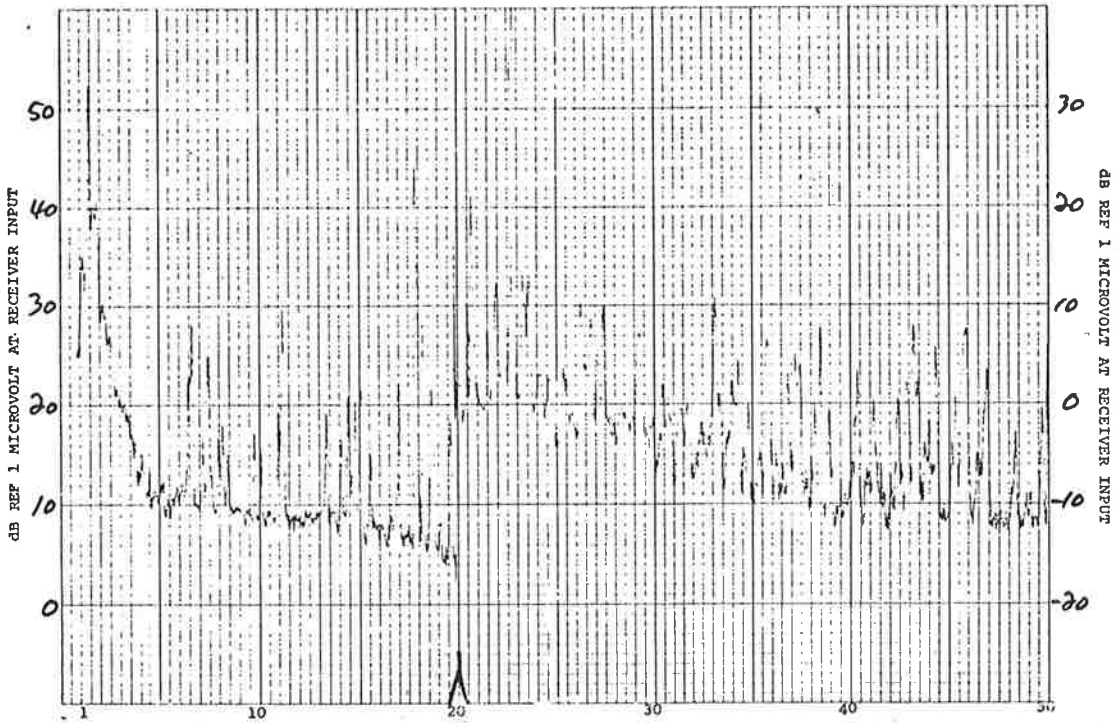
1142
EJ

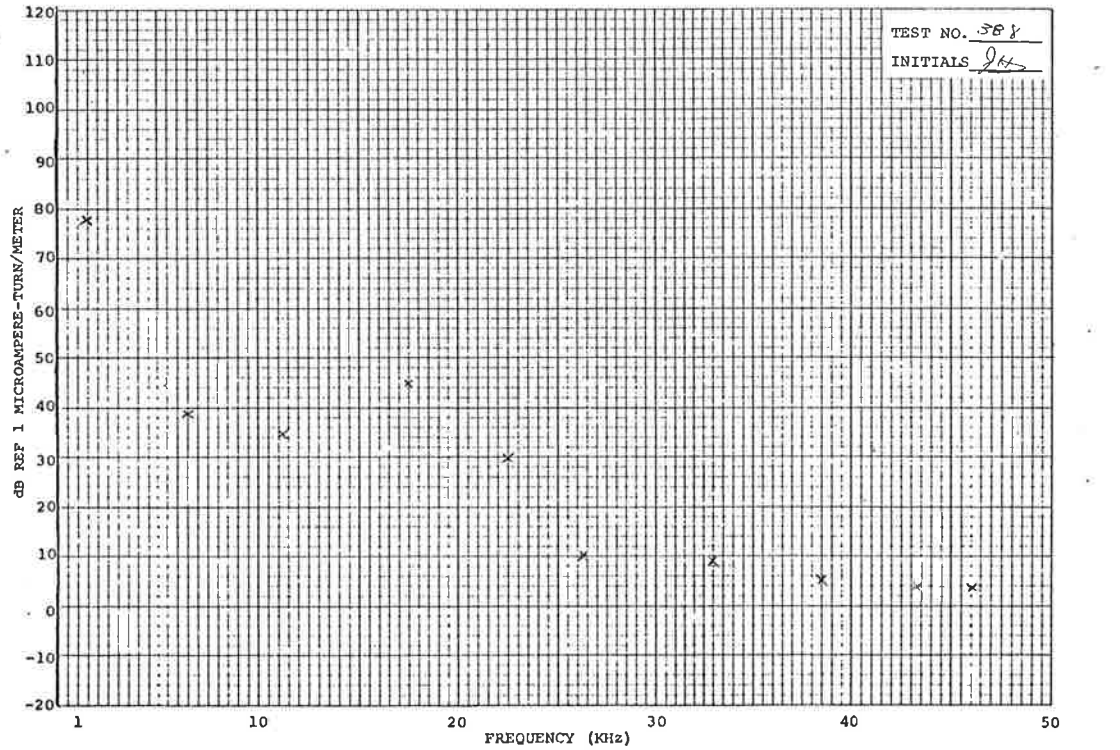




TEST NO. 38A
TEST SPECIMEN Site 4
TEST TYPE MSR N/S
TEST EQUIP. IMC-10
BANDWIDTH 50 Hz
DATE 8-1-72

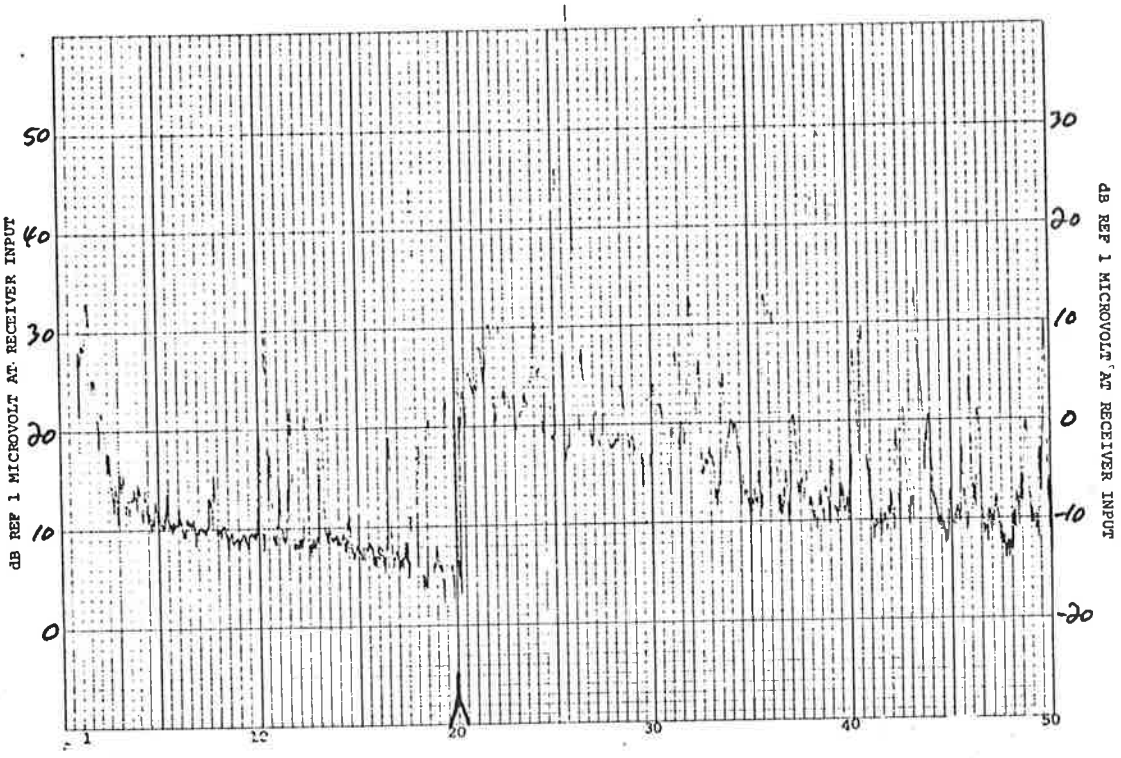
1133
EBJ

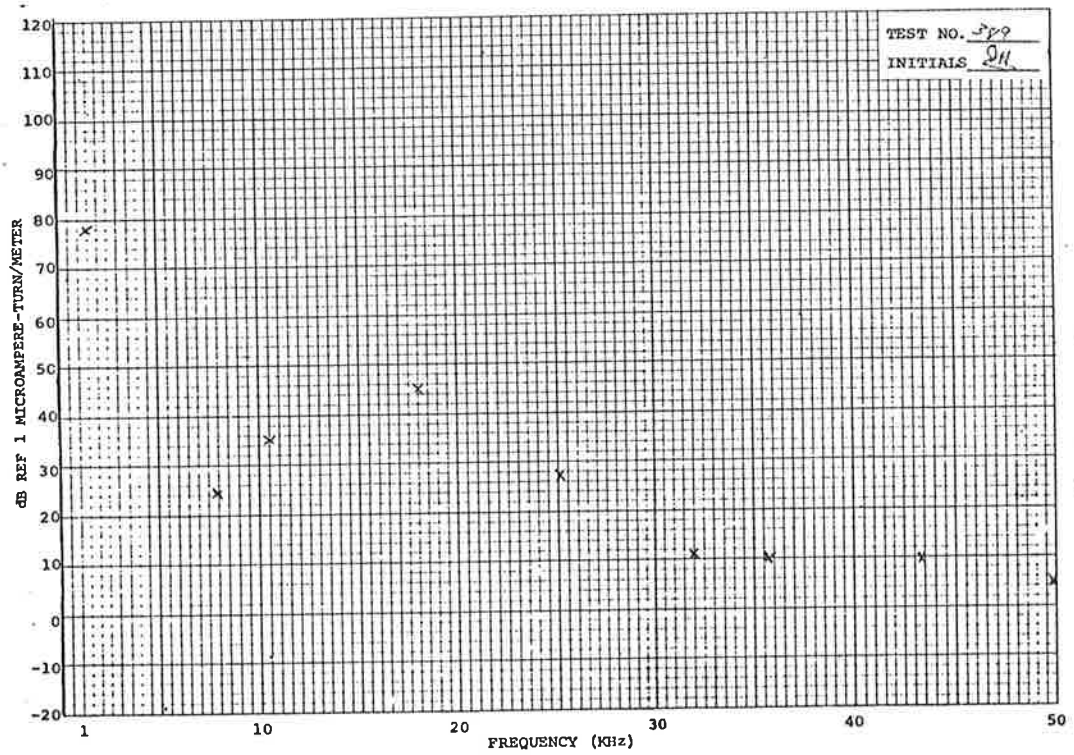




TEST NO. 389
TEST SPECIMEN Site 4
TEST TYPE MSR N/S
TEST EQUIP. ENC-10
BANDWIDTH 50 Hz
DATE 8-1-72

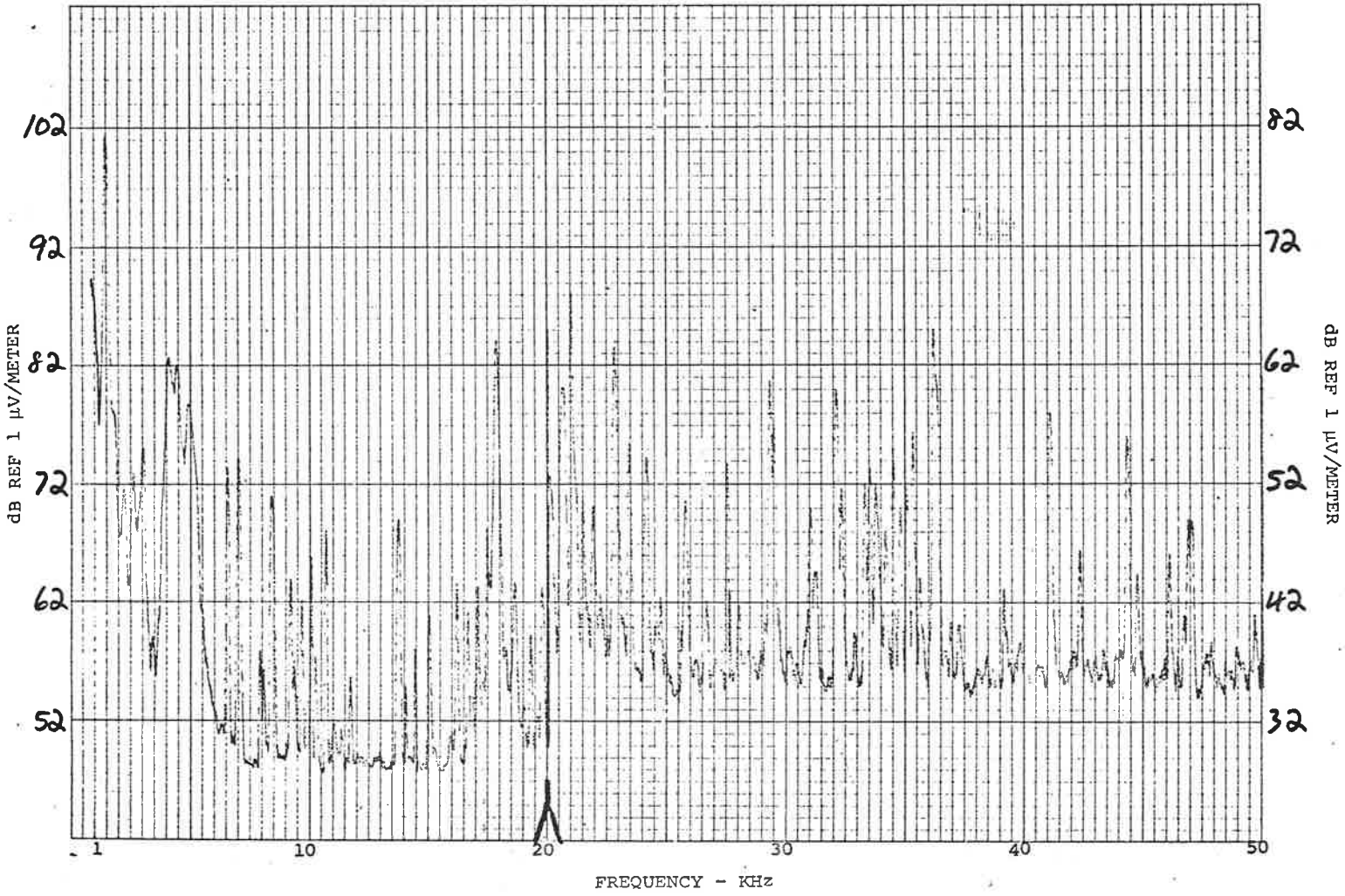
1136
EEJ





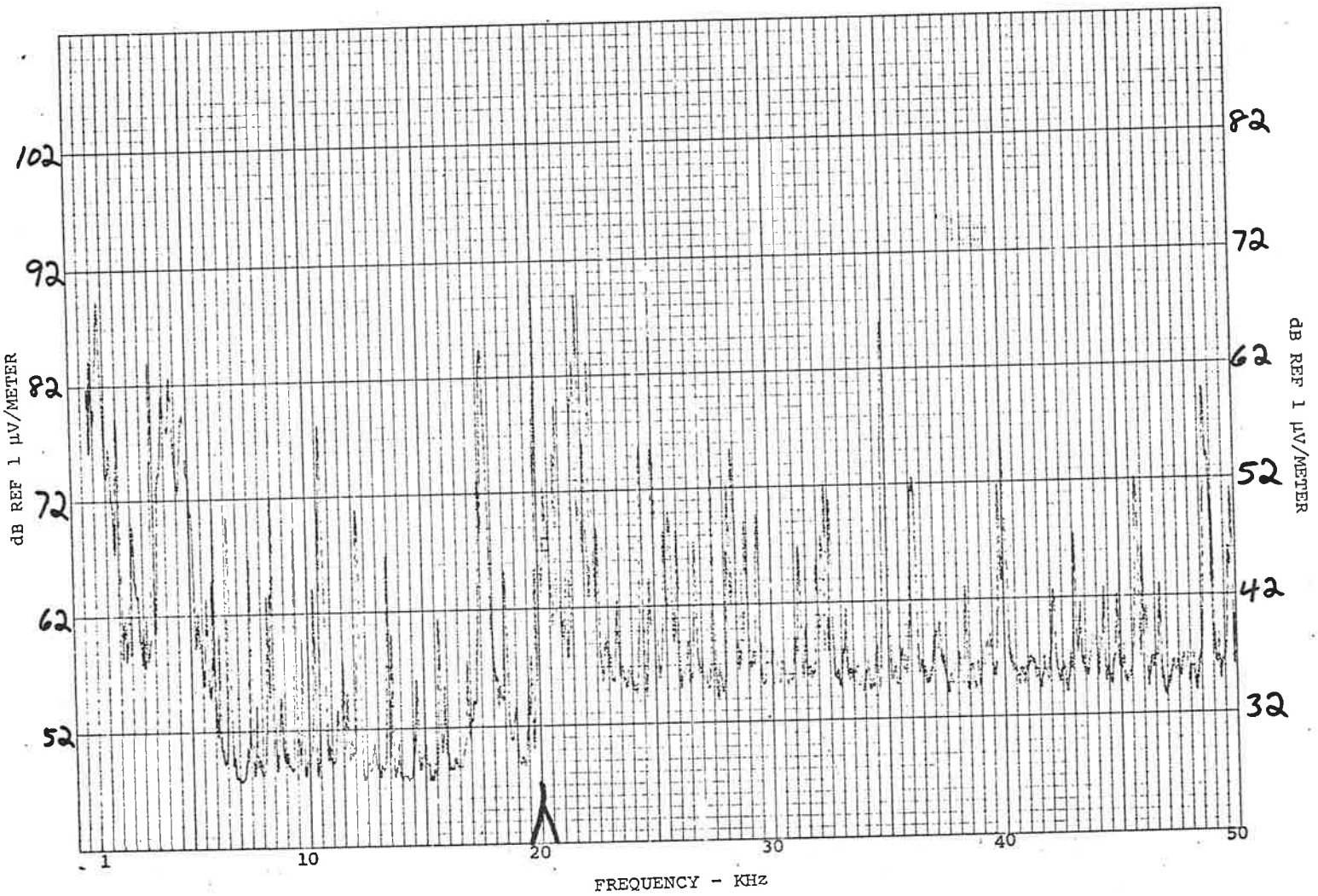
TEST NO. 384 TEST TYPE ESR E/W BANDWIDTH 50Hz
TEST SPECIMEN 8 to 4 TEST EQUIP. EMC-10 DATE 8-1-72

1117
VRC

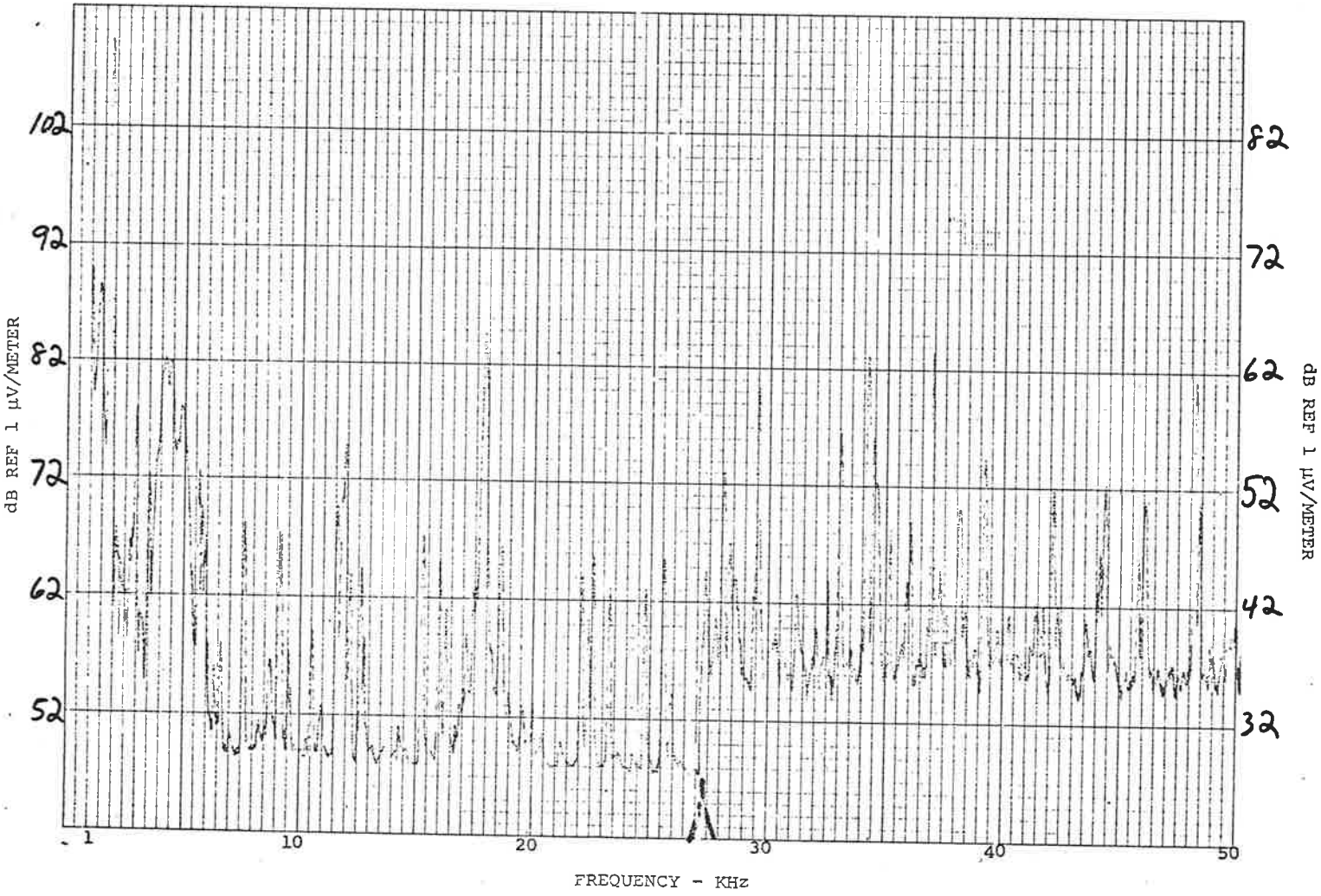


TEST NO. 385
TEST SPECIMEN Sta 4
TEST TYPE ESR E/W
TEST EQUIP. EMC-10
BANDWIDTH 50 Hz
DATE 8-1-72

1120
URC



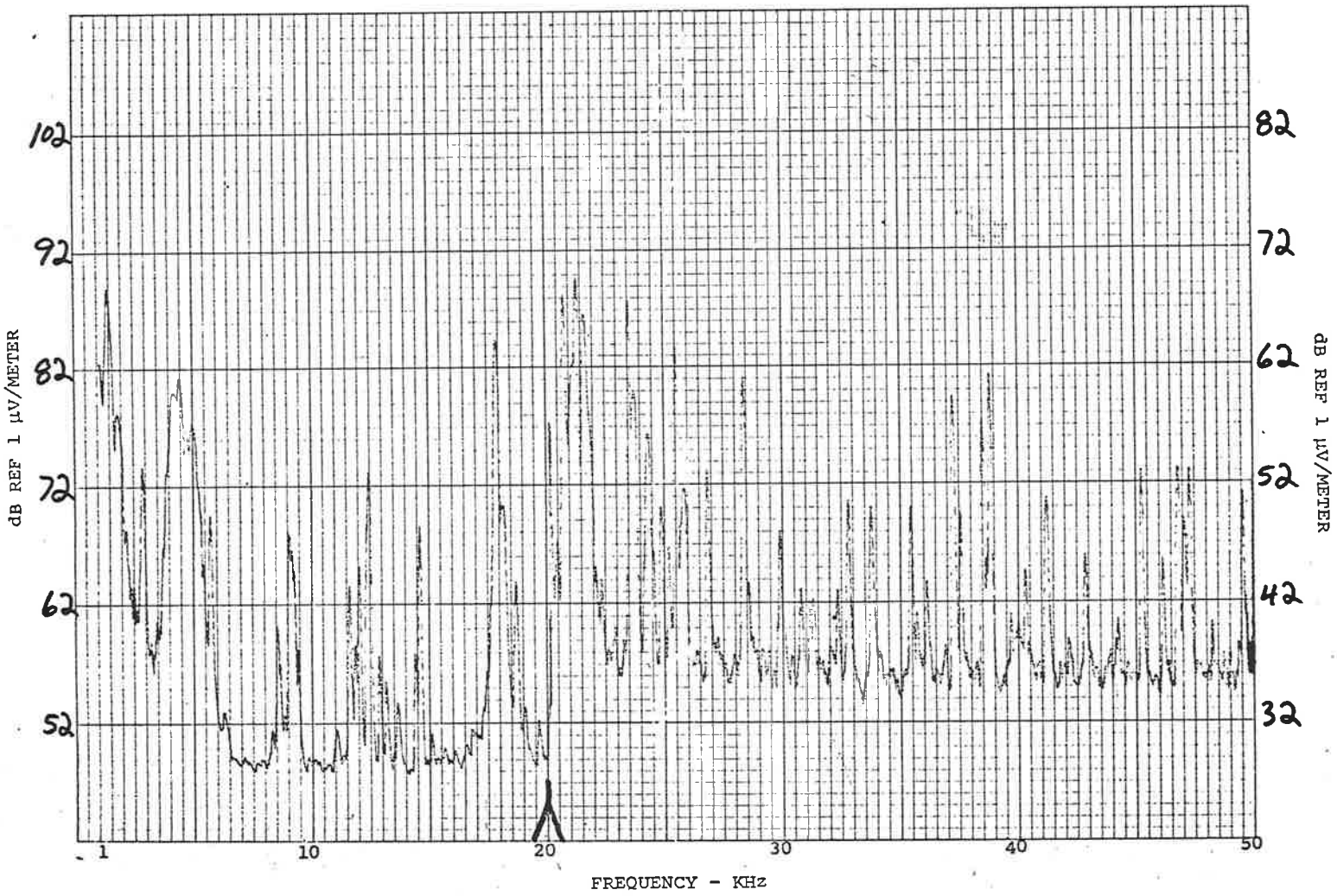
TEST NO. 386 TEST TYPE ESR N/S BANDWIDTH 50 Hz 1124
TEST SPECIMEN ~~Ant 4~~ TEST EQUIP. EMC-10 DATE 8-1-72 EEJ



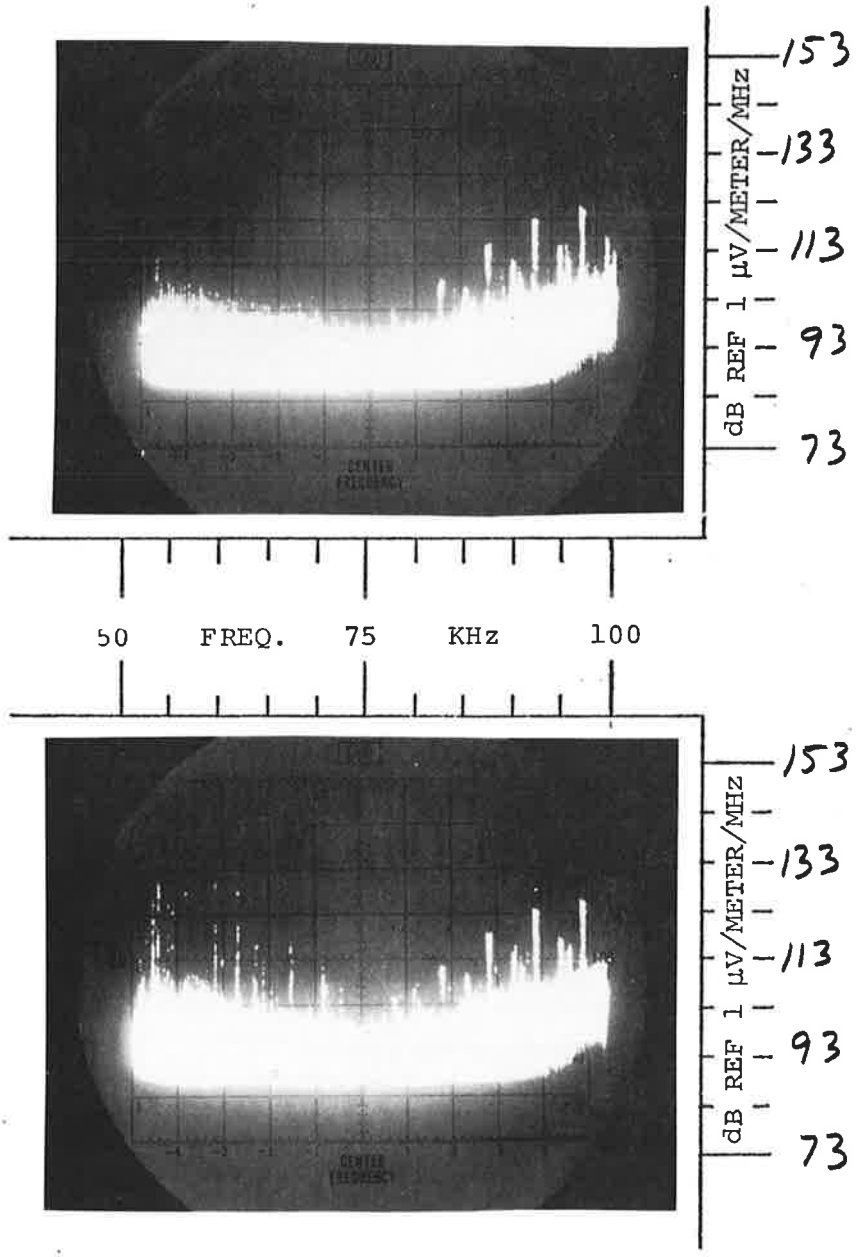
TEST NO. 387 TEST TYPE ESR N/S BANDWIDTH 50 Hz

TEST SPECIMEN Sub 4 TEST EQUIP. EMC-10 DATE 8-1-72

1127
EEI



LOCATION: SITE 4 TYPE TEST ESR DATE 8-1-72

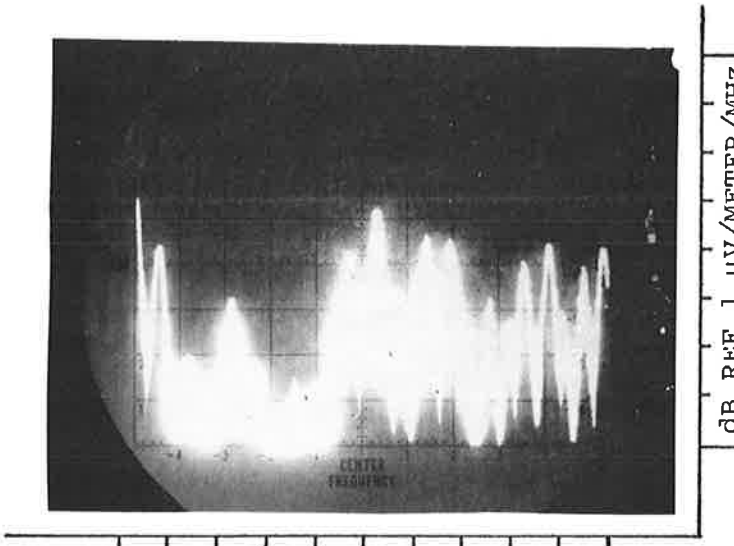


TEST 383
TIME 1104

FREQ. SCAN: 5 KHz/Div.
Bandwidth: 10 KHz

TEST 383
TIME 1104.5

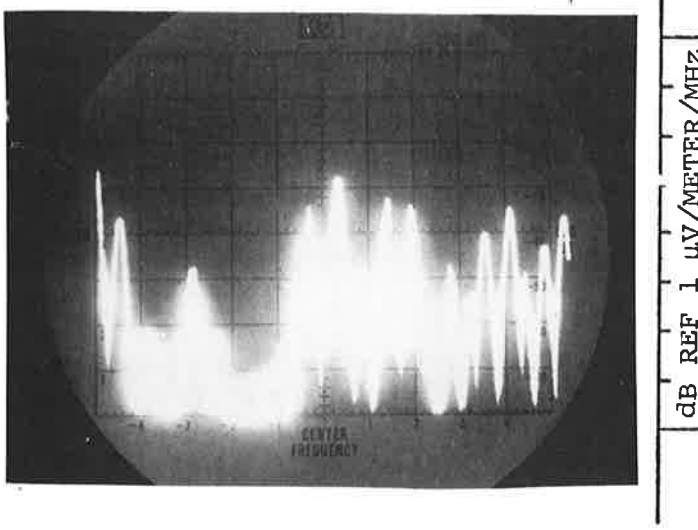
LOCATION: SITE 4 TYPE TEST ESR DATE 8-1-72



TEST 382
TIME 1102

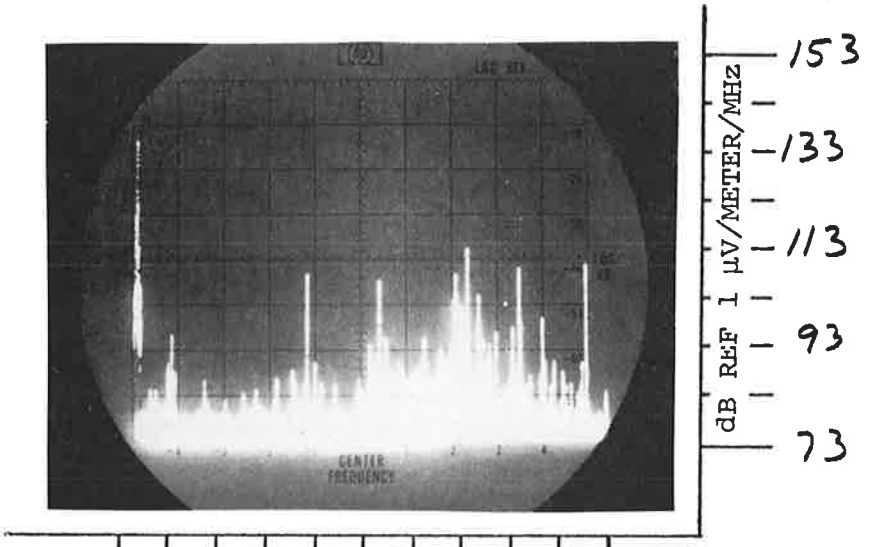
0.1 FREQ. 0.6 MHz 1.1

FREQ. SCAN: 0.1 MHz/Div.
Bandwidth: 10 KHz



TEST 382
TIME 1102.5

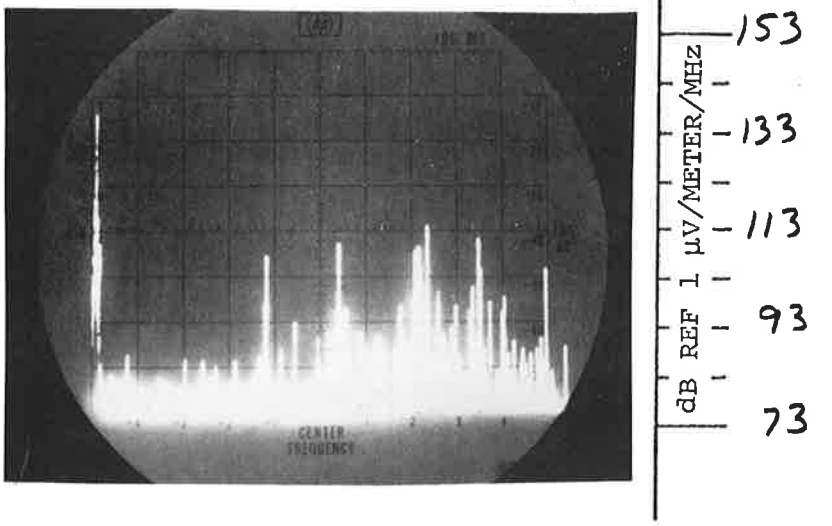
LOCATION: SITE 4 TYPE TEST ESR DATE 8-1-72



TEST 381
TIME 1100

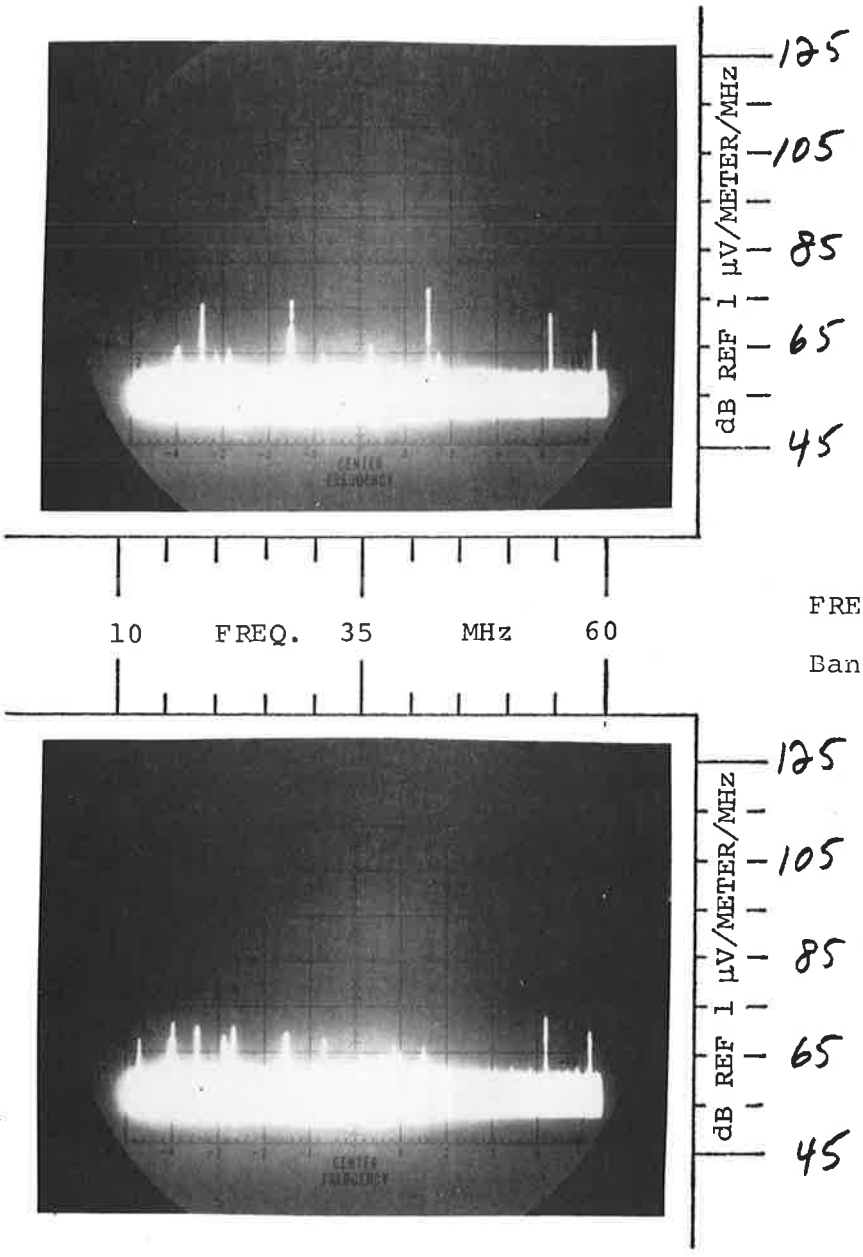
1 FREQ. 11 MHz 21

FREQ. SCAN: 2MHz/Div.
Bandwidth: 10 KHz



TEST 381
TIME 1100.5

LOCATION: SITE 4 TYPE TEST ESR E/W DATE 8-1-72

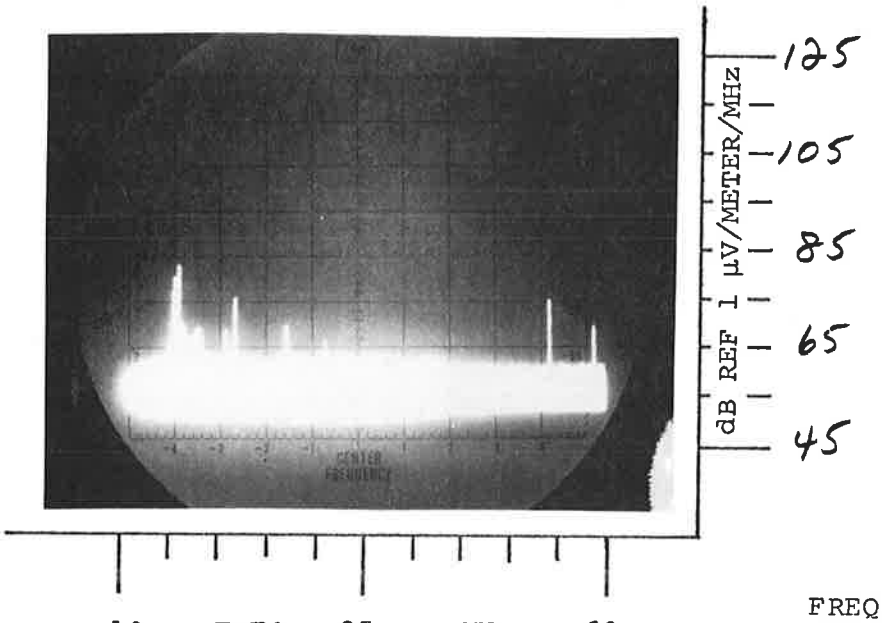


TEST 379
TIME 1053

FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz

TEST 379
TIME 1054

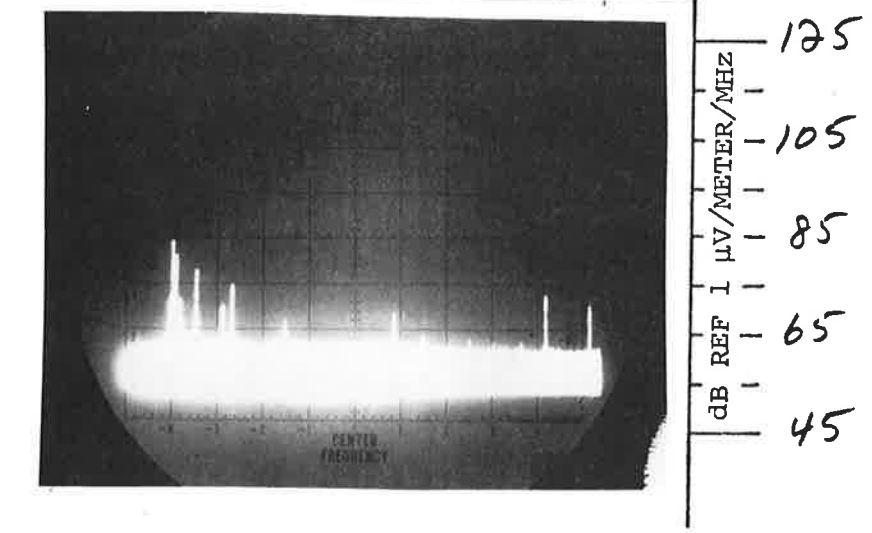
LOCATION: SITE 4 TYPE TEST ESR N/S DATE 8-1-72



TEST 380
TIME 1054.5

10 FREQ. 35 MHz 60

FREQ. SCAN: 5MHz/Div.
Bandwidth: 10 KHz



TEST 380
TIME 1055

ranspo 72®

DULLES SYSTEM

Ford

NATOR N. Sammet

O.D. READING ✓ MILES

LE RACHEL

HOUR METER READING ✓ HOURS

8-1-72

steps were made AT A+E as at time 6 sec 9 sec

or Subject: Activety Record for Eni test

nations:

8.00 Power is turned on RACHEL for 1 Vehicle mode
8.02 Begin 1st cycle on Rachel from A-E
8.02 LOST Power
8.20 Power back on cont cycle
8.22 Begin 2st cycle on Rachel
8.25 Power triped off
8.26 Power back on for 3rd Cycle
8.28 Begin 4th cycle on RACHEL
8.31 " 5th " " "
8.33 " 6th " " "
8.35 " 7th " " "
8.37 " 8th " " "
8.40 " 9th " " "
8.42 " 10th " " "
8.47 " 11th " " "
8.46 " 12th " " "
8.49 " 13th " " "
8.51 " 14th " " "
8.53 " 15th " " "
8.57 " 16th " " "
8.59 " 17th " " "
9.01 " 18th " " "
9:04 " 19th " " "
9:07 " 20th " " "
9:09 " 21st " " "
9:12 " 22nd " " "
9:14 " 23rd " " "
9:16 " 24th " " "
9:18 " 25th " " "

Form STS 5

Transpo 72®

DULLES SYSTEM

Ford

ATOR _____ O.D. READING _____ MILES

E _____ HOUR METER READING _____ HOURS

_____

or Subject: Activity Record for Emi test

_____

ations:

9:25 - Begin 27th Cycle on Rachel
9:27 " 28 " " " "
9:30 " 29 " " " "
9:33 " 30 " " " "
9:35 " 31 " " " "
9:37 " 31 " " " "
9:40 " 32 " " " "
9:42 " 33 " " " "
9:45 " 34 " " " "
9:47 " 35 " " " "
9:50 " 56 " " " "
9:52 " 37 " " " "
9:55 " 58 " " " "
9:57 " 39 " " " "
10:00 " 40 " " "
10:01 Power dropout, Breakers on vehicle at Point E
10:05 - Reset breakers; back to Point A
10:09 Point A to S switch area - Reset Doors
10:10 Back to Point A
10:12 Begin #41 - Cycle on Rachel
10:15 " 42 " " " "
10:17 " 43 " " " "
10:20 " 44 " " " "
10:22 " 45 " " " "

Form STS 5

Transpo 72

DULLES SYSTEM

Ford

NATOR

LE Rachel

8-1-72

O.D. READING ✓ MILES

HOUR METER READING ✓ HOURS

or Subject: Activity Record for Esi test

nations:

10:27 Begin 47 th cycle on Rachel
10:30 " 48 " " " "
10:32 " 49 " " " "
10:36 " 50 " " " "
10:39 " 51 " " " "
10:41 " 52 " " " "
10:49 " 53 " " " "
10:52 " 54 " " " "
10:54 Racked in Sta A
11:15 Begin 55 th " " "
11:17 " 56 " " " "
11:20 " 57 " " " "
11:23 " 58 " " " "
11:25 " 59 " " " "
11:27 TRIPED POWER OFF
11:27 POWER BACK ON
11:28 TRIPED POWER OFF
11:30 POWER BACK ON
11:31 Begin 60 th cycle on Rachet
11:34 " 61 " " " "
11:36 " 62 th " " "
11:38 " 63 th " " "
11:41 " 64 th " " "
11:44 " 65 th " " "
11:46 " 66 th " " "
11:49 " 67 th " " "
11:51 " 68 th " " "
11:54 " 69 th " " "