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ELECTROMAGNETIC ENVIRONMENT MEASUREMENTS OF PRT SYSTEMS AT "TRANSPO®72" VOLUME I

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16. Abstract

An X-Y plot is made of the ambient radiated electromagnetic signals and noise between 1KHz and 50KHz at Dulles International Airport for the purpose of assessing the local environment at each of the four Personalized Rapid Transit (PRT) sites prior to operation of each system. A Polaroid scope camera was used in conjunction with a spectrum analyzer to photograph signals between 50KHz and 50MHz.

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 under the same conditions first with each system operating individually and then 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.

AMBIENT RADIATED FIELD NOISE SURVEY
PRT SYSTEMS - TRANSPO® '72

1. INTRODUCTION

This technical report details results obtained in measurements of ambient radiated field noise at selected sites near each PRT exhibit at TRANSPO® '72. This test program was performed for DOT, Transportation Systems Center, by National Scientific Laboratories pursuant to Item 1 of Contract No. DOT-TSC-375, and the approved test procedures submitted by NSL on February 24, 1972. Item 1 called for the performance of EMI measurements in the frequency range from 1 kHz to at least 50 MHz, with all PRT systems off.

The objective of the test program was establishment of a base line for use in interpreting data taken at a later date with the PRT systems operating. Such data would enable characterization of the noise increase attributable to system operation.

The measurements described in this report were made at various times, as indicated, on the night of 29 February - 1 March 1972, the time of measurement being chosen to minimize interference from construction equipment.

2. METHOD OF MEASUREMENT

2.1 Equipment

2.1.1 1 kHz to 50 kHz

The measurements made in the range of 1 to 50 kHz were performed using the test setup illustrated in Figure 1. The receiver used for the measurements was a Fairchild EMC-10 Interference Analyzer. This device is a battery operated calibrated EMI/RFI meter which, when operated as a narrowband tunable device, covers the frequency range from 10 Hz 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. This feature permits the receiver to be used with an X-Y plotter.

To permit rapid taking of data, a Hewlett Packard Model 7005B X-Y Plotter was operated from the receiver.

Signals were obtained from the electromagnetic environment by use of either a Fairchild PEF-10 Electric Field Probe or a Fairchild ALP-10 Magnetic Field Loop Antenna. The former incorporates a high impedance input preamplifier to enable coupling of signals from the electrically short dipole to the receiver. Accordingly, graphs taken with this antenna may be interpreted directly, since a conversion factor constant with

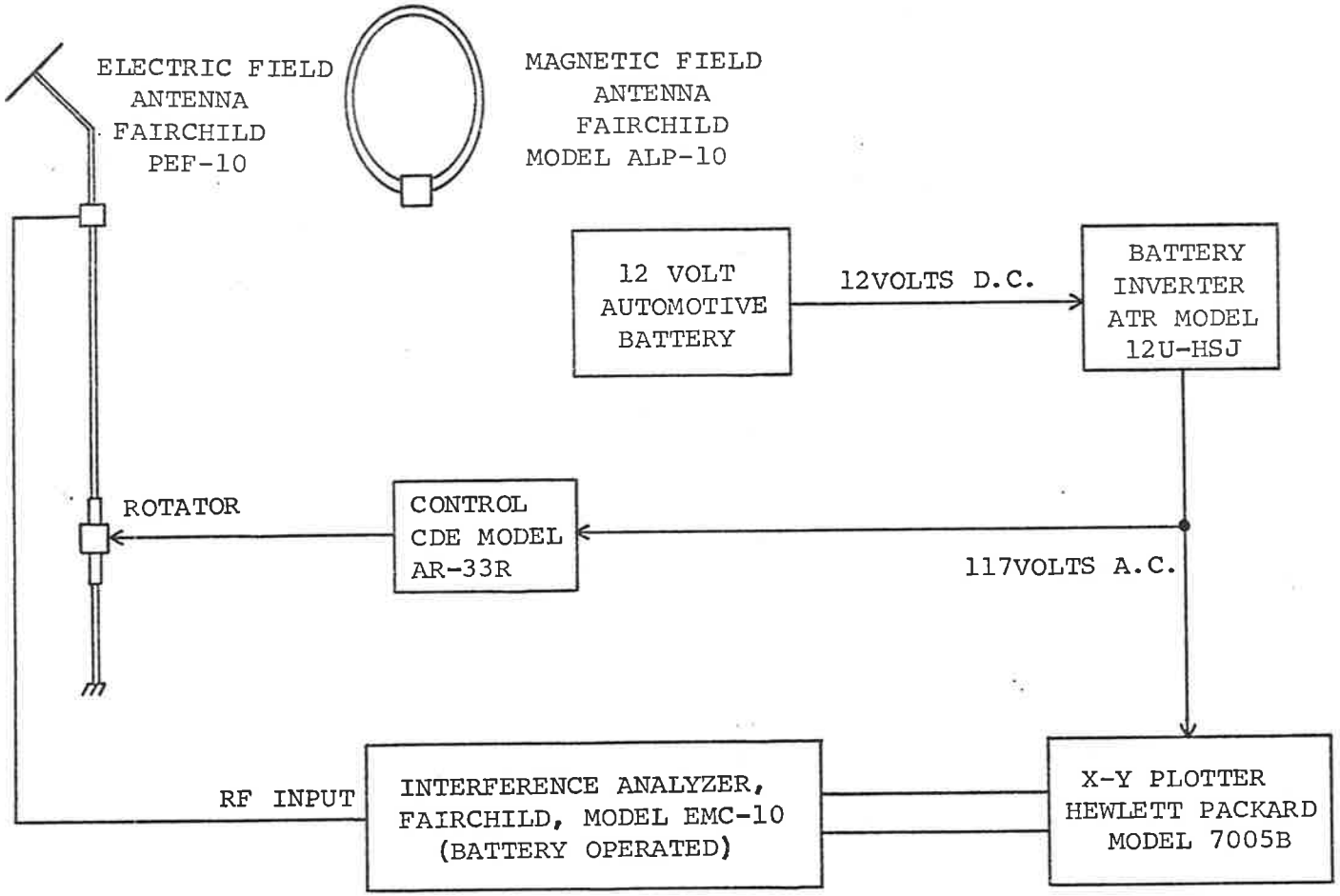


FIGURE 1. TEST SETUP - RADIATED ELECTRIC AND RADIATED MAGNETIC MEASUREMENTS 1 KHZ TO 50 KHZ.

frequency is involved. The magnetic-field antenna, on the other hand, has a factor which is a function of frequency. Graphs taken using this antenna must be replotted to obtain calibration in the appropriate units.

Both of the above antennas are directional in the horizontal plane. Therefore, a CDE Model AR-33R rotator was incorporated in the antenna mount to enable rotation in azimuth.

The rotator and X-Y Plotter were powered from a 12-volt automotive battery by means of an inverter.

2.1.2 50 kHz - 60 MHz

The measurements made in the frequency range of 50 kHz - 60 MHz were performed by means of the equipment configuration illustrated in Figure 2.

The receiver used was a spectrum analyzer, Hewlett-Packard Model 8552/8553A. This analyzer, as configured for the test, features a scanning unit capable of scanning various selectable frequency ranges between d.c. and 100 MHz. The ranges may be tuned with a variety of bandwidths, at selectable scan rates, and scan widths.

To aid in determination of scanned center frequency, a General Radio Model 1330A oscillator was used to inject markers when desired.

The spectrum analyzer incorporates a storage oscilloscope display unit which is capable of producing a calibrated

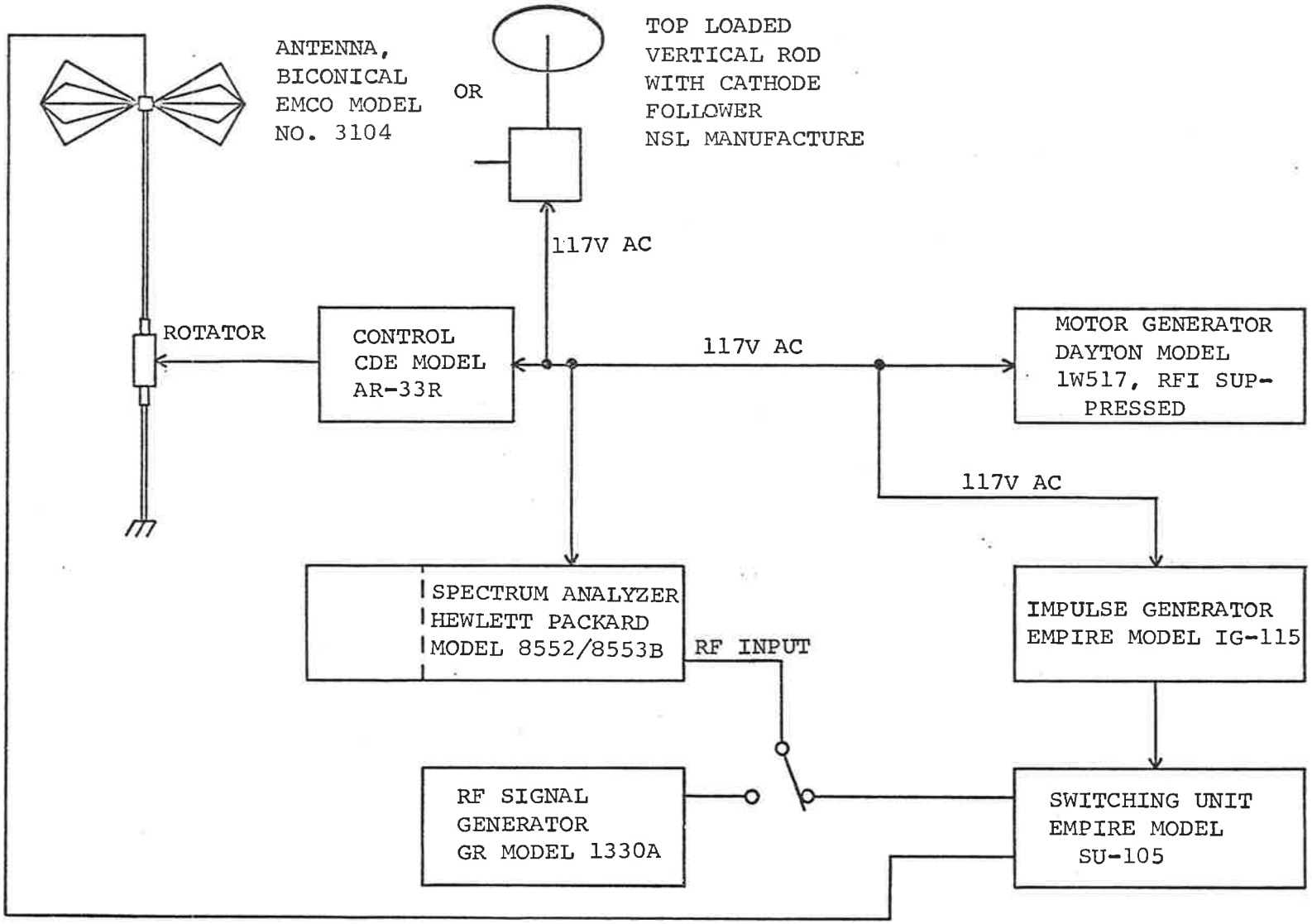


FIGURE 2. SETUP FOR RADIATED ELECTRIC FIELD MEASUREMENTS - 50 KHZ - 60 MHZ.

plot of amplitude vs. frequency expressed in terms of decibels.

Calibration of the analyzer was achieved by use of an Empire Devices IG-115 Impulse Generator which was substituted for the antenna at the input to the analyzer.

The display was recorded by means of a Hewlett Packard oscilloscope camera.

The antenna used for measurement in the frequency range of 50 kHz to 21 MHz was a vertical top loaded whip mounted on a cathode follower. This antenna is non-directional in the horizontal plane and features a constant conversion factor, enabling direct interpretation, i.e., without replot of photographic data.

In the range 20 MHz - 60 MHz, a MIL-STD-461 biconical (EMCO Model 3104) was utilized. This antenna, like all dipoles, is directional in the horizontal plane. Accordingly, it was rotated to the desired position by use of a CDE Model AR-33R rotator. Within the limited frequency range in which it was used, the conversion factor for this antenna is essentially constant.

All of the equipment used in the test was powered from a Dayton Model 1W517 engine generator. This device incorporates

various suppression and shielding techniques and does not contribute measurable amounts of noise to the electromagnetic environment.

2.2 Technique

Electric and magnetic field measurements were taken at selected sites chosen for proximity to each PRT system. For convenience, these sites were assigned numerical designations between 1 and 10, inclusive. The location of the sites are illustrated in the plan of Figure 3.

Electric field measurements were performed at sites 1, 2, 3, 4, 5, 6, and 7. These measurements covered the frequency range from 1 kHz to 60 MHz.

Magnetic field measurements were performed at sites 1, 8, 9, and 10. These measurements covered the frequency range of 1 kHz to 50 kHz.

The electric field sites were chosen so as to characterize the environment either at the center of a given exhibit or between that exhibit and the immediate adjacent exhibit. In the case of Monocab, which is somewhat remote from the other PRT exhibits, two electric-field measurement sites near the ends of the loop track were selected.

The magnetic field sites were chosen to characterize the overall exhibit environment. Given that no exhibit is running

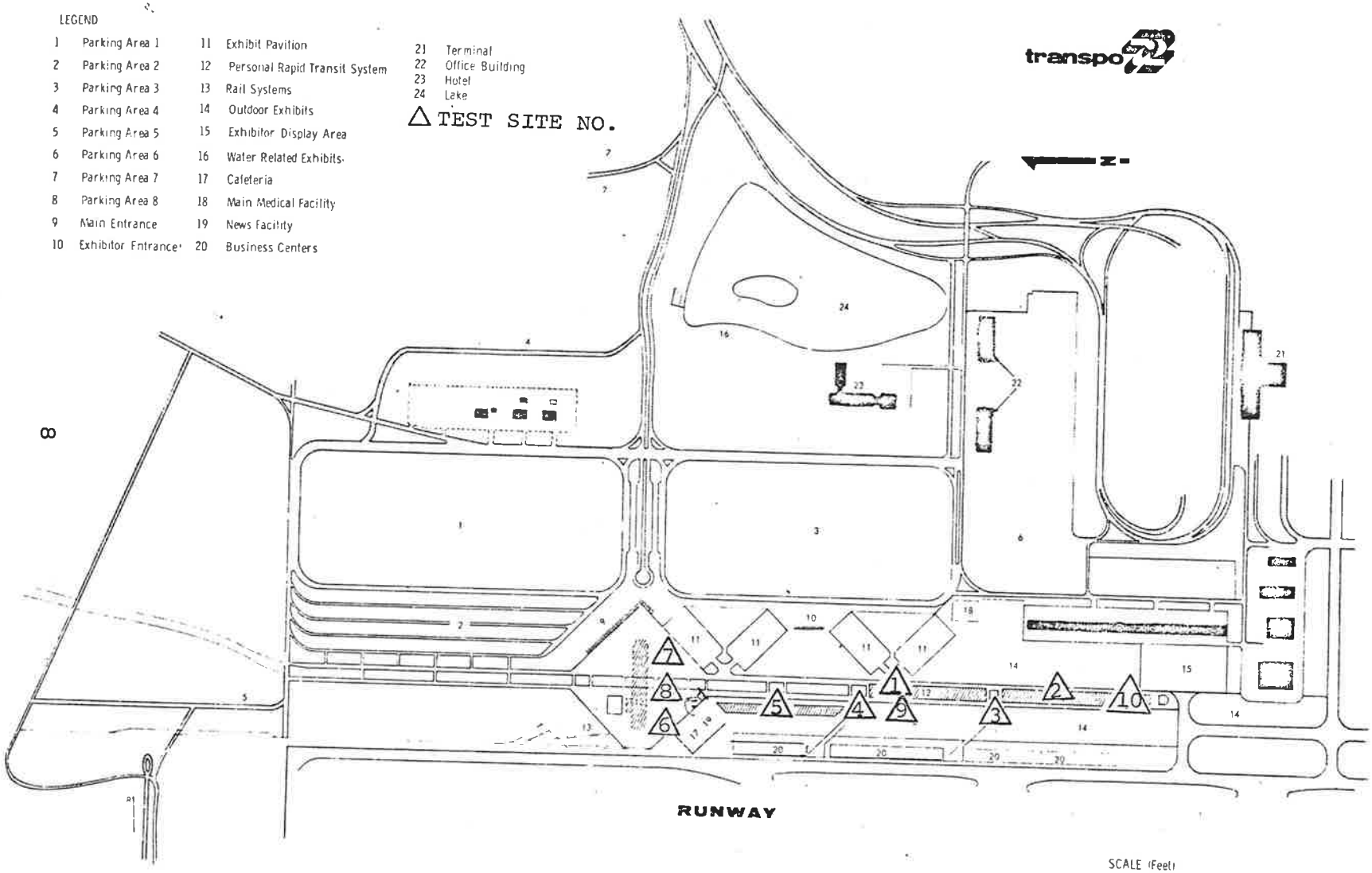


FIGURE 3. TRANSPO® RADIATED FIELD TEST SITES

magnetic-field data, being less dependent on ground effects, are less site-dependent. Accordingly, only four test sites were deemed necessary. These corresponded to the north end of the exhibit road loop, the center of the west road, the center of the east road, and the south end of the PRT exhibits.

The magnetic antenna and the certain electric field antennas (the biconical and the PEF-10) are directional in nature. Accordingly, where necessary, two measurements were made at each site with the antennas aimed for north-south and east-west pickup.

All measurements were performed with the antenna attached to the top of a mast mounted on the NSL truck. Accordingly, the antenna height above ground was approximately 12 feet.

The procedure most convenient and efficient in taking data was to mount a given antenna on the mast and perform all the necessary measurements at each site in sequence. The antenna was then changed and measurements again performed at the sites in sequence. Because this procedure was employed, low frequency data were taken prior to midnight while higher frequency data were taken somewhat later.

3. INTERPRETATION OF RESULTS

3.1 General

The results obtained during the ambient radiated field noise survey are presented in Appendix A. Pages A-2 through A-22, contain photographic spectrum plots obtained using the Hewlett Packard Spectrum Analyzer. These data cover the frequency range of 50 kHz to 60 MHz. The data are organized by site, beginning with site 1, and were taken at a total of seven sites, being sites 1 through 7.

These data are followed by results obtained using the EMC-10 and X-Y Plotter covering the frequency range 1 kHz to 50 kHz. Pages A-23 through A-36 contain plots of electric field data, while pages A-37 through A-40 contain magnetic-field data.

3.2 Electric-Field Measurements - 50 kHz through 60 MHz

The electric field data in the frequency range 50 kHz through 60 MHz were taken using the Hewlett Packard Spectrum Analyzer. The results obtained are presented in the form of calibrated oscilloscope photographs, in four frequency ranges. All of the data were taken between the hours of approximately 1:30 and 5:00 A.M. on the morning of 1 March 1972. The bandwidth used in all cases was 10 kHz.

The first photograph of each set, e.g., no. 59 on page A-2, covers the frequency range of 50 kHz to 100 kHz at a frequency scale of 5 kHz per division. The data were taken using a top-loaded vertical rod antenna incorporating a cathode follower. The correction factor for this antenna is constant over the test frequency range, allowing direct calibration of the data without replotting the data taken in this frequency range show little other than noise. Some photographs, e.g., test no. 78 on page A-17, show time domain noise bursts from an unknown source.

The second photograph of the set, e.g., no. 50 on page A-2, covers the frequency range of 100 kHz to 1100 kHz at a scale of 100 kHz per division. The vertical rod-cathode follower antenna was used in obtaining the data. The photographs in this frequency range show a number of peaks due to transmitter carriers, the origin of which can be determined by inspection of known transmitter frequency listings. The 100 kHz peak is due to the LORAN navigation system, which uses this frequency, while the peak at approximately 130 kHz is undoubtedly due to the Naval Radio Station, NSS. The carriers in the frequency range 200 to 400 kHz result from navigation beacons and aviation weather broadcast stations, e.g., Washington Area Radio, 332 kHz. The remainder of the photograph shows a large number of standard broadcast transmitters. The principle difference between

this result and that which would be obtained in the day time, had a day time measurement been possible, would have been a lower density of carriers due to lack of ionospheric propagation of signals from distant locations.

The third photograph, illustrates the frequency range from 1 MHz to 21 MHz at a scale of 1 MHz/div. The vertical rod antenna was used, eliminating the need for replotting. The photographs for this range show a high density of carrier phenomena below about 13 MHz. Extremely high densities are seen to coincide with the 6 and 9.5 MHz International Broadcast bands. This is typical for ambient data taken in the early morning hours. Had the ambient been taken in the day time, however, the carrier occupancy would have been considerably different, revealing a lower level between 1.6 and 11 MHz with high levels between 11 MHz and 21 MHz. Much of the latter region in this photograph reveals noise alone. These differences are attributable to the daily variations in ionospheric propagation.

Two photographs, e.g., nos. 92 and 91 on page A-4, were taken for the frequency range 10 MHz to 60 MHz, due to the fact that a directional antenna (MIL-STD-461 biconical) was used. The antenna was oriented for pickup in two orthogonal positions, corresponding to north-south and east-west pickup. This antenna has a relatively constant $\pm$ 2 dB antenna factor between 20 MHz

and 60 MHz only. Below 20 MHz the antenna factor rapidly increases. The calibration levels given at the side of the photograph apply between 20 and 60 MHz only.

The photographs show carriers associated with local citizens band, and utility transmitters as well as some time domain noise bursts, all of which are presumably local in origin. The density of such carriers is anticipated to be much higher in the day time, reflecting increased usage. Since these transmitters with certain exceptions are typically used for extremely short duration transmissions, it is anticipated that some difficulty will arise in distinguishing these events from noise pulses of extremely short duration. The photographs, because of the hour at which they were taken do not show the television signal of channel 2 (54 to 60 MHz) locally assigned to Baltimore. It is anticipated that this will appear if later testing is done during day time or evening hours.

3.3 Electric Field Measurements - 1 kHz to 50 kHz

The electric field measurement between 1 kHz and 50 MHz was performed at each of seven sites using the PEF-10 antenna, Fairchild EMC-10 Interference Analyzer and Hewlett Packard X-Y Plotter. Since the antenna was directional, readings were taken in each of two directions corresponding to east-west and north-south pickup. The fourteen graphs which resulted are illustrated on pages A-23 through A-36.

The PEF-10 antenna has a constant correction factor (i.e., one which is not a function of frequency) enabling direct calibration of the amplitude scale of the plot in field intensity units.

The graphs show principally noise phenomena, with the exception of a large carrier at 17.8 kHz. The latter corresponds to the Naval Radio Station, NSS. The data were taken between the hours of approximately 8:00 P.M. and 11:00 P.M. on the night of 29 February 1972. A gasoline engine was being operated near site 6 during the period of data taking at site 7. The ambient obtained does not seem to be substantially contaminated by noise presumably emitted from this engine.

3.4 Magnetic Field Measurements - 1 kHz to 50 kHz

Magnetic field measurements were taken at sites 1, 8, 9, and 10, between the hours of approximately 11:00 P.M. and 12 midnight on 29 February 1972. The measurements were made using a loop antenna which does not have a correction factor constant with frequency. Therefore, each original graph, e.g., page A-37, is presented with a replot expressed in magnetic field units. The loop antenna has a directional characteristic, and in each instance was positioned for maximum pickup in the direction shown.

The data obtained show the carrier (17.8 kHz) of the Naval Radio Station, and in addition, show noise pulses of unknown origin.

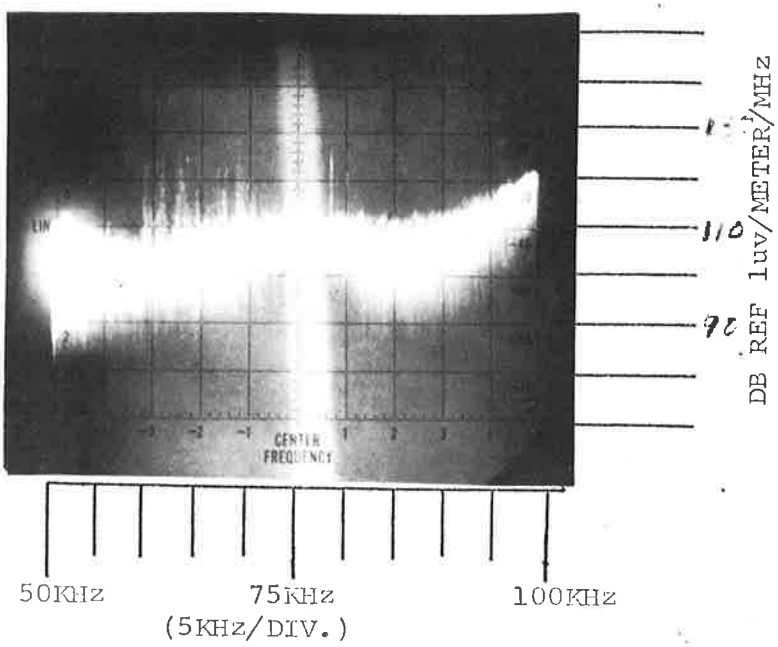
APPENDIX A

RADIATED FIELD AMBIENT

TEST

DATA

TEST NO. 57 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE #1 TEST EQUIP. S.A. DATE 1 MAR 72



TEST NO. 58 TEST TYPE ESR BANDWIDTH 10KHz
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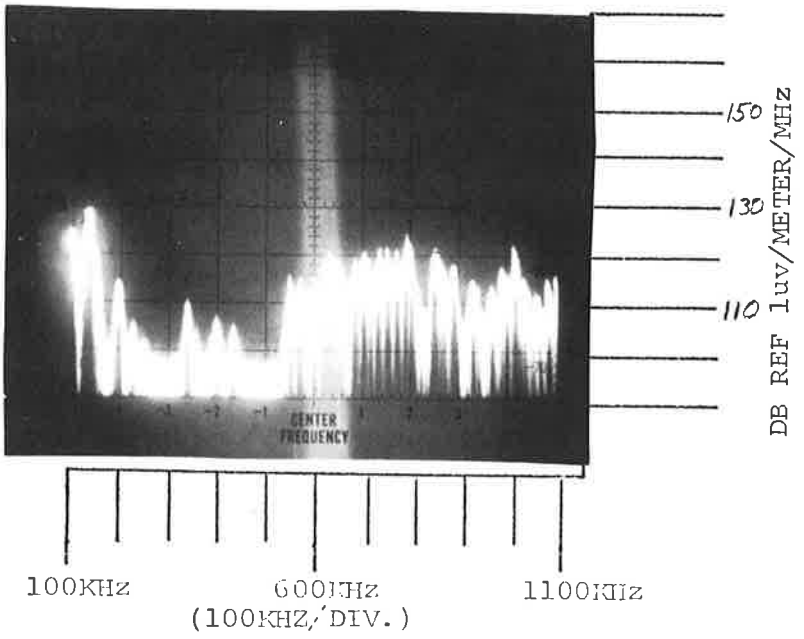
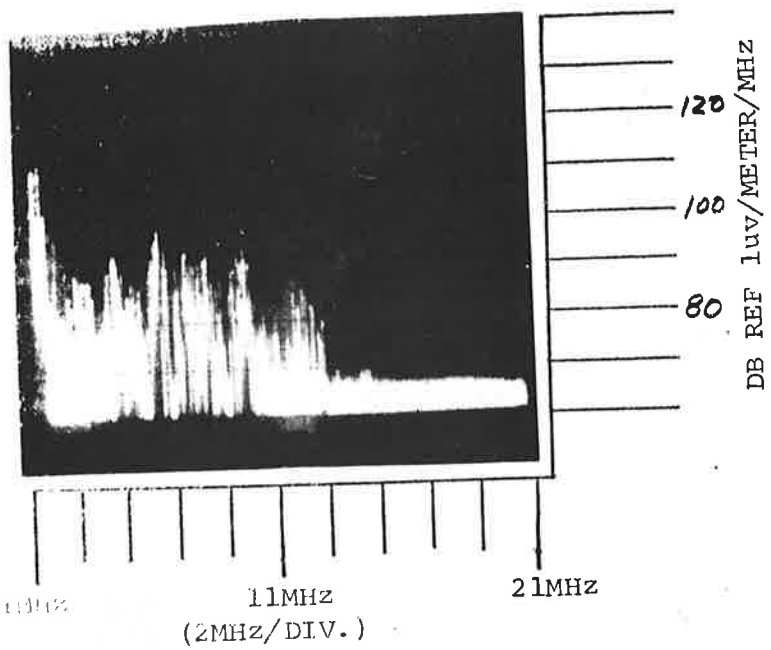


RFR 6/72

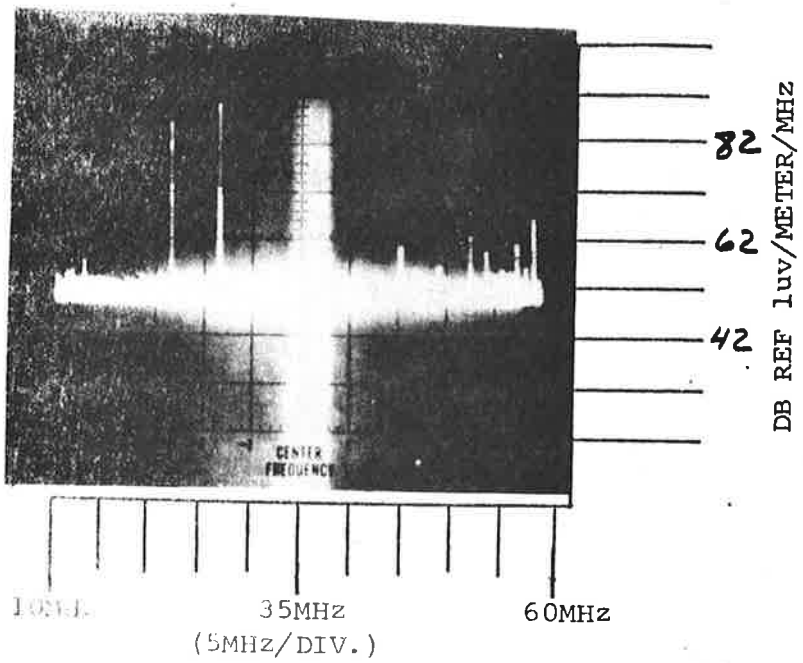
TEST NO. 58 TEST TYPE ESR BANDWIDTH 10KHz

TEST SPECIMEN SITE #1 TEST EQUIP. S.A. DATE 1 MAR 72



OBC EUT

TEST NO. 92 TEST TYPE ESR(N/S) BANDWIDTH 10KHz
TEST SPECIMEN SITE 1 TEST EQUIP. S.A. DATE 1 MAR 72



TEST NO. 91 TEST TYPE ESR(E/W) BANDWIDTH 10KHz
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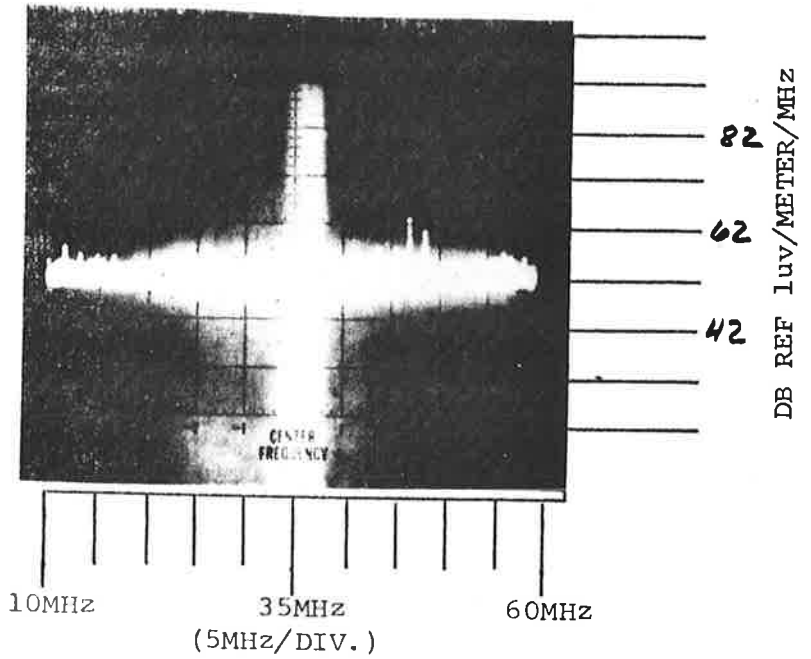

RBR CUH

TEST NO. 67 TEST TYPE ESR BANDWIDTH 10KHz
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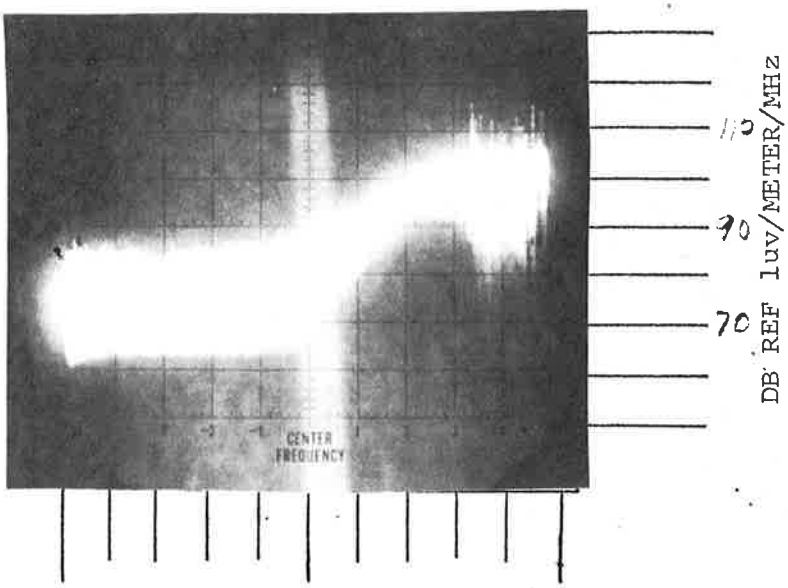

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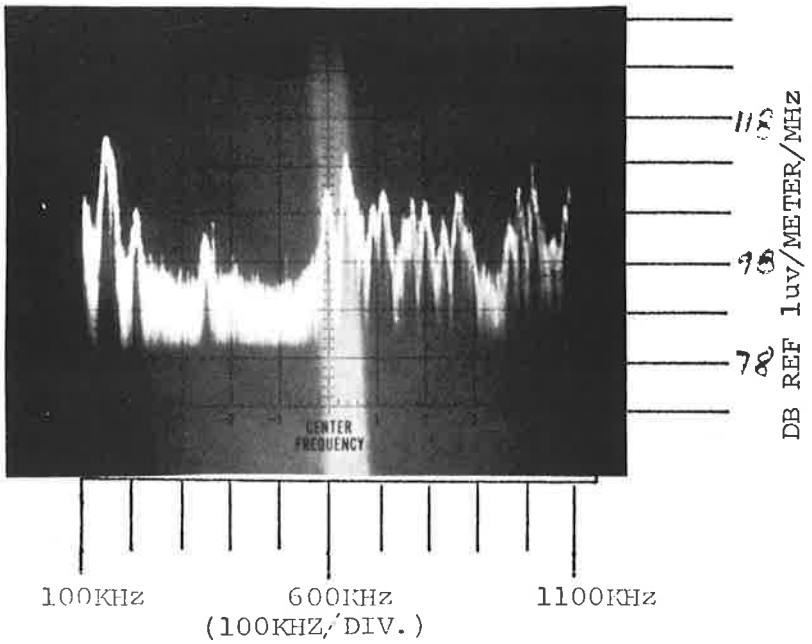

All ckd

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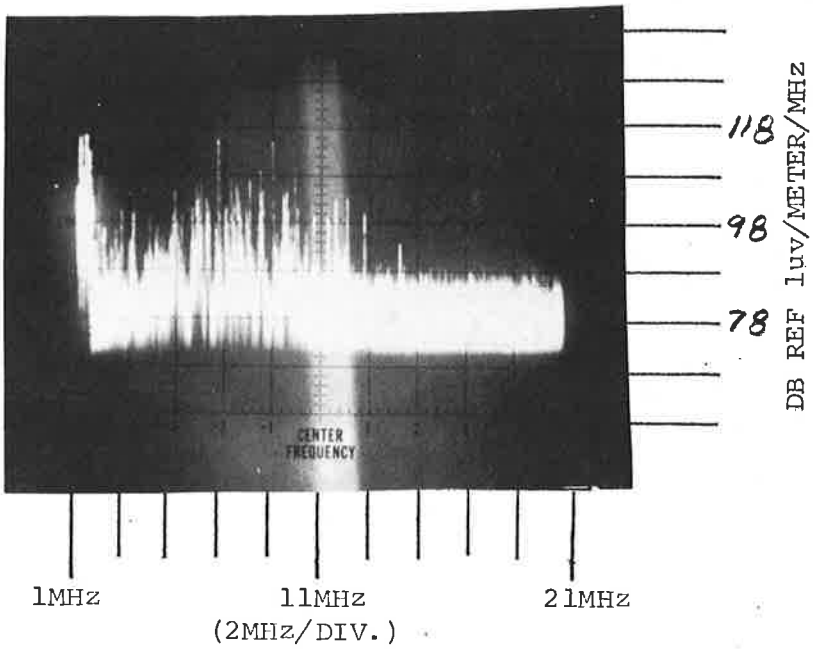

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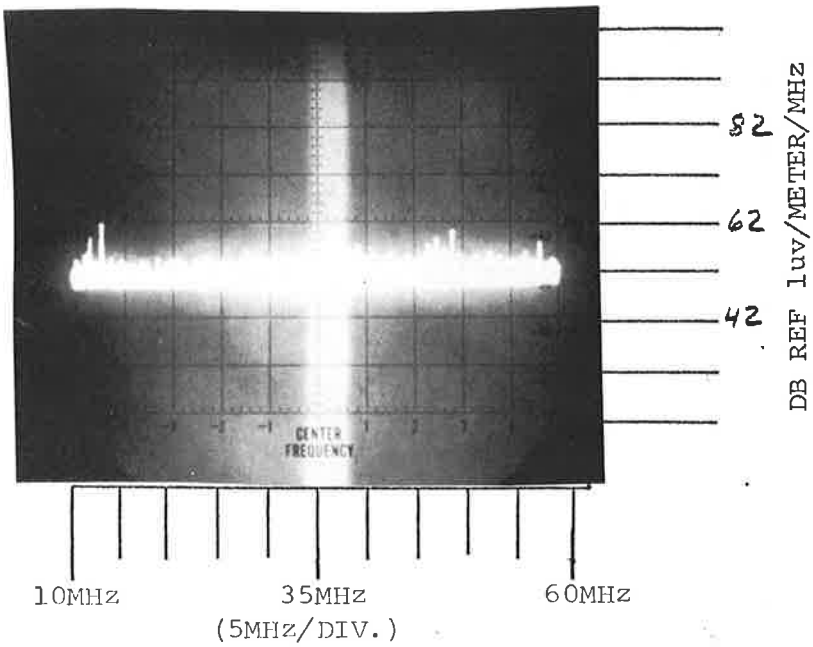

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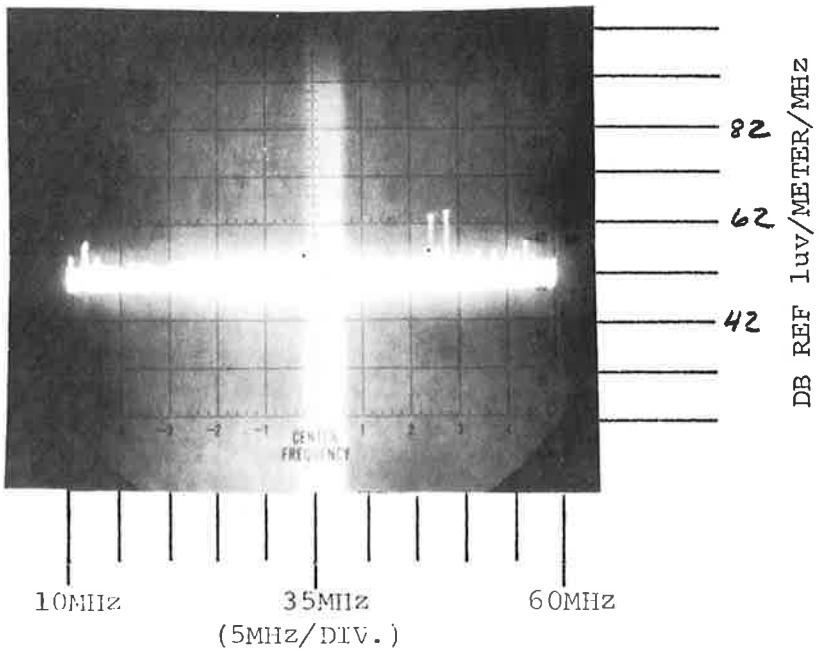

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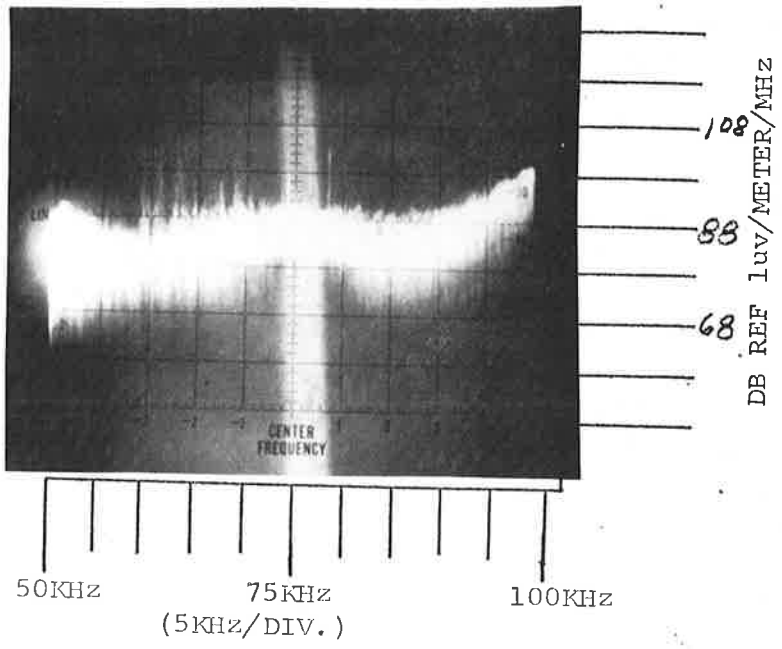

TEST NO. 65 TEST TYPE ESR BANDWIDTH 10KHz
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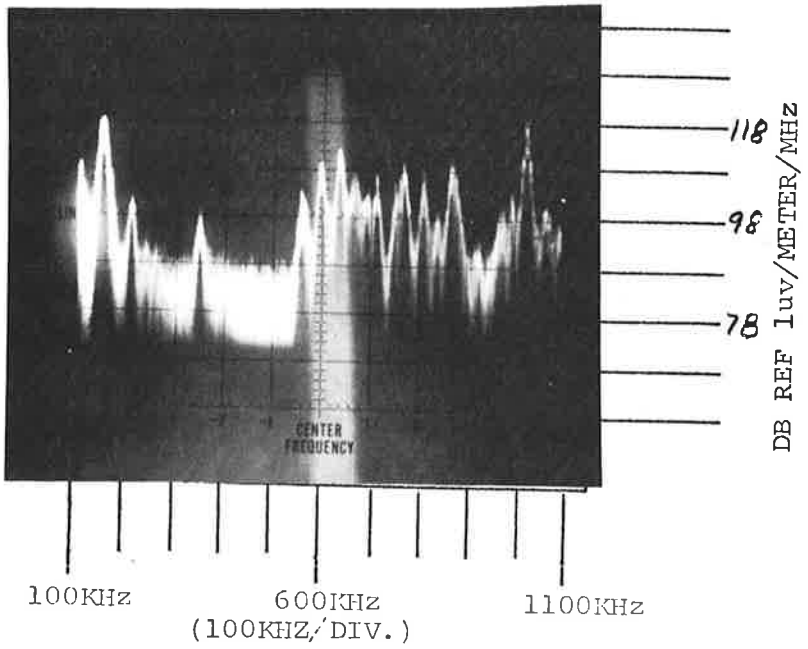
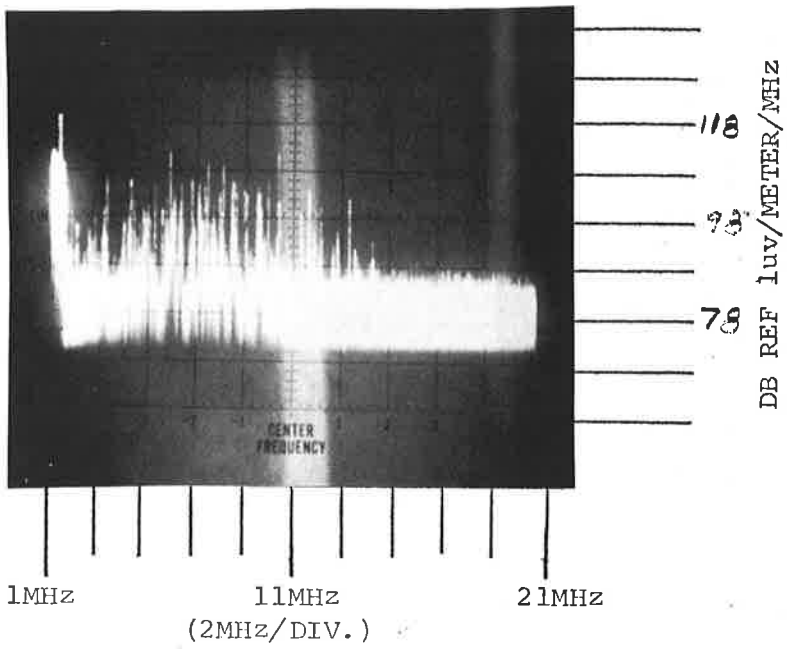


FBK 203

TEST NO. 64 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 3 TEST EQUIP. S.A. DATE 1 MAR 78



ESR 2057

TEST NO. 88 TEST TYPE ESR(N/S) BANDWIDTH 10KHz
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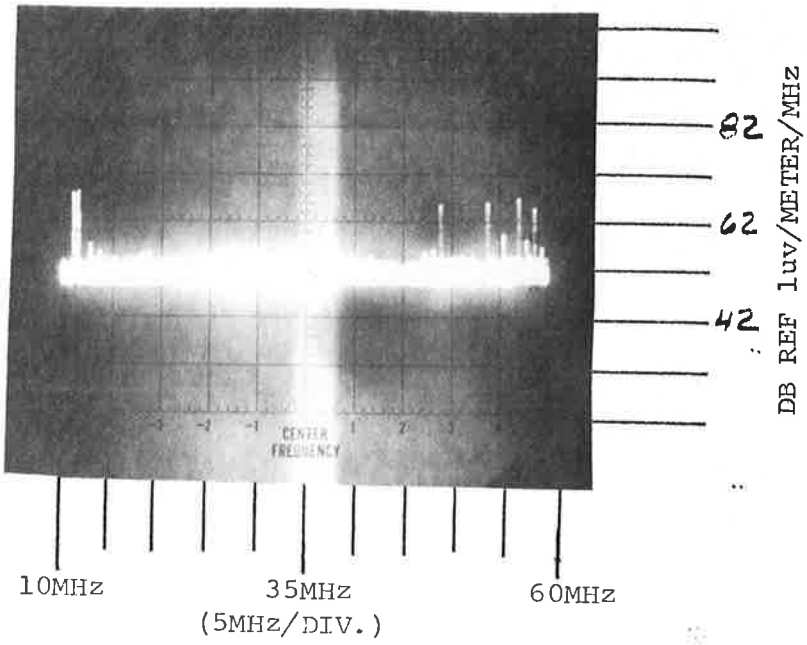

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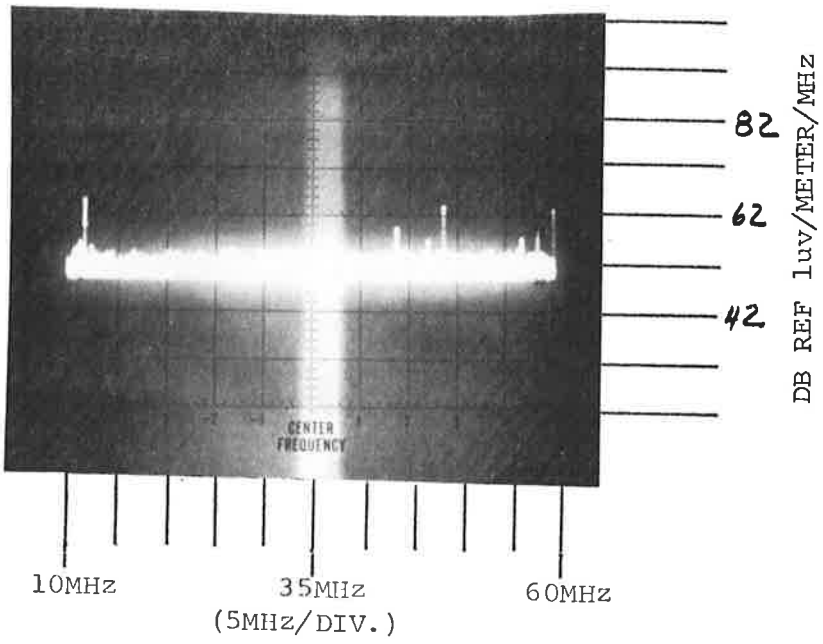

RBR cvh

TEST NO. 67 TEST TYPE ESR BANDWIDTH 10KHz
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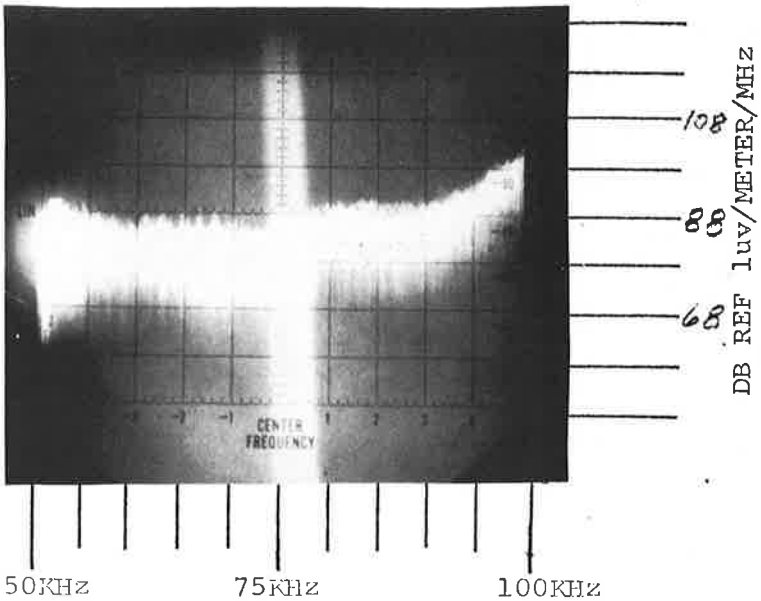

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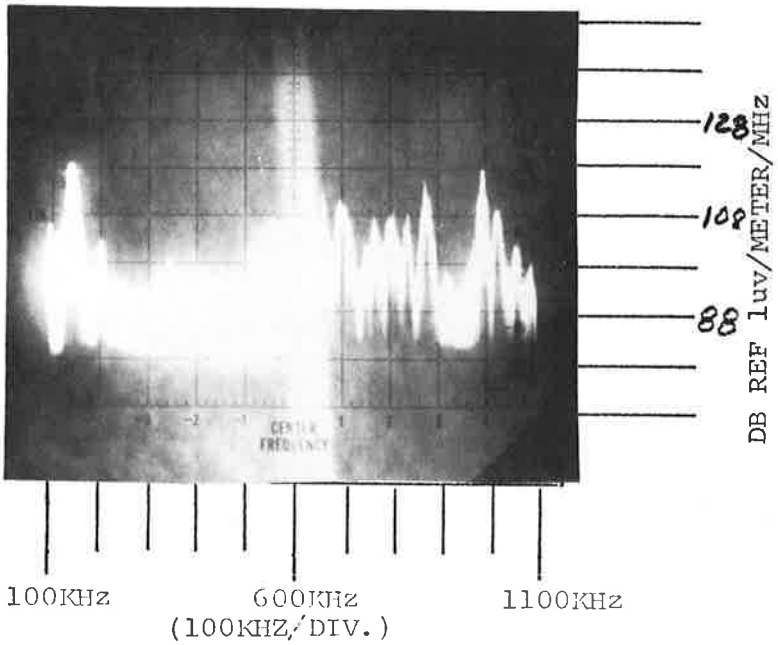

FBR CVH

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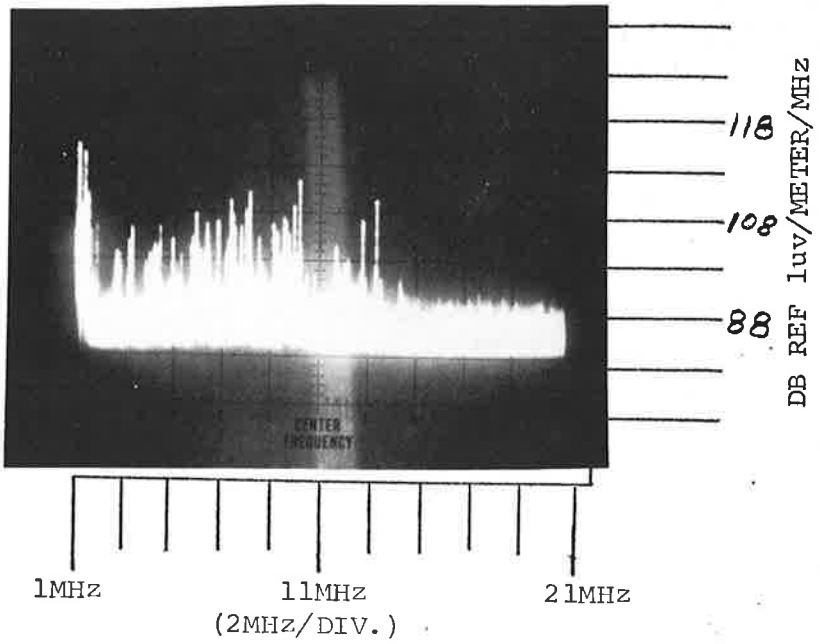
TEST SPECIMEN SITE 4 TEST EQUIP. S.A. DATE 1 MAR 72



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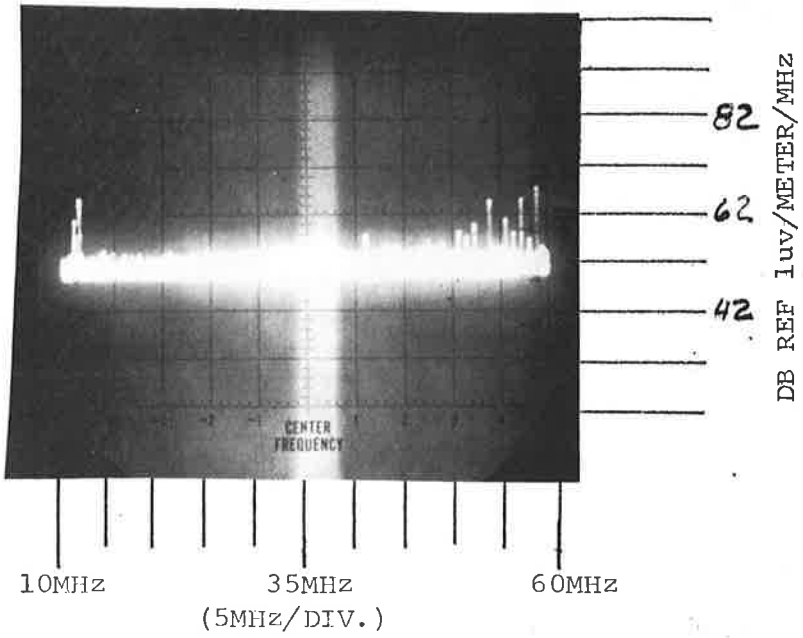

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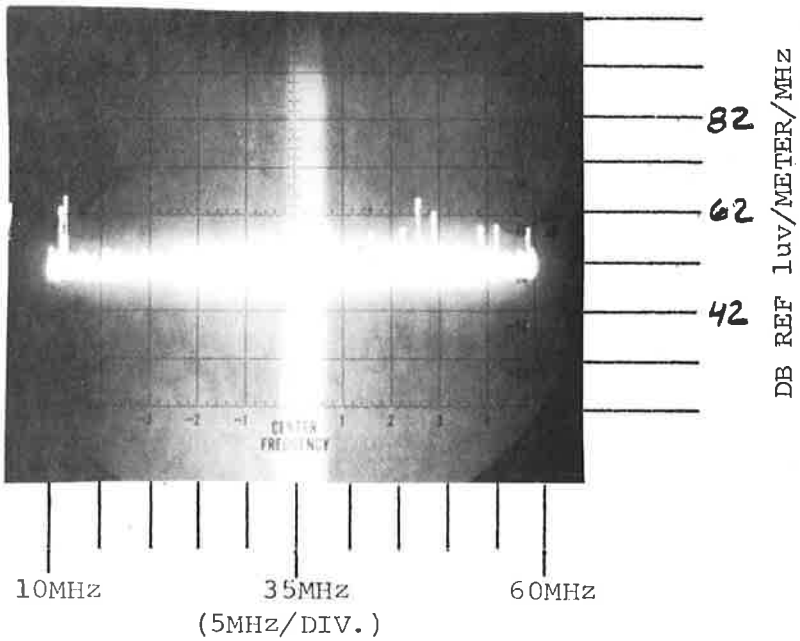

RBK 002

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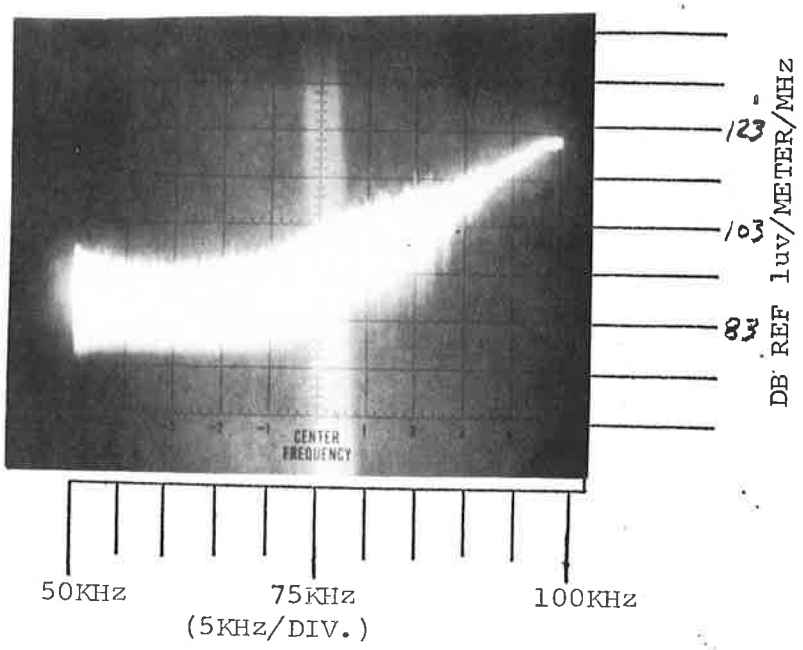

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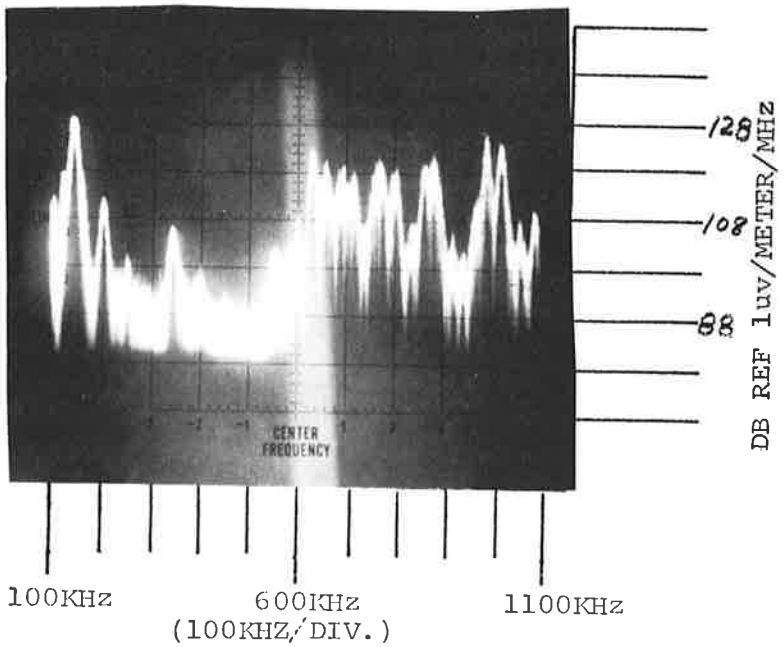
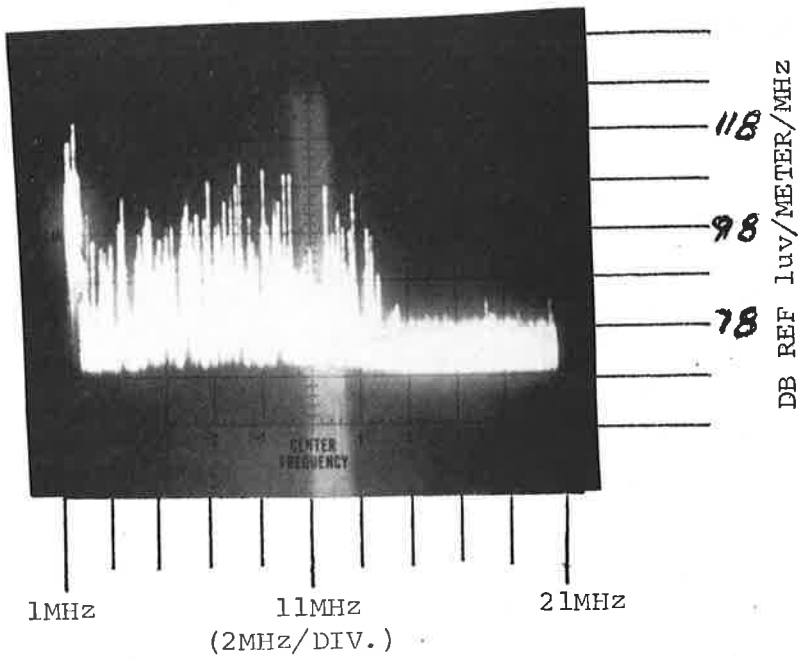


RBR 002

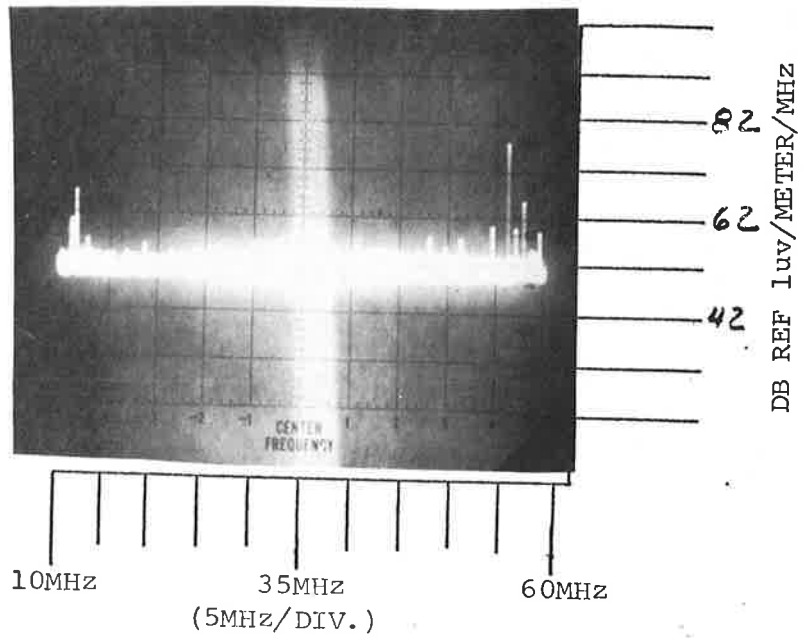
TEST NO. 70 TEST TYPE ESR BANDWIDTH 10KHz

TEST SPECIMEN SITE 5 TEST EQUIP. S.A. DATE 1 MAR 72

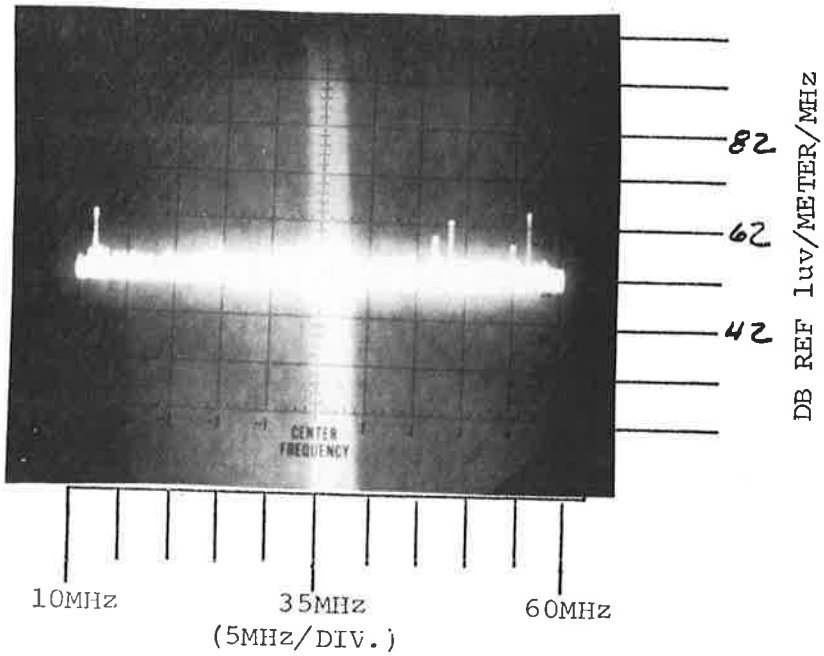


FBR 811

TEST NO. 84 TEST TYPE ESR(N/S) BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1MAR 72

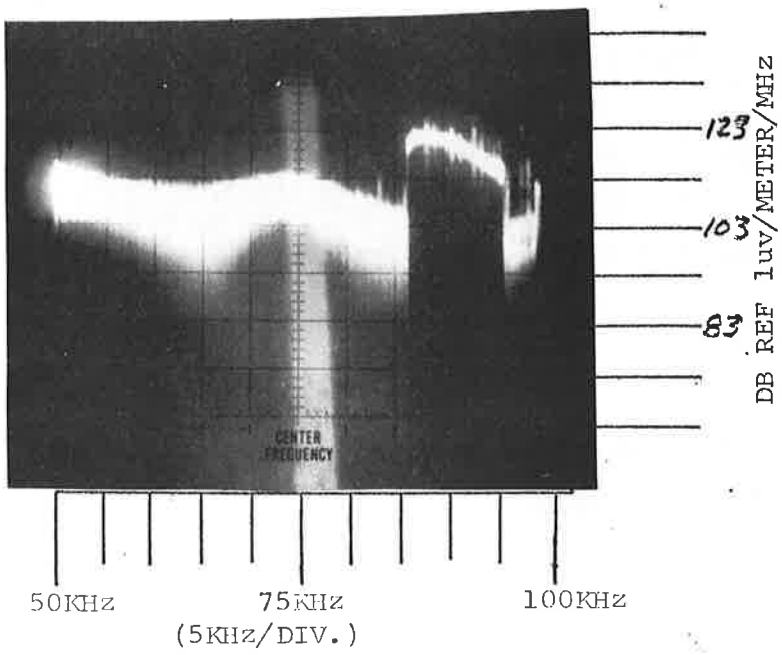


TEST NO. 83 TEST TYPE ESR(E/W) BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1MAR 72

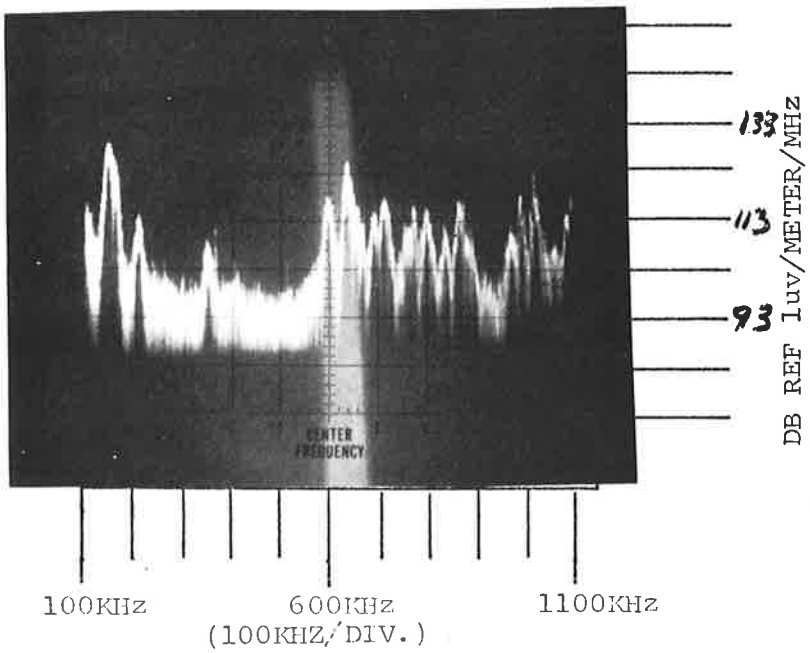


RBR 623

TEST NO. 78 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1 MAR 72

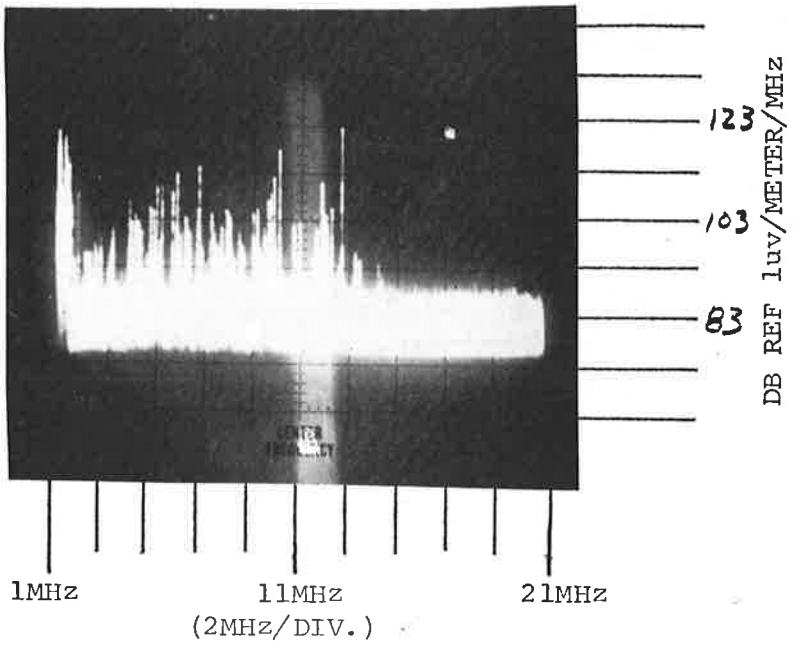


TEST NO. 76 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1 MAR 72



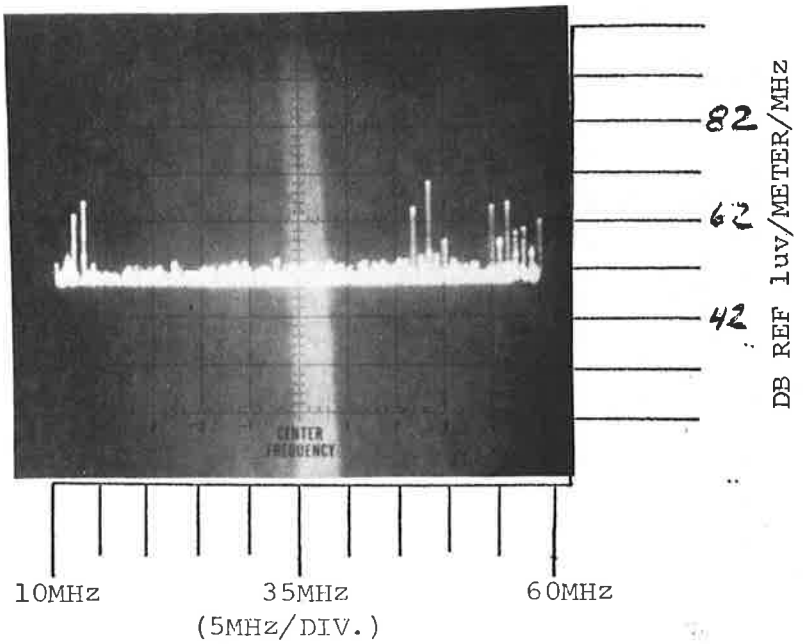
TEST NO. 77 TEST TYPE ESR BANDWIDTH 10KHz

TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1 MAR 72

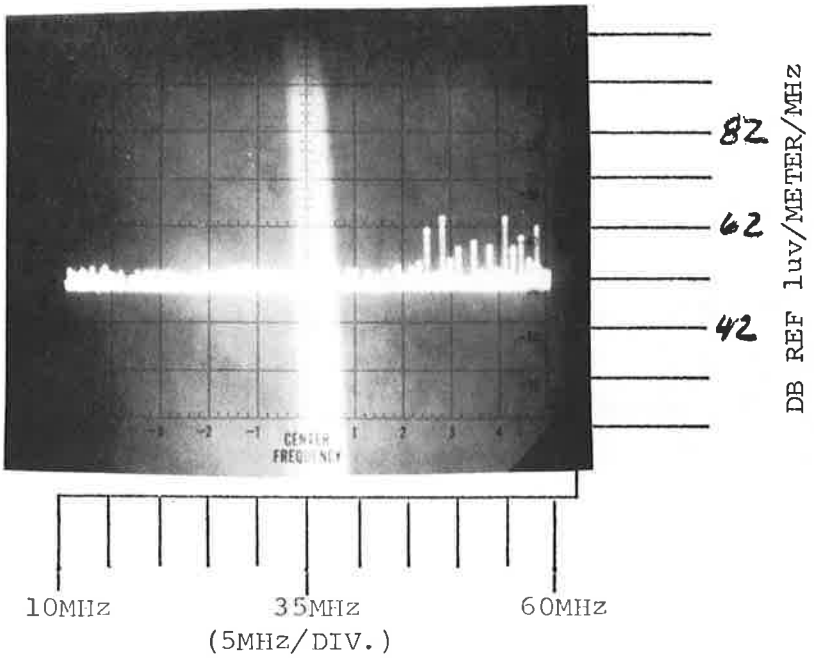


KBR ctd

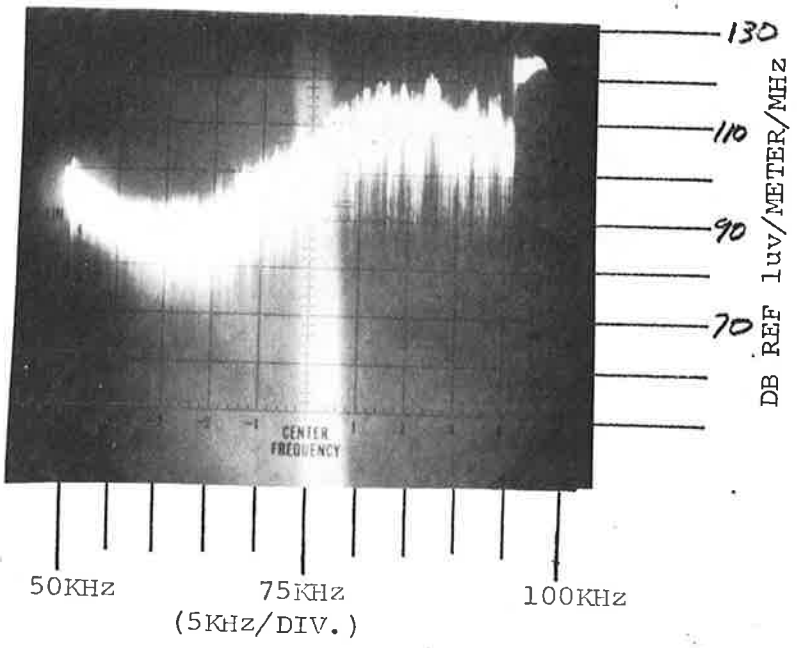
TEST NO. 80 TEST TYPE ESR(N/S) BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1 MAR 72



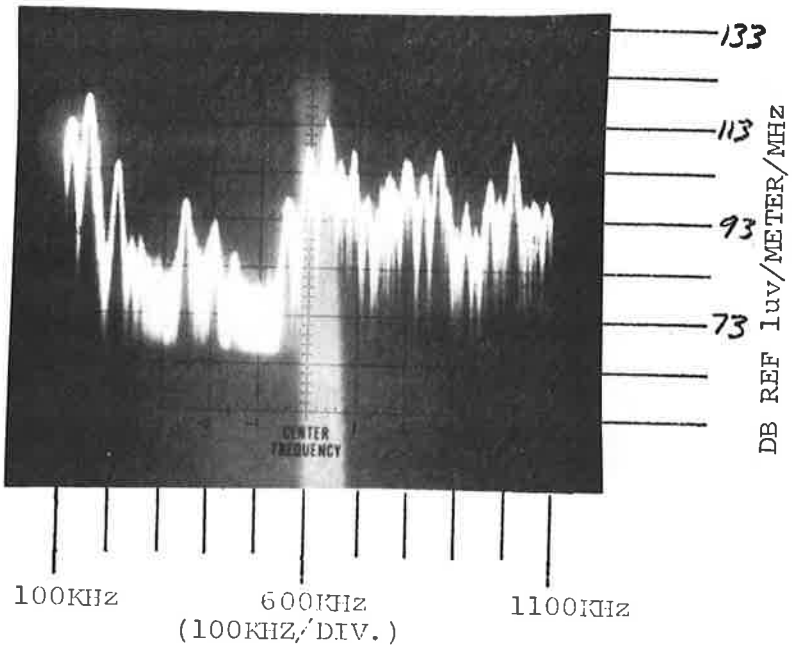
TEST NO. 79 TEST TYPE ESR(E/W) BANDWIDTH 10KHz
TEST SPECIMEN SITE 6 TEST EQUIP. S.A. DATE 1 MAR 72



TEST NO. 73 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 7 TEST EQUIP. S A DATE 1 MAR 72

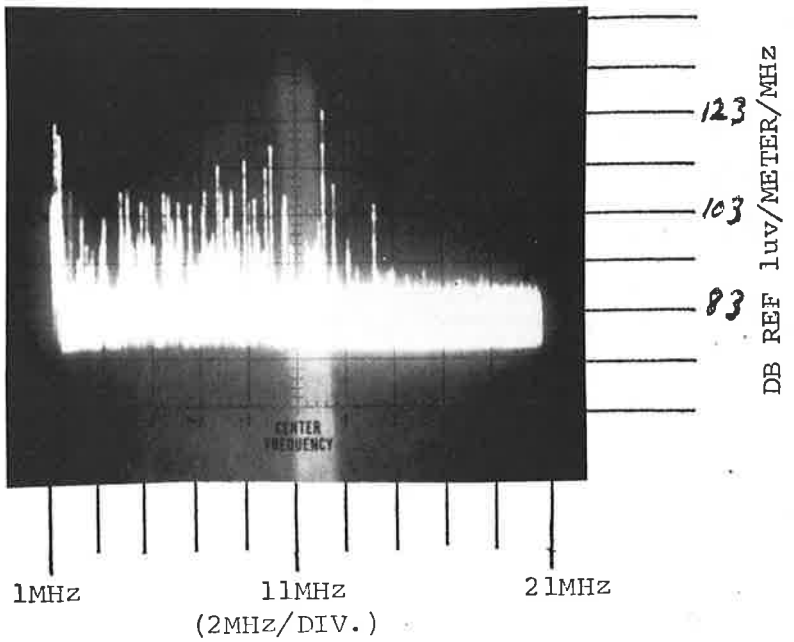


TEST NO. 75 TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 7 TEST EQUIP. S.A. DATE 1 MAR 72

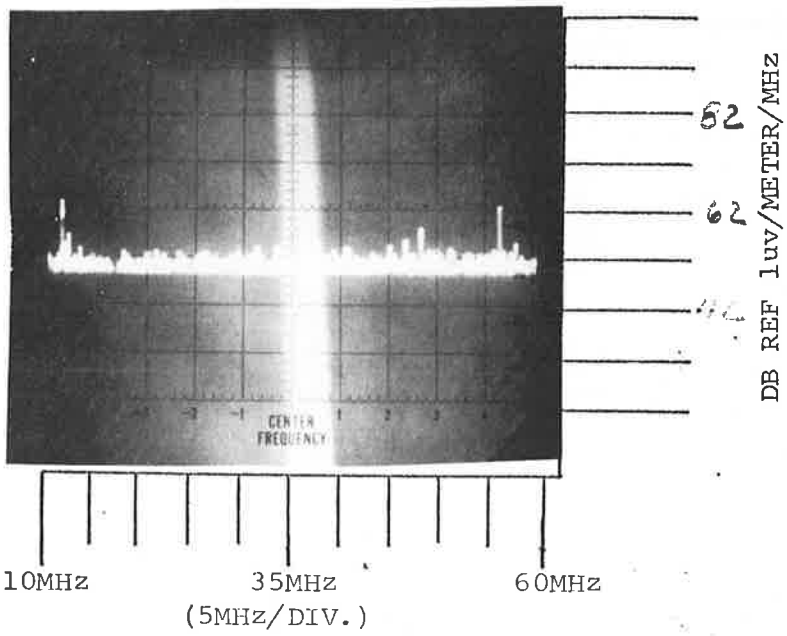


RBR 227

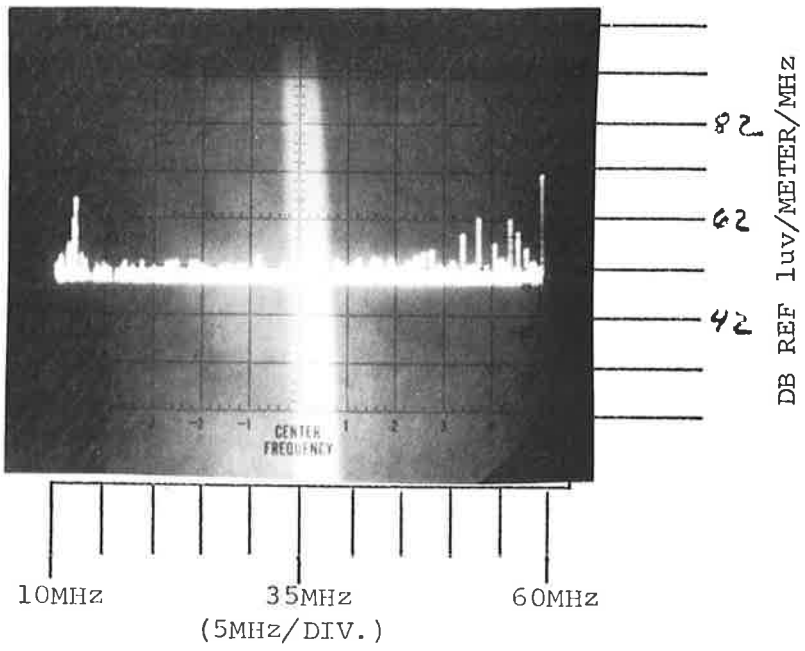
TEST NO. 74. TEST TYPE ESR BANDWIDTH 10KHz
TEST SPECIMEN SITE 1 TEST EQUIP. S.A. DATE 1 MAR 72



TEST NO. 82 TEST TYPE ESR(N/S) BANDWIDTH 10KHz
TEST SPECIMEN SITE 7 TEST EQUIP. S.A. DATE 1 MAR 72



TEST NO. 81 TEST TYPE ESR(E/W) BANDWIDTH 10KHz
TEST SPECIMEN SITE 7 TEST EQUIP. S.A. DATE 1 MAR 72

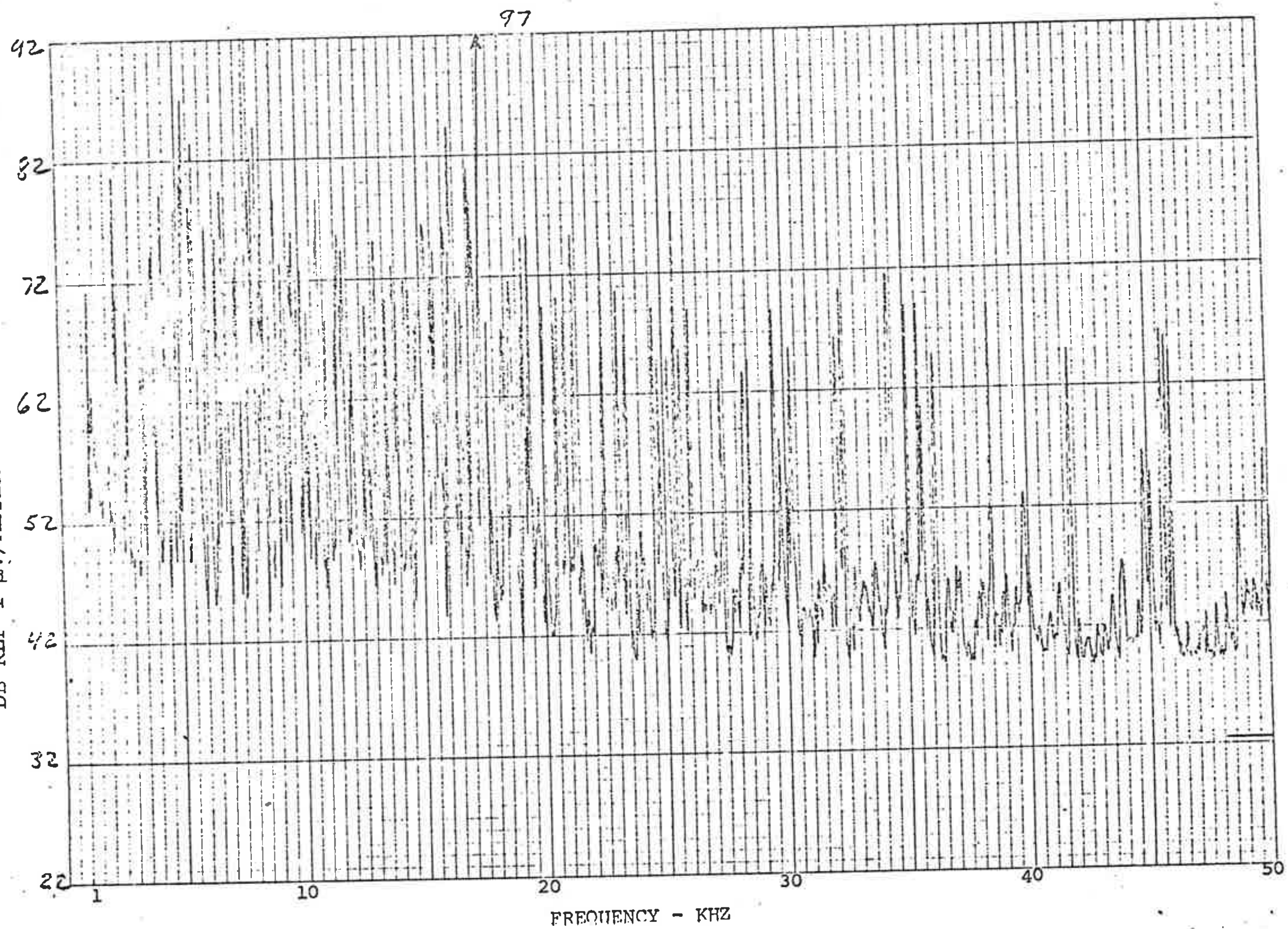


ESR E/W

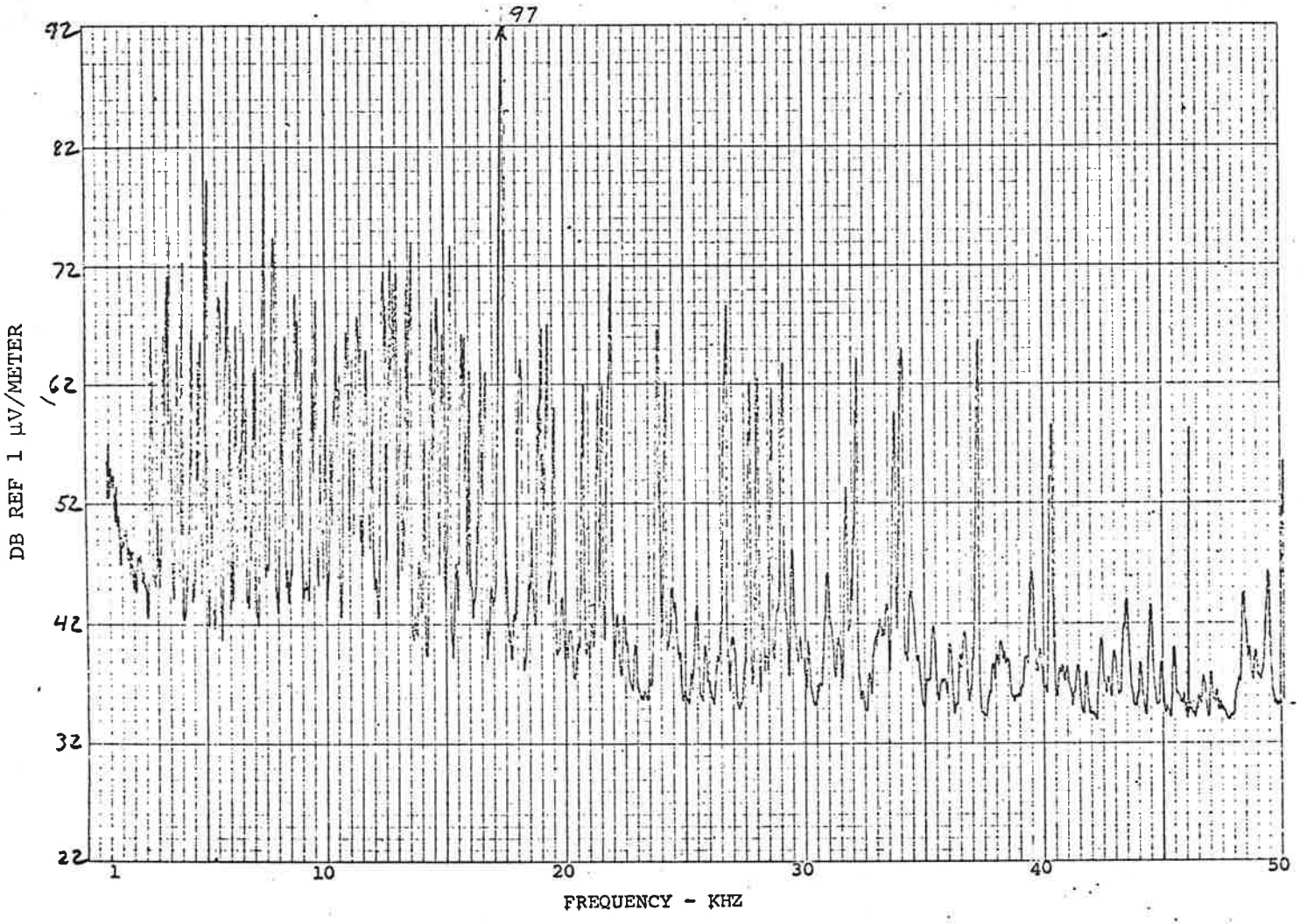
TEST NO. 39
TEST SPECIMEN SITE 1

TEST TYPE ESR E/W
TEST EQUIP. [illegible]

BANDWIDTH 50 HZ
DATE 29 FEB 72

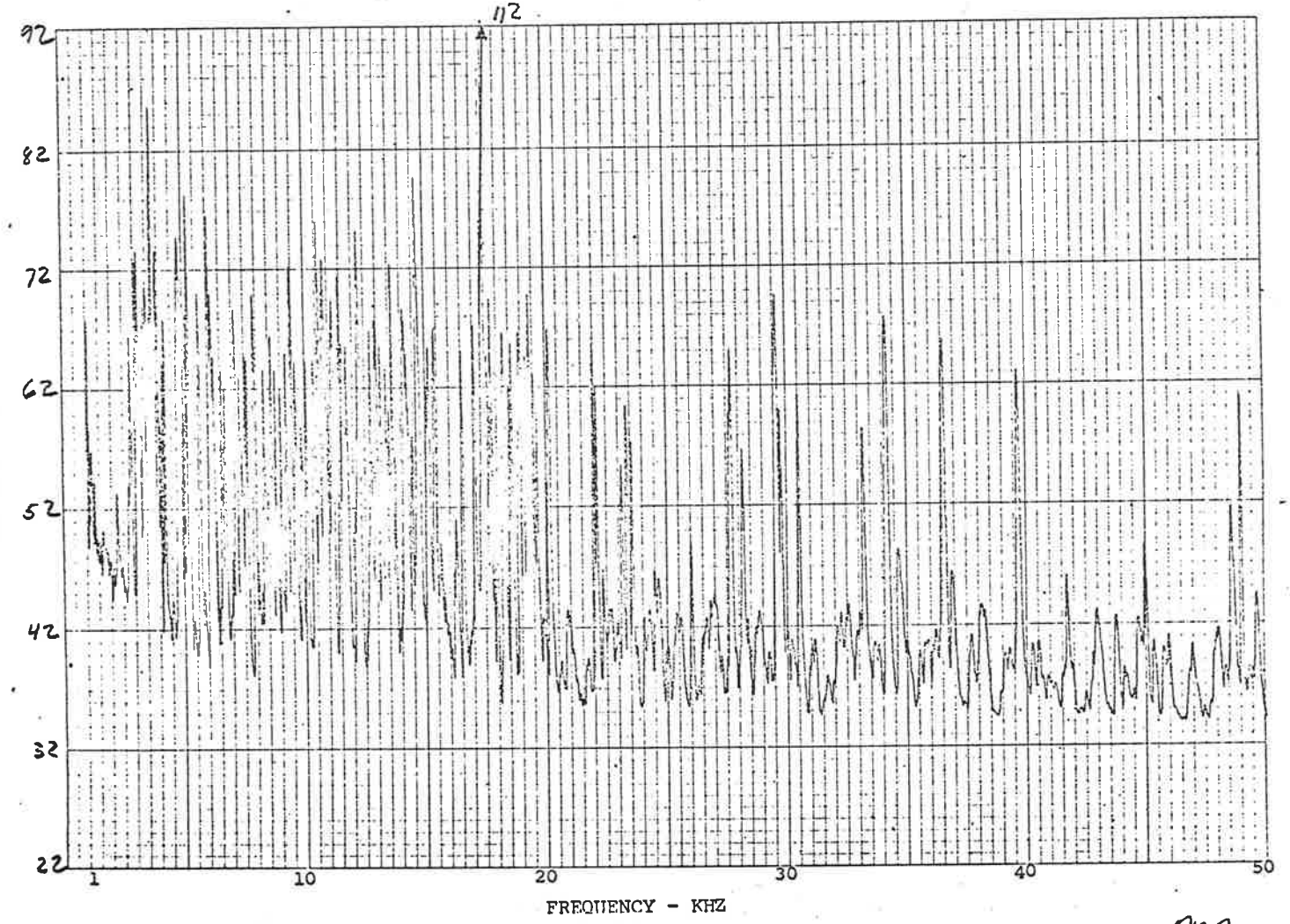


TEST NO. 40 TEST TYPE E-P N/S BANDWIDTH 50Hz
TEST SPECIMEN SITE 1 TEST EQUIP. EMC-10 DATE 29 FEB 72



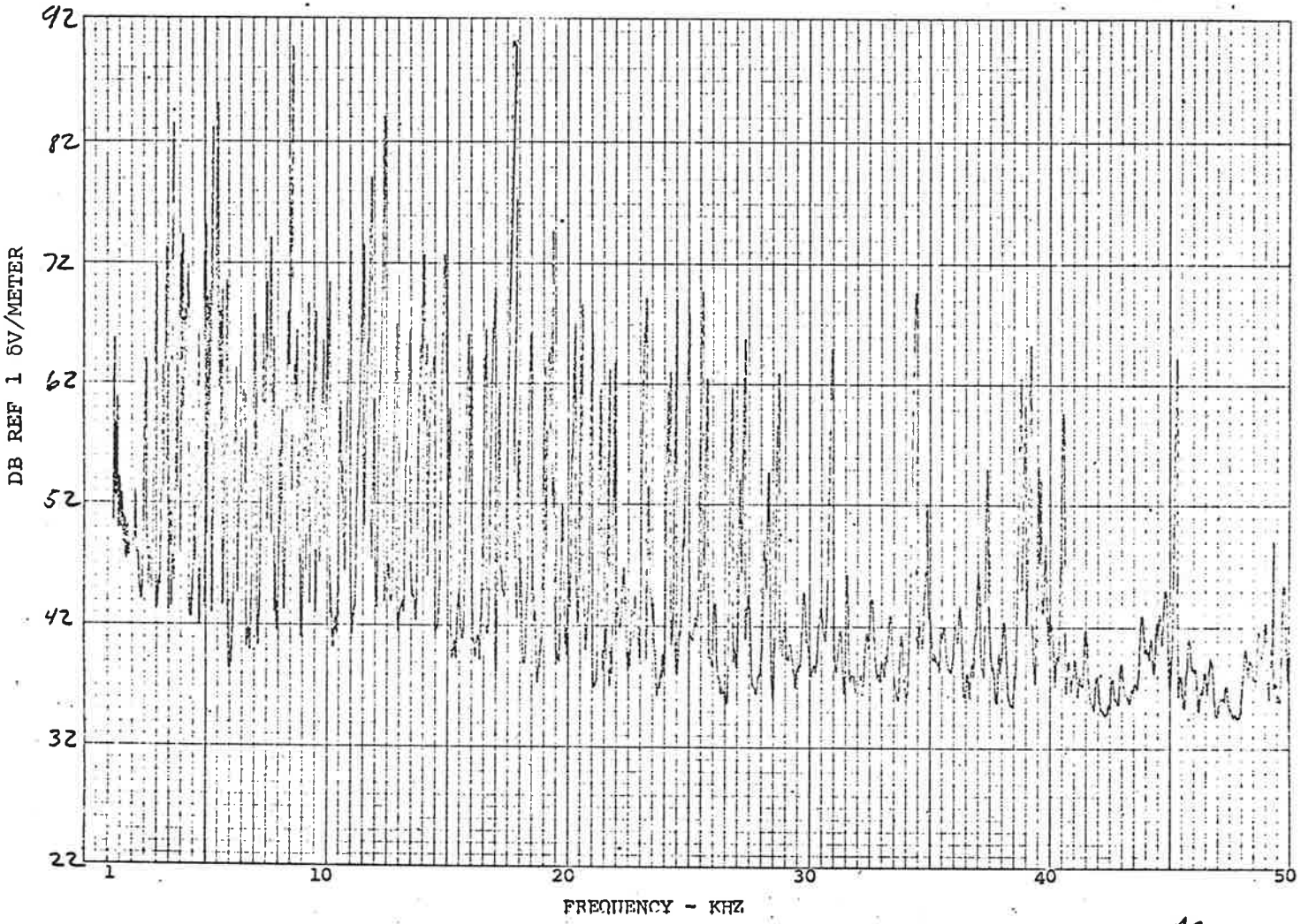
RBR EUS

TEST NO. 41 TEST TYPE ESR E/W BANDWIDTH 50 KC
TEST SPECIMEN SITE 2 TEST EQUIP. EMC-10 DATE 27 FEB 77

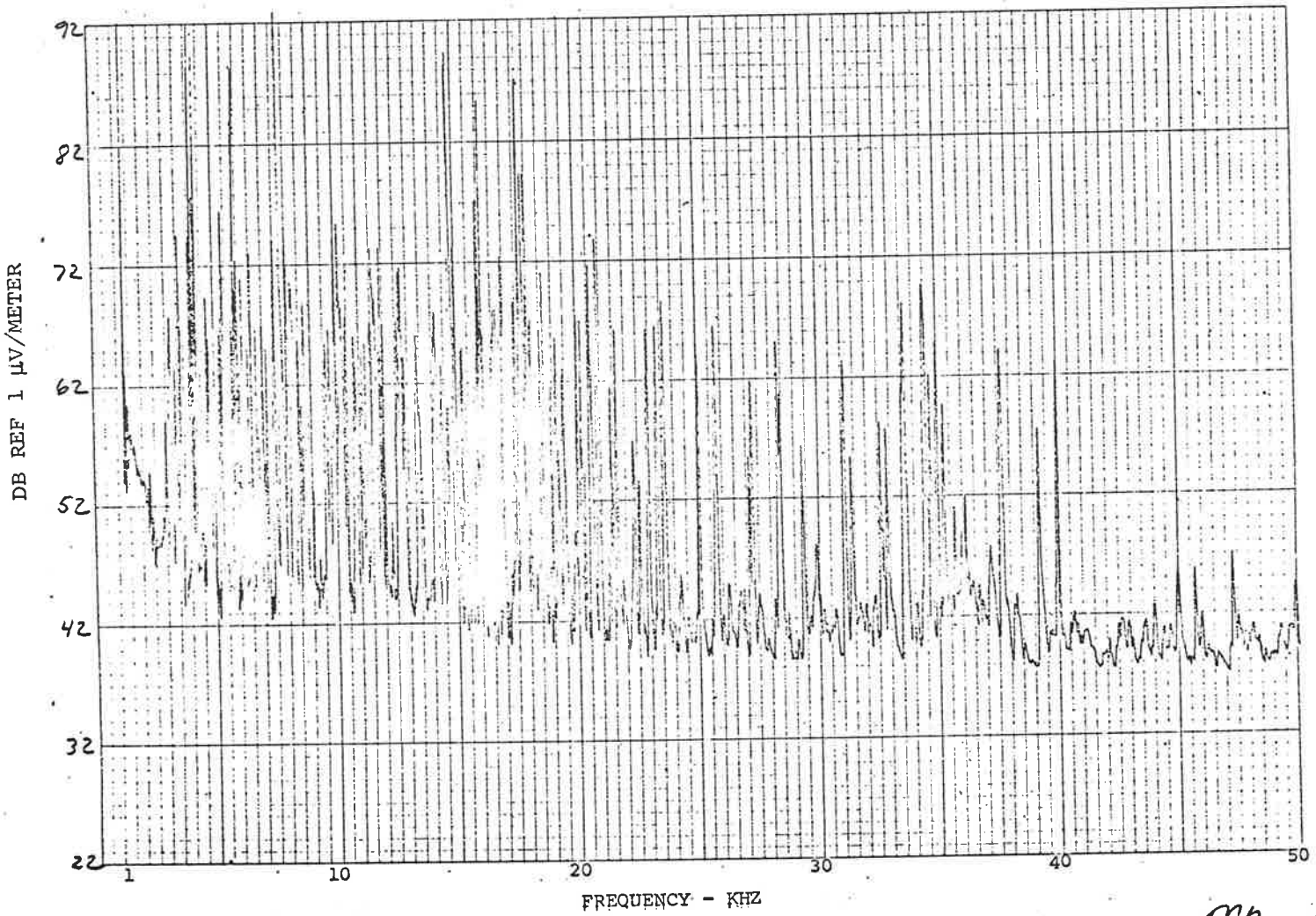


RBR 202

TEST NO. 42 TEST TYPE ESR N/S BANDWIDTH 50 H +
TEST SPECIMEN SITE 2 TEST EQUIP. EMC-10 DATE 29 FEB 72

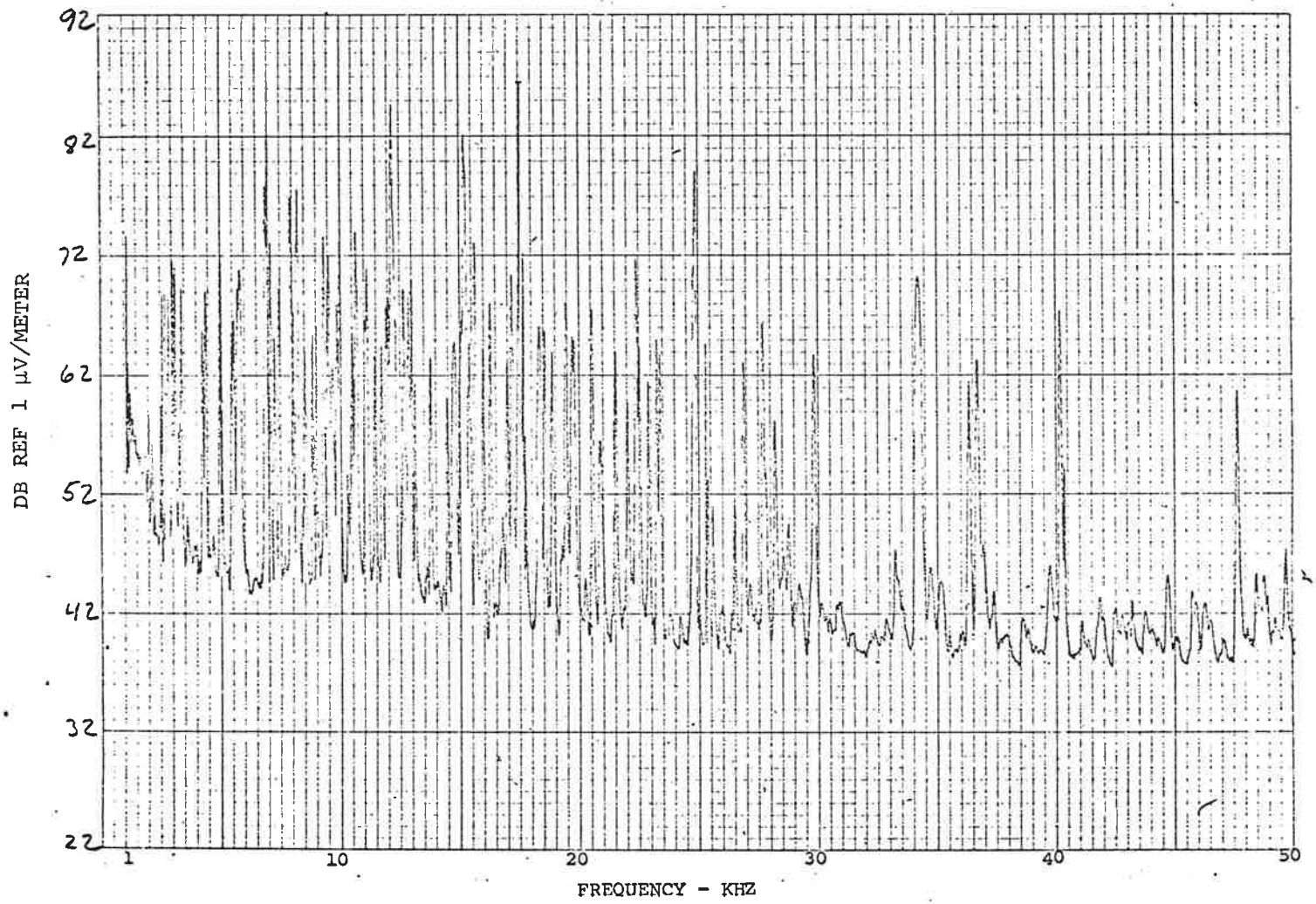


TEST NO. 43 TEST TYPE ESR N/S BANDWIDTH 50 Hz
TEST SPECIMEN SITE 3 TEST EQUIP. ENC-10 DATE 24 FEB 77



ESR 223

TEST NO. 44 TEST TYPE ESA E/U BANDWIDTH 50 Hz
TEST SPECIMEN Site 3 TEST EQUIP. EMC-10 DATE 29 FEB 72

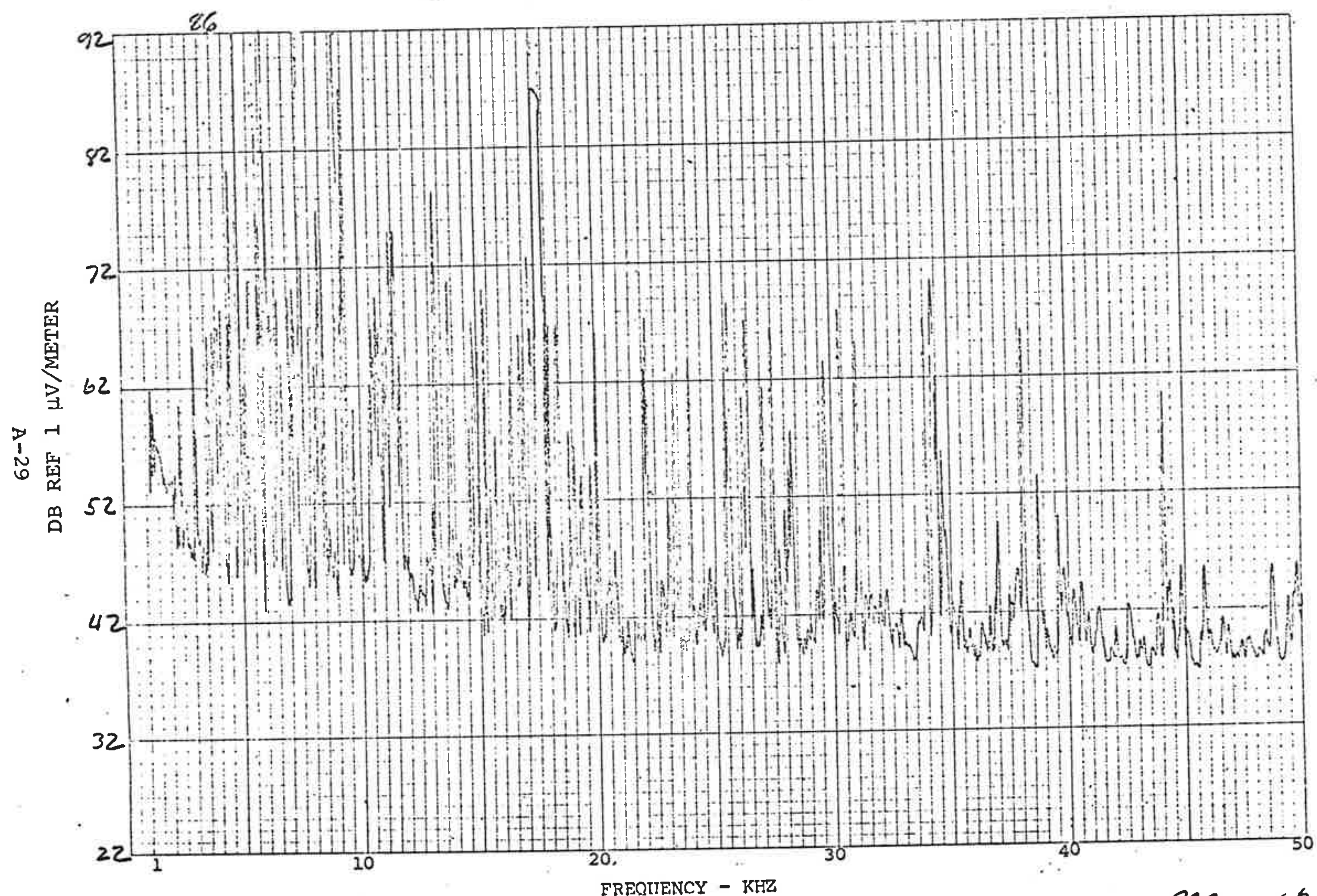


A-28

TEST NO. 45
TEST SPECIMEN 1S1TE4

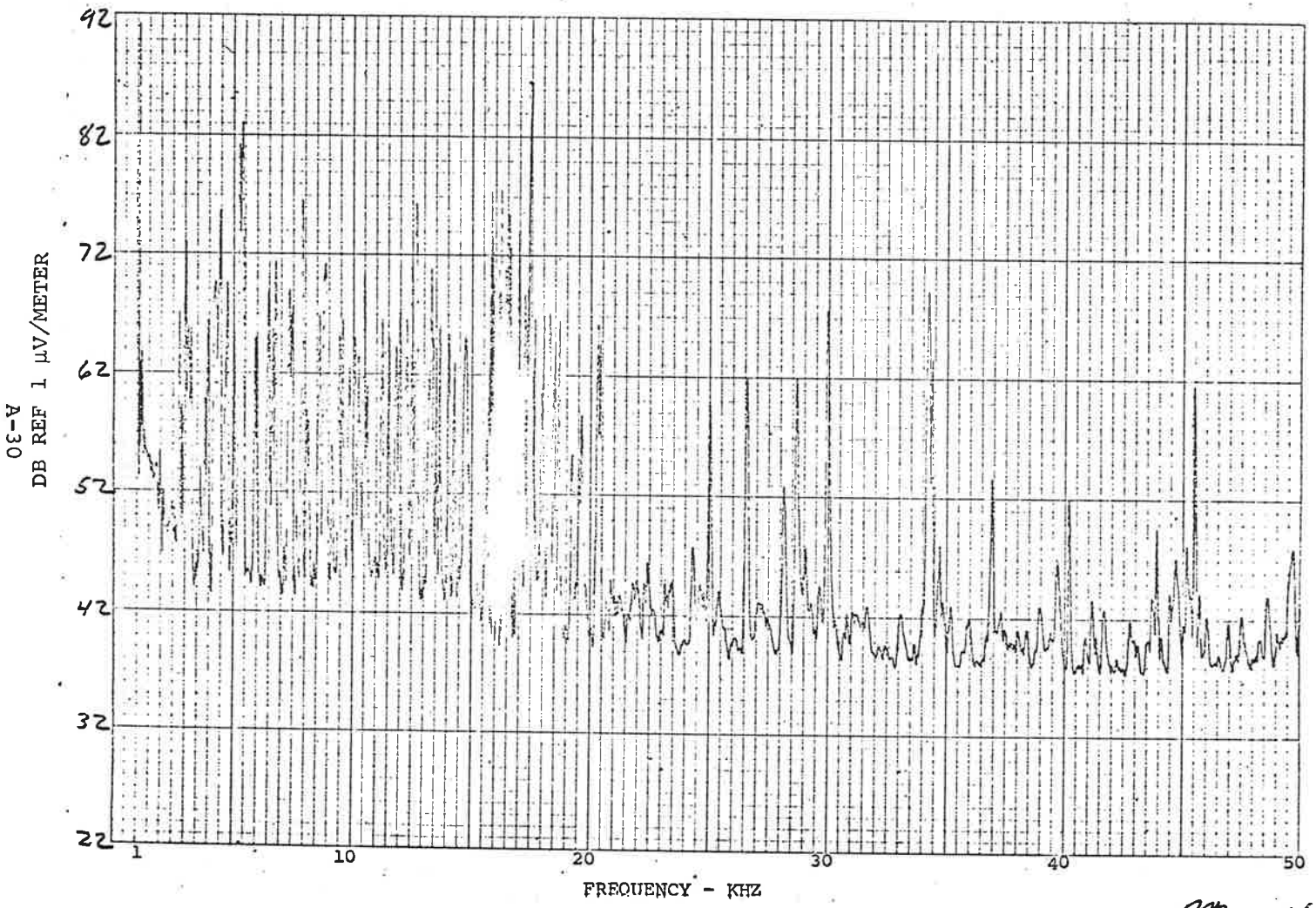
TEST TYPE ESR E/W
TEST EQUIP. EMC-10

BANDWIDTH 50 Hz
DATE 29 FEB 72



RBR 803

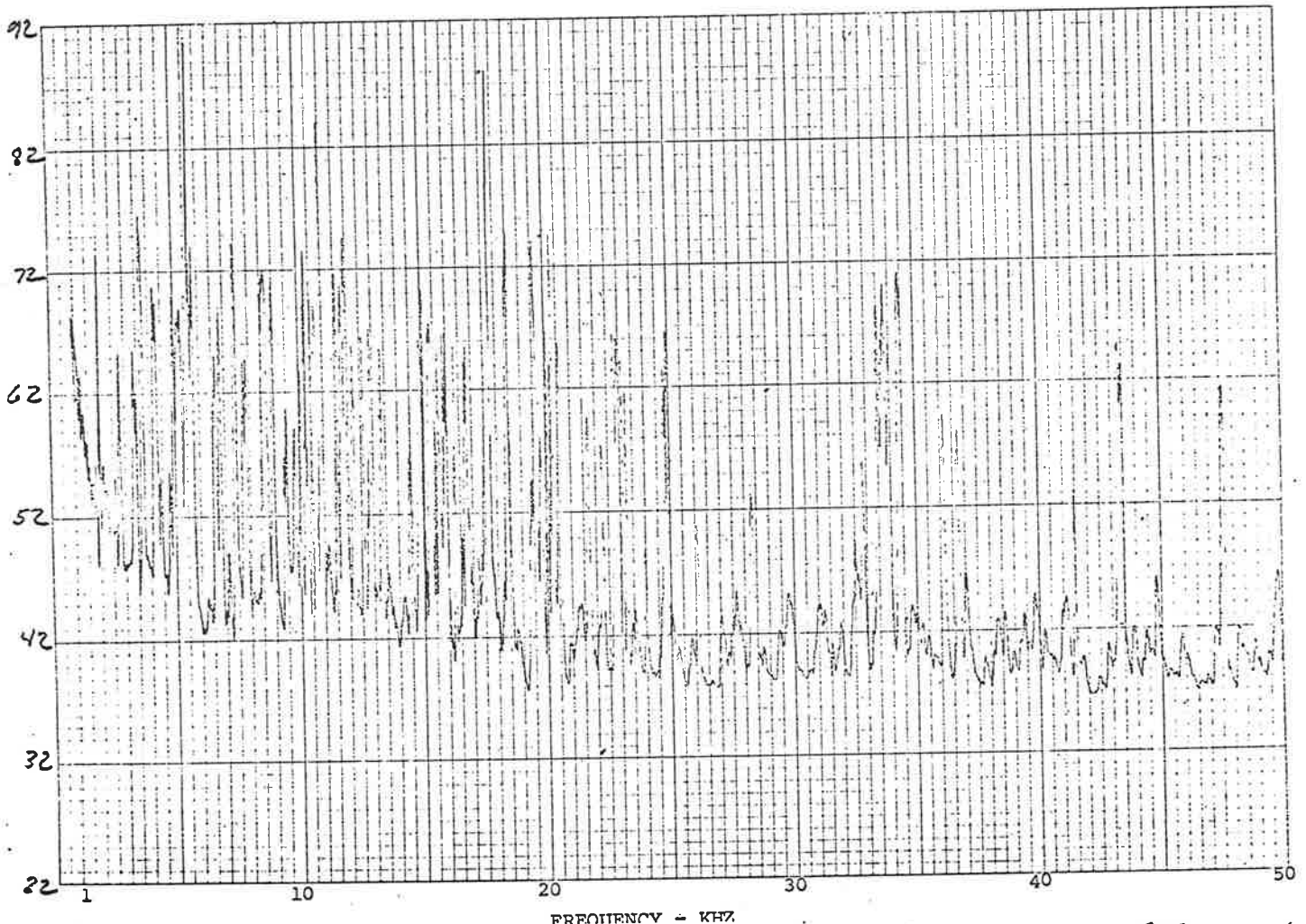
TEST NO. 46
TEST SPECIMEN Site 4
TEST TYPE ESR (N-S)
TEST EQUIP. EMC-10
BANDWIDTH 50Hz
DATE 27 FEB 72



A-30

RBR 6/73

TEST NO. 47 TEST TYPE ESR(E-W) BANDWIDTH 50 Hz
TEST SPECIMEN Site 5 TEST EQUIP. EMC-17 DATE 29 FEB 92

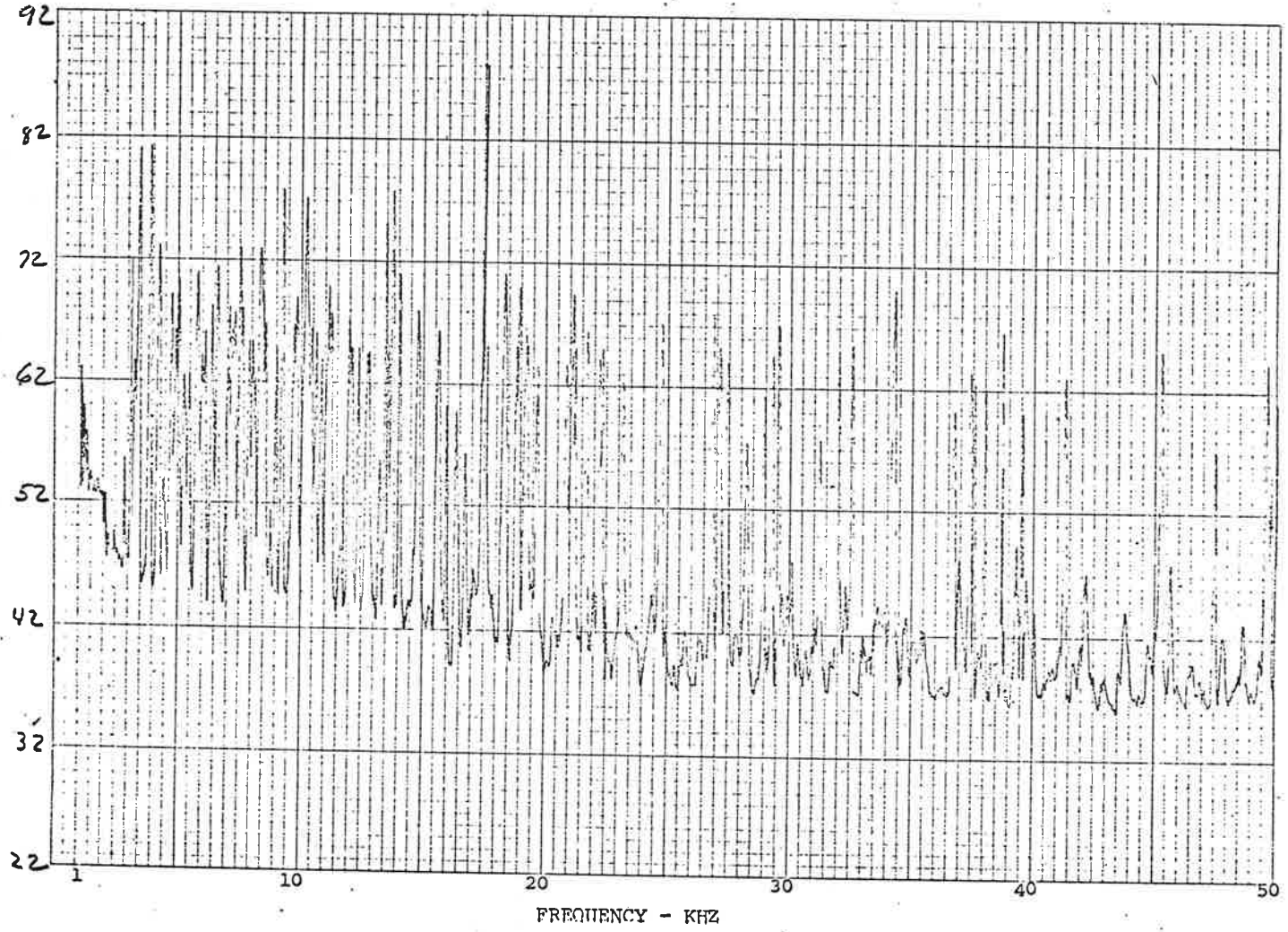


DB REF 1 µV/METER

A-31

KBR EVS

TEST NO. 48
TEST SPECIMEN SITE 5
TEST TYPE ESR (N-S)
TEST EQUIP. EMC-10
BANDWIDTH 50 Hz
DATE 28 FEB 77



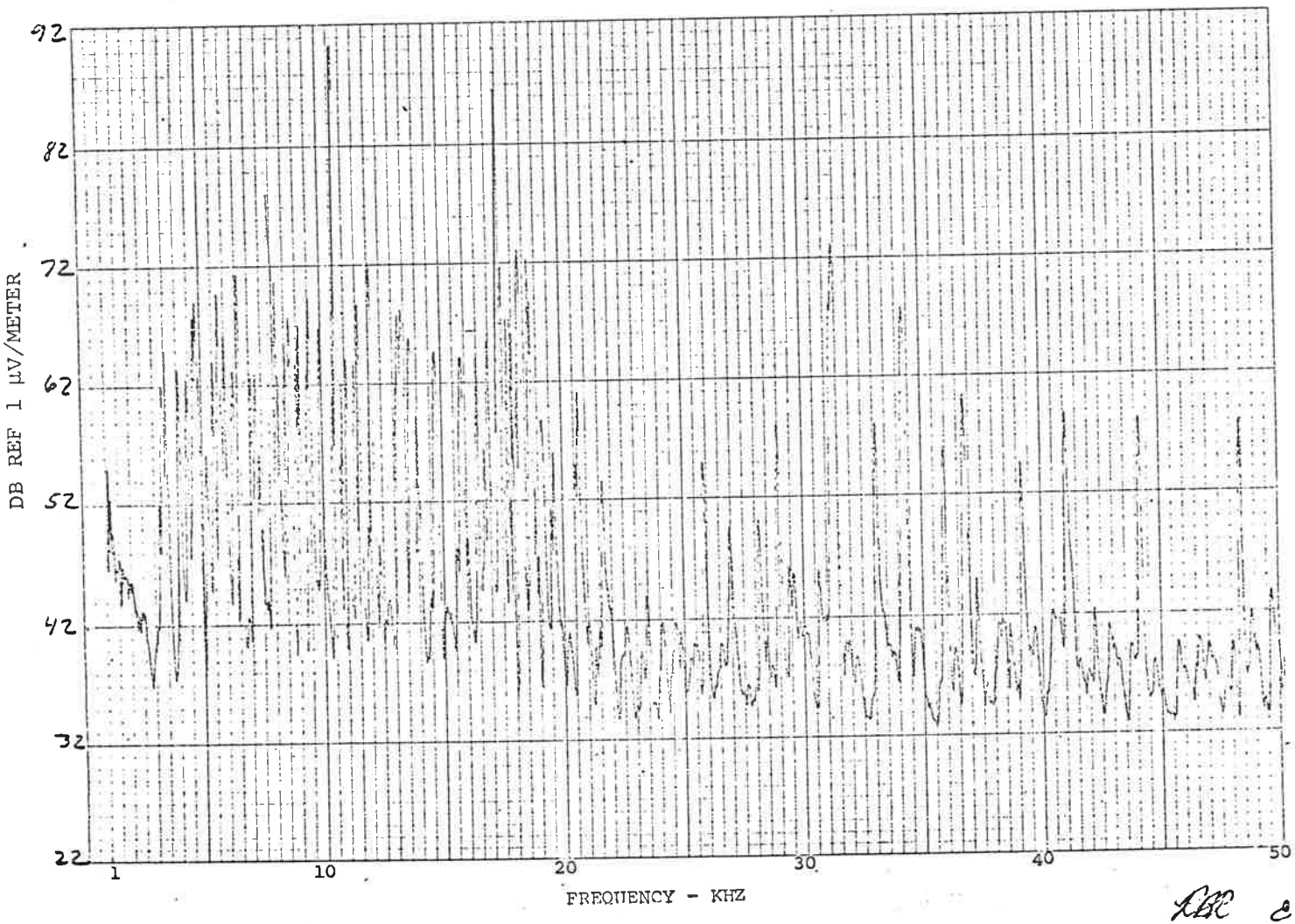
DB REF 1 μV/METER

A-32

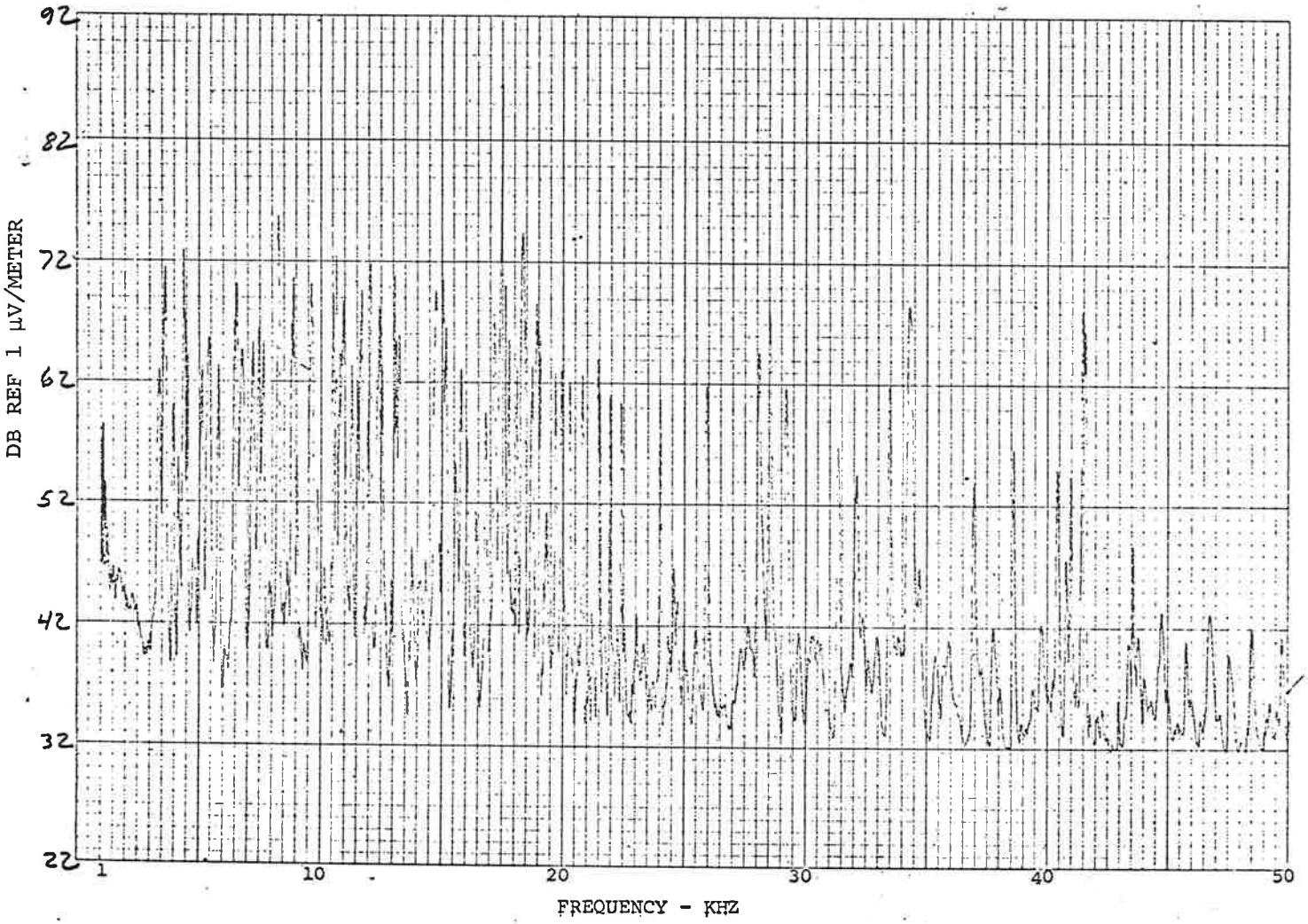
RBR 2 63

TEST NO. 49 TEST TYPE ESR (E-W) BANDWIDTH 50Hz

TEST SPECIMEN Site 6 TEST EQUIP. EMC-10 DATE 3 FEB 87

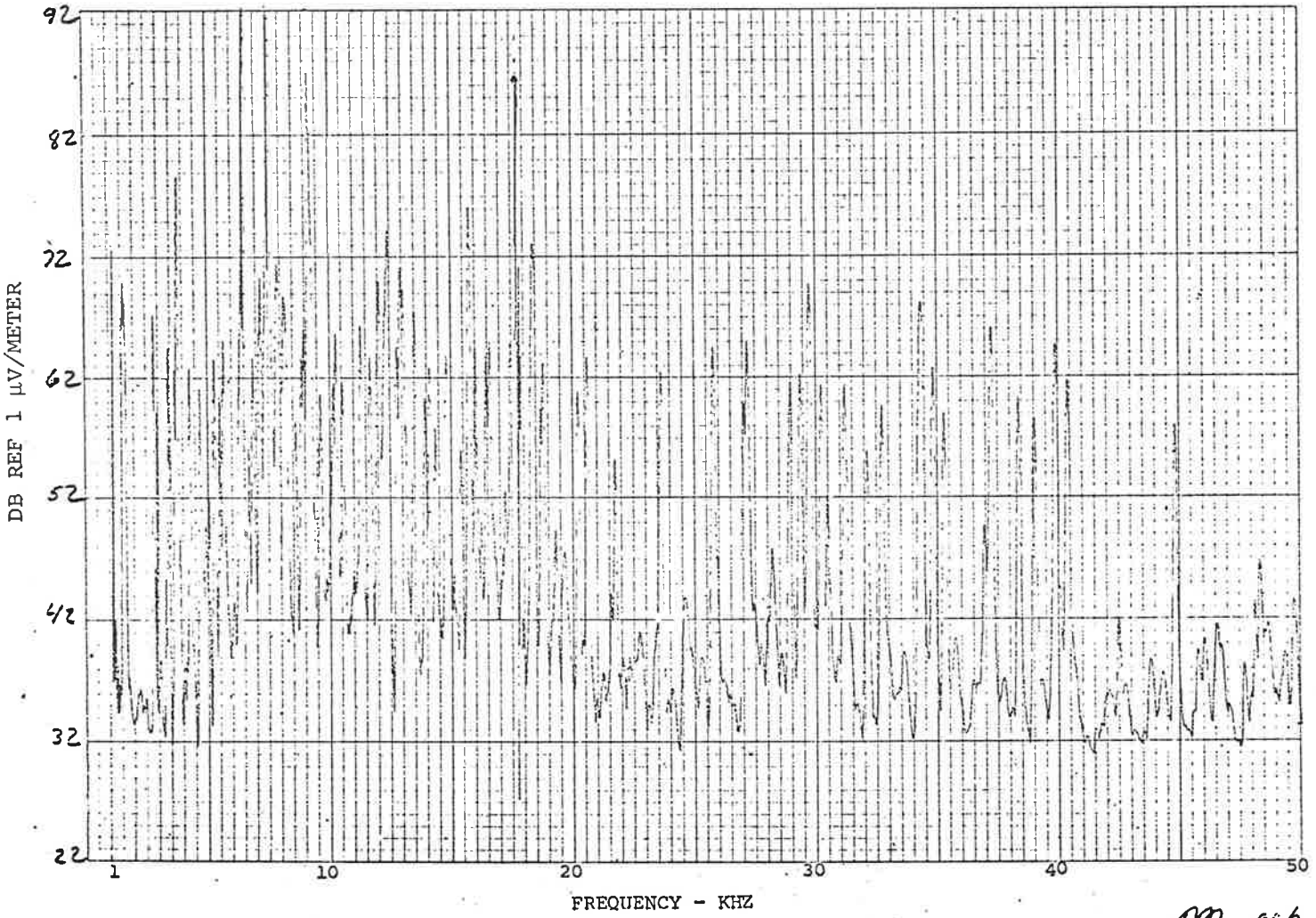


TEST NO. 50 TEST TYPE ESR (N-S) BANDWIDTH 50 HZ
TEST SPECIMEN SITE G TEST EQUIP. EMC-10 DATE 29 FEB 72



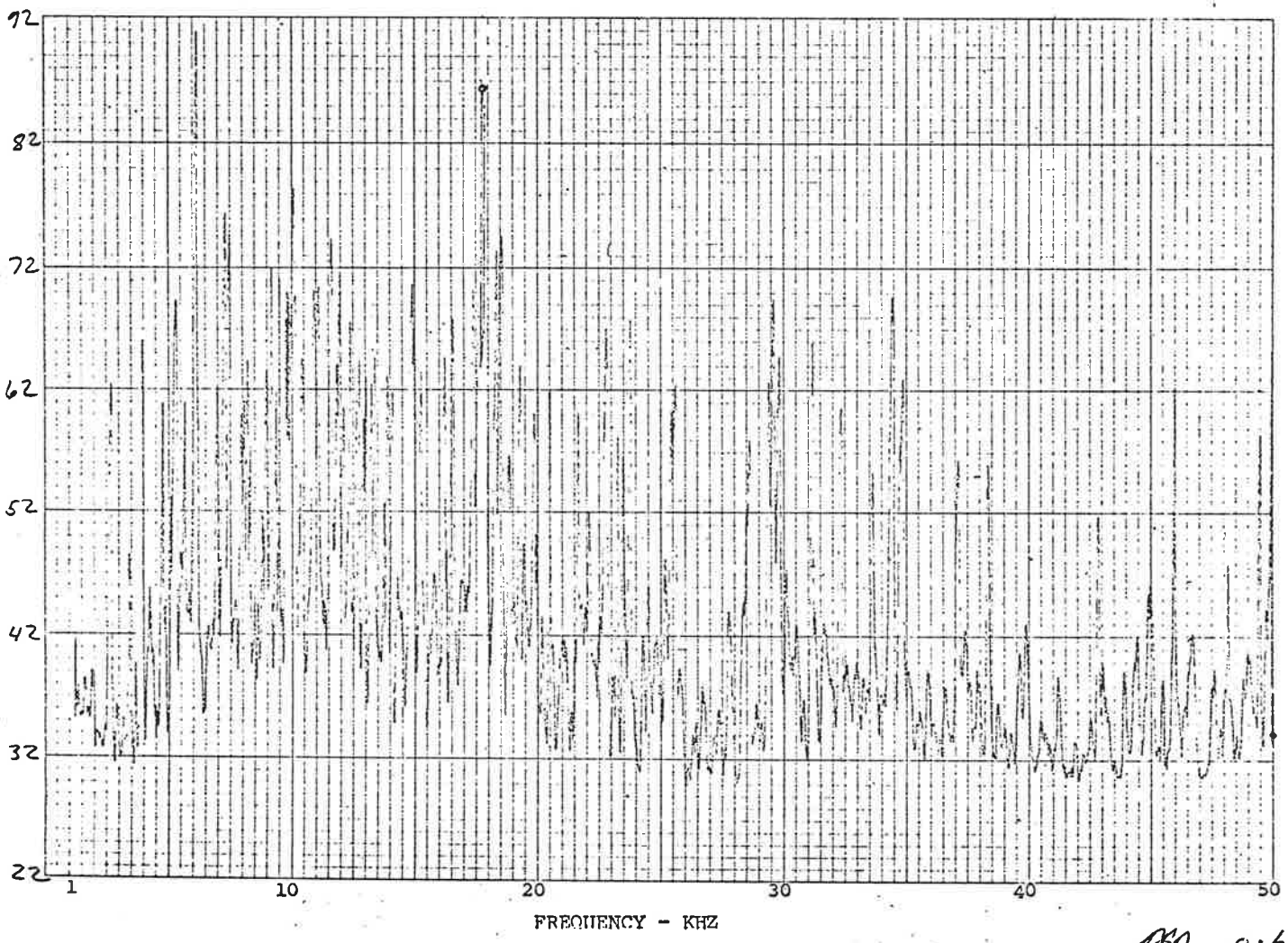
ESR EVR

TEST NO. 51 TEST TYPE ESR(E-W) BANDWIDTH 50 Hz
TEST SPECIMEN SITE 7 TEST EQUIP. EMC-10 DATE 29 FEB 72



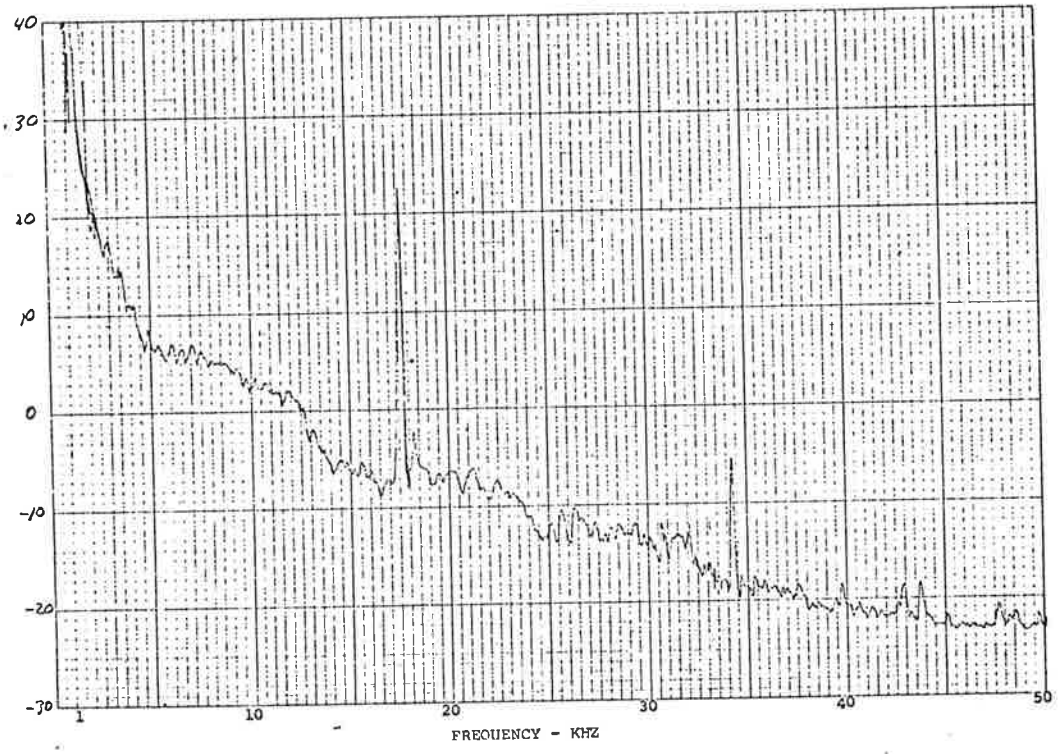
ER 6054

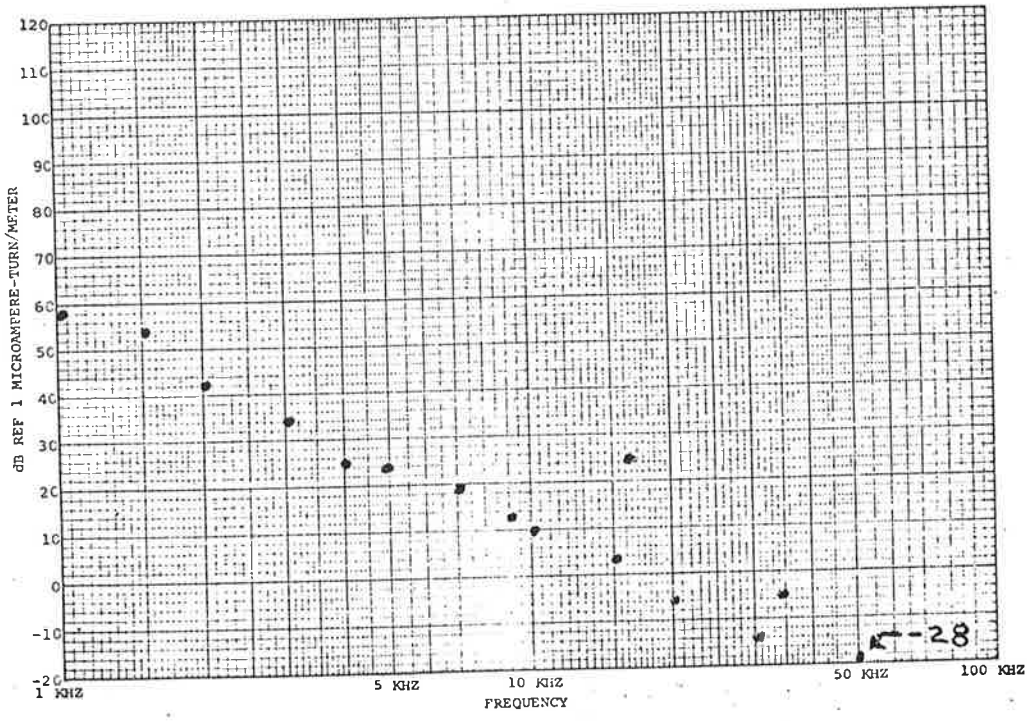
TEST NO. 52 TEST TYPE ESR (N-S) BANDWIDTH 50 Hz
TEST SPECIMEN Sys 7 TEST EQUIP. EMC-10 DATE 29 Feb 72



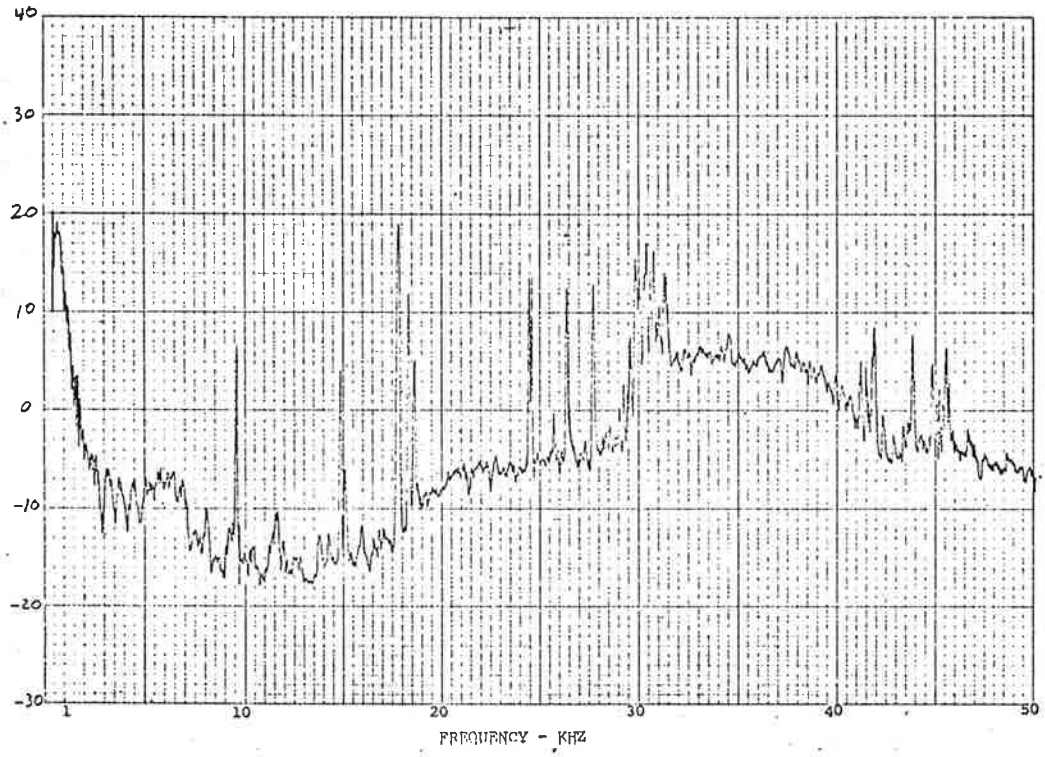
A-36

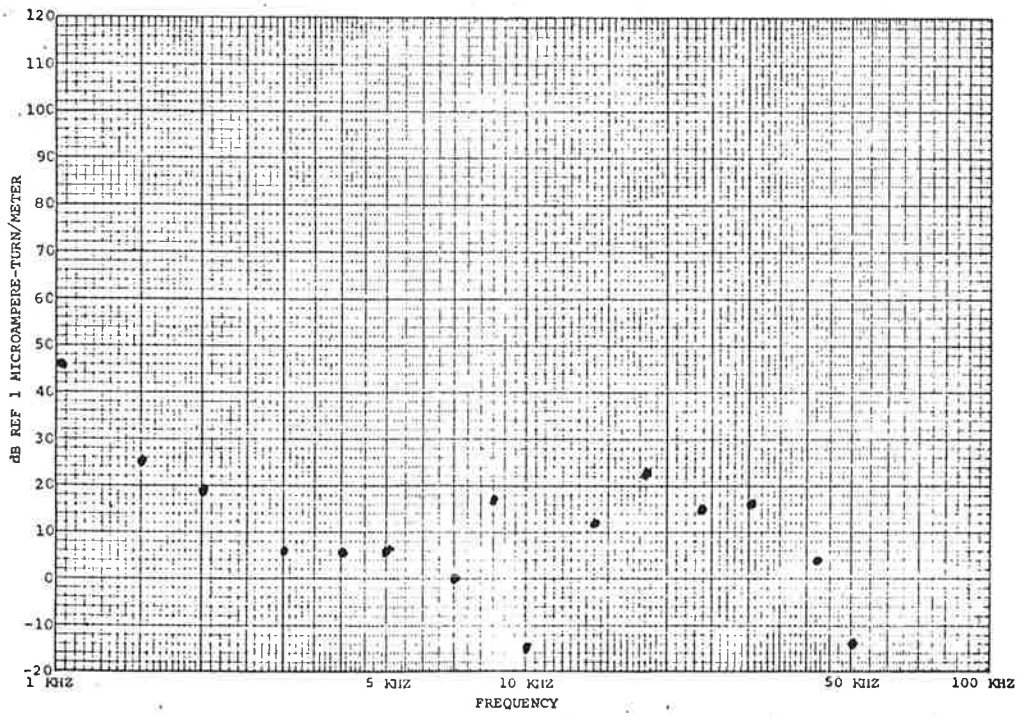
TEST NO. 57 TEST TYPE MSR (N-S) BANDWIDTH 50 Hz
TEST SPECIMEN SITE 1 TEST EQUIP. ENC-10 DATE 29 Feb 72





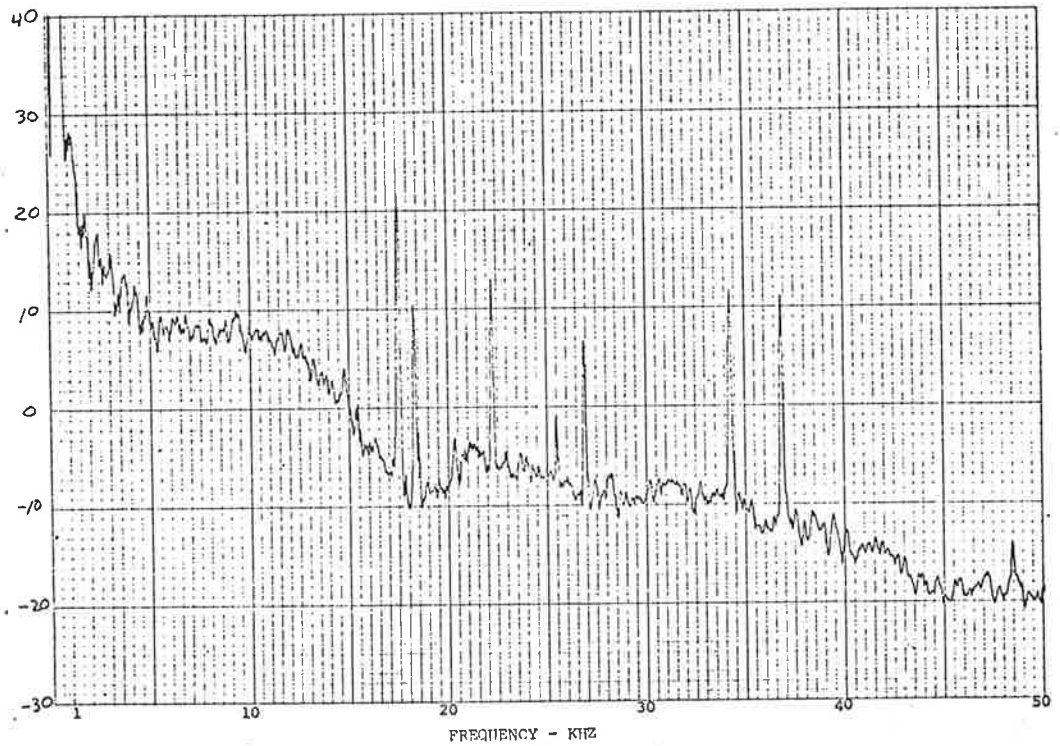
TEST NO. 53 TEST TYPE MSR (N-S) BANDWIDTH 50 HZ
TEST SPECIMEN SITE B TEST EQUIP. EMC-10 DATE 29 FEB 72

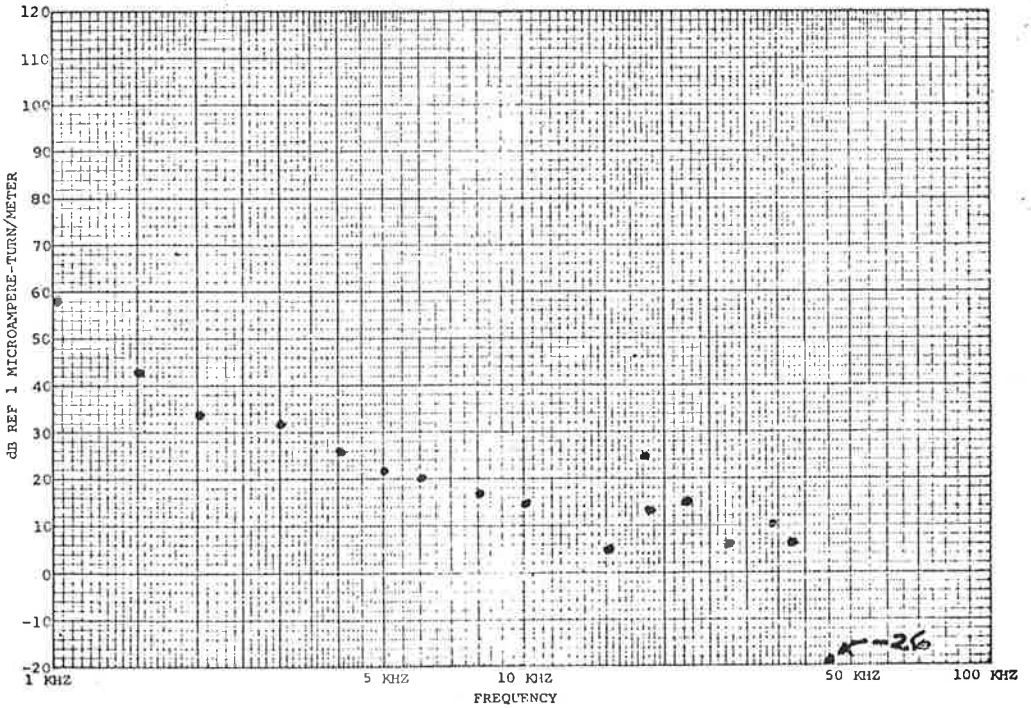




FSR EU7

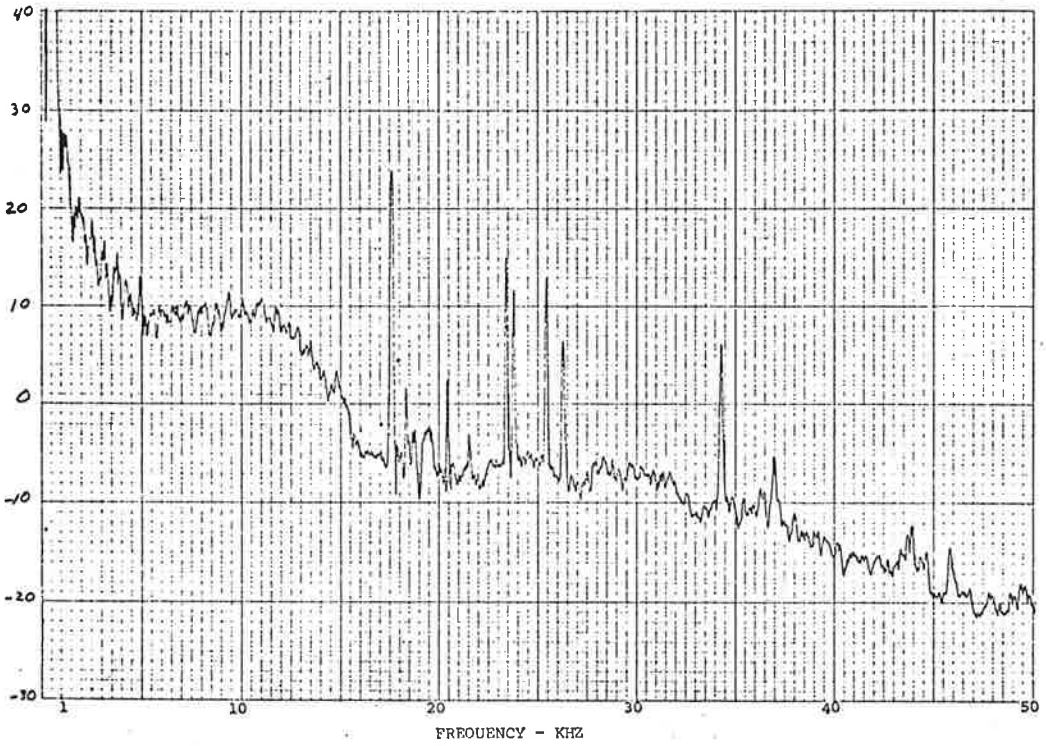
TEST NO. 54 TEST TYPE MSR (E-W) BANDWIDTH 50Hz
TEST SPECIMEN Site 9 TEST EQUIP. EMC-10 DATE 29 FEB 1972

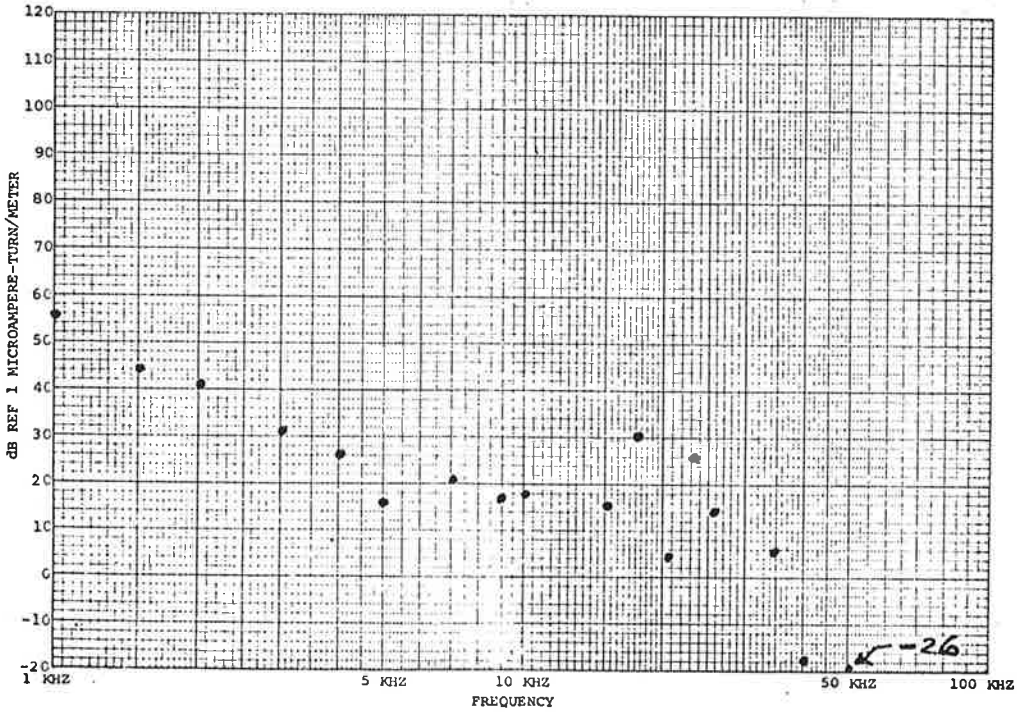




RFR EVA

TEST NO. 56 TEST TYPE NSR (E-W) BANDWIDTH 50 HZ
TEST SPECIMEN SITE 10 TEST EQUIP. EMC-10 DATE 24 FEB 72





RBR EWH