NTS

Test Report 60251-94N-2
Revision 2

No. of Pages 30

TEST REPORT
FOR
ANALYSIS OF EMI MAIN CONTROL ROOM MAPPING DATA AND GE NUMAC LDM (PART 1)

FOR

CAROLINA POWER AND LIGHT COMPANY
ONE HANOVER SQUARE BUILDING - 5B5
RALEIGH, NC 27601-1755

Contract No. XTA3000098

Prepared by: _______________ Date 7-July-93

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1.0 INTRODUCTION

1.1 Scope

This report (Part I) describes in detail the analytical methods and procedures used, and the results obtained therefrom, in analyzing the mapping data taken at the CP&L Brunswick Plant, Units #1 and #2, and comparing these data to the EMI susceptibility test data obtained during the testing on various General Electric NUMAC monitors. A second report (Part II) will be generated in the future which will describe in detail the analytical methods and procedures used and the results obtained in analyzing the mapping data taken at the CP&L Brunswick Station, Units #1 and #2, and comparing these data to the EMI emissions and susceptibility test data obtained during the testing performed on the General Electric NUMAC Leak Detection Monitor (LDM) monitors.

1.2 Purpose

The purpose of this analysis is threefold:

1) To establish the EMI environmental parameters of the point of installation area within Brunswick Plant Control Rooms, Units #1 and #2.

2) To establish the test criteria for conducted and radiated emission and susceptibility testing to be applied to the GE NUMAC LDM to ensure compatible operation within the intended electromagnetic environment; and

3) To compare the site electromagnetic profile measurement data to the presently available GE NUMAC equipment conducted and radiated susceptibility measurement data to predict the adequacy of the GE NUMAC LDM equipment for use within the measured environment.

2.0 APPLICABLE DOCUMENTS

IEC Standard 801-3	International Electrotechnical Commission IEC Standard, Edition 1, dated 1984
SAMA PMC33.1-1978	Electromagnetic Susceptibility of Process Control Instrumentation, Scientific Apparatus Makers Association
MIL-STD-461C	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, dated 4 August 1986
MIL-STD-462	Electromagnetic Interference Characteristics Measurement of, dated 31 July 1967
MIL-STD-463	Definitions and System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology.
MIL-STD-45662A	Calibration Systems Requirements dated 1 August 1988
DI-EMCS-80201	Electromagnetic Interference Test Plan
MIL-STD-1399 Section 070, Part 1	Interface Standard for Shipboard Systems, DC Magnetic Field Environment, dated 26 February 1979
	Code of Federal Regulations, Title 10, Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants, January 1988
	Code of Federal Regulations, Title 10, Part 21, Reporting of Defects and Noncompliance, as of January 1988
	NTS/Acton Quality Assurance Manual, Revision 3, dated 14 July 1992
IE Information No. 83-83	Use of Portable Radio Transmitters Inside Nuclear Plants
NTS Test Report No. 60251-94N-1	Test Report for Point of Installation for Electromagnetic Interference (EMI) Mapping of Control Rooms, Brunswick Station, Units #1 and #2

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2.0 APPLICABLE DOCUMENTS (continued)

CP&L Letter NLS-93-045	Completion of Response to NRC Request for Additional Information, Steam Leak Detection Instrumentation NUMAC Upgrade (NRC TAC Nos. M84686 and M84687) dated 2/8/93
NTS Test Procedure No. 60251-94N-1	Test Procedure for Point of Installation Electromagnetic Interference (EMI) Mapping of Control Rooms, Brunswick Plant, Units #1 and #2, dated 5/6/93
NTS Test Procedure No. 60251-94N-2	Test Procedure for Analysis of EMI Main Control Room Mapping Data, dated 5/6/93.
General Electric Report	EMI Analysis, NUMAC Leak Detector Monitor, dated January 1993.
	Reference Data for Radio Engineers, 4th Edition

3.0 REQUIREMENTS

The requirements of this analysis are threefold:

1) Establish the EMI environmental parameters of the point of installation area within the Brunswick Plant, Control Rooms, Unit #1 and #2,

2) Establish the test criteria for conducted and radiated emissions and susceptibilities to be applied to the GE NUMAC LDM to ensure compatible operation within the intended electromagnetic environment; and

3) Compare the site electromagnetic profile measurement data to the presently available GE NUMAC equipment conducted and radiated susceptibility measurement data to predict the adequacy of the GE NUMAC LDM equipment for use within the measured environment.

4.0 ANALYSIS

4.1 General

4.1.1 Prime Power Source Impedance

The data taken during the site survey of the Brunswick Plant, Units 1 and 2, does not allow for directly calculating the source impedance of the prime power source feeding the equipments in Units 1 and 2. Therefore, and engineering estimate of the source impedance in question was made based upon past experience with such sources. Figure 4-1 shows the estimated source impedance, in dB relative to 50 ohms. In addition, the impedance of the 10 μF Line Impedance Stabilization Capacitors, used during the laboratory EMI testing, is plotted. The sum of these two curves from the correction factor to be used to normalize the site survey conducted emission data to the laboratory EMI test data. This correction factor is also plotted on Figure 4-1. Normalizing this data is necessary to facilitate comparisons between the site emissions data and the laboratory tested equipment susceptibility levels.

4.1.2 Narrowband vs. Broadband

An analysis has been performed to determine if the broadband conducted and radiated emission data taken during the site survey of the Brunswick Plant, Units 1 and 2, is of sufficient magnitude to effect the compatibility analysis.

A comparison of the narrowband and broadband spectra, generated by a typical digital data pulse stream, has been performed to determine the magnitude of the difference between the numerical values of amplitude (dBuA vs. dBuA/MHz and dBuV vs. DBuV/MHZ) associated with the narrowband and broadband spectra.

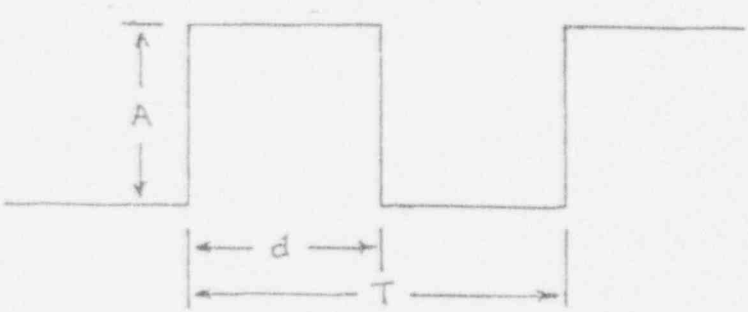
4.0 ANALYSIS (continued)

4.1 General (continued)

4.1.2 Narrowband vs. Broadband (continued)

If the numerical value of the difference between the composite narrowband and broadband spectra, as measured during the site survey tests, is less than the numerical difference between the narrowband and broadband spectra from the typical data pulse stream then the broadband test data can be ignored as it would theoretically have been generated by a data pulse stream whose amplitude would be lower than that which generated the narrowband data.

The following data pulse stream has been selected as the typical data pulse stream. Any other data pulse stream would generate similar results.



Where: $A = 1$ Volt
$d = 1$ millisecond
$T = 2$ milliseconds

The narrowband spectra for this pulse train is given by:

$$C_{nb} = 20 \log \left[\frac{2Ad}{T} \left| \frac{\sin n\pi d/T}{n\pi d/T} \right| \right] + 120 \text{ (dB}\mu\text{A or dB}\mu\text{V)}$$

(Equation derived from equation found in Reference Data for Radio Engineers, 4th Edition, Page 1019.)

4.0 ANALYSIS (continued)

4.1 General (continued)

4.1.2 Narrowband vs. Broadband (continued)

and the broadband spectra is given by:

$$C_{bb} = 20 \log (2Ad) + 240 \text{ (dBuA/MHz or dBuV/MHz)}$$

(Equation derived from above equation.)

Figure 4-2 shows the spectral envelopes for both the narrowband and broadband spectra of this typical data pulse stream. As can be seen from Figure 4-2, the same data pulse stream yields narrowband and broadband spectra whose numerical amplitude difference is approximately 70 dB. Therefore, if the differences between the narrowband and broad band data obtained during the site survey tests is less than 70 dB, then the broadband data can be ignored.

Figures 4-3 through 4-9 show the composite worst case envelopes for the site survey taken at the Brunswick Plant, Units 1 and 2. It can be seen by comparing the narrowband and broadband data taken for RE02 that the amplitude differences are less than 70 dB and therefore, the broadband data may be ignored. Comparing the narrowband and broadband data for CE03 shows the numerical amplitude difference to exceed the 70 dB criteria at all frequencies between 15 kHz and 100 kHz. The analytical treatment of this exceedance is discussed in detail in Section 4.2.1.1.

4.2 Brunswick Plant, Units 1 & 2, Electromagnetic Environment

The electromagnetic environment presently existing at the Brunswick Plant, Units 1 and 2, is shown on Figures 4-3 through 4-9.

4.0 ANALYSIS (continued)

4.2 Brunswick Plant, Units 1 & 2, Electromagnetic Environment (continued)

Emissions (conducted and radiated) were measured during the site survey testing at the Brunswick Plant, Units 1 and 2. These data will be used to : 1) quantify the on site electromagnetic environment, and 2) generate proposed limits to be employed during the laboratory EMI testing of the GE NUMAC LDM. In addition, where limited susceptibility testing has been performed on the GE NUMAC (not necessarily in the LDM configuration), these data will be compared to the NUMAC susceptibility data to make an analytical assessment of the NUMAC's suitability for employment in the Brunswick Plant, Units #1 and #2.

4.2.1 Power Line Conducted Emission Environment

4.2.1.1 Frequency Domain Environment

A comparison of the narrowband and broadband data for CE03 shows the numerical amplitude difference to be greater than 70 dB at all frequencies between 15 kHz and 100 kHz. An inverse Fourier Transform was performed on the CE03 broadband worst case envelope to predict the waveshape of the digital data pulse stream that, theoretically, would have created this envelope. A Fourier Transform was then performed on this theoretical digital data pulse stream to develop the narrowband spectra associated with such a digital data pulse stream. This theoretical narrowband spectra was then combined with the other narrowband spectra to complete the narrowband worst case spectra envelope.

The frequency domain power line conducted emissions environment is shown of Figures 4-3, 4-4, and 4-5 for the Brunswick Plant, Units 1 and 2 site survey data.

4.0 ANALYSIS (continued)

4.2 Brunswick Plant, Units 1 & 2, Electromagnetic Environment (continued)

4.2.1 Power Line Conducted Emission Environment (continued)

4.2.1.2 Time Domain Environment

Conducted transients were measured during the site survey testing at the Brunswick Plant, Units 1 and 2. The conducted transient time domain data was converted to the frequency domain and the resultant is plotted on Figure 4-6. The envelope of the time domain is equal to or lower than the frequency domain data, and therefore the time domain data will be disregarded in the generation of the proposed conducted emission limits.

4.2.2 Radiated Emission Environment

4.2.2.1 Magnetic Field Emission Environment

The on site magnetic field emission environment is shown on Figure 4-7.

4.2.2.2 Electric Field Emission Environment

The on site electric field emission environment is shown on Figures 4-8 through 4-9.

4.3 Proposed GE NUMAC LDM EMI Test Limits

Proposed limits for conducted and radiated emissions, to be applicable to the GE NUMAC LDM, have been generated based upon the measured site conducted and radiated emission environment. In order to ensure that the addition of the GE NUMAC LDM into the on site environment will not adversely impact the present environment, the proposed limits have been quantified by subtracting 6 dB from the site environment data. This 6 dB subtraction will assure that in the worst case (coherent addition of signals) the site

4.0 ANALYSIS (continued)

4.3 Proposed GE NUMAC LDM EMI Test Limits (continued)

environment will not be increased by the addition of the GE NUMAC LDM. Figures 4-10 through 4-15 show the proposed conducted and radiated emission limits for the GE NUMAC LDM.

Proposed conducted and radiated susceptibility limits, to be applicable to the GE NUMAC LDM, have been generated in a two step process. The first step involved adding 6 dB (to ensure a 6 dB safety margin) to the site narrowband conducted and radiated composite worst case spectra envelopes. This resulted in susceptibility signal levels which, although ensuring the 6 dB safety margin, would be cumbersome to implement in a test program due to the continually changing amplitude requirement across the entire test frequency ranges. Therefore, a second step was introduced whereby the signal levels arrived at in Step 1 were compared to the susceptibility signal levels of MIL-STD-461C and found to be below the signal levels required by MIL-STD-461C over most of the test frequency ranges. Where the Step 1 signal levels exceeded the requirements of MIL-STD-461C, the limits of MIL-STD-461C were adjusted to achieve at least the minimum 6 dB safety margin. The conducted and radiated susceptibility limits, thus developed, are as follows:

Conducted Susceptibility

CS01	30 Hz to 15 kHz	5 Volts
CS02	15 kHz to 50 MHz	1 Volt

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4.0 ANALYSIS (continued)

4.3 Proposed GE NUMAC LDM EMI Test Limits (continued)

Magnetic Field Radiated Susceptibility

RS01 30 Hz to 50 kHz 144 dBpT

Electric Field Radiated Susceptibility

RS03 14 kHz to 1 GHz 1V/m

4.4 Susceptibility Analysis

4.4.1 Power Line Conducted Susceptibility

The following conducted susceptibility tests were performed on the GE NUMAC equipment:

> Conducted susceptibility tests as performed for the radiated magnetic field tests (LRM, SRM, WRNM, DCWRM, RBVRM) and 3 KV pulses capacitively coupled to the power and I/O ports at power, ± 2 to 4 KV sawtooth transients (up to 50 nsec.) applied to power and signal I/O ports at power and a 0.5 -1 KV damped 1 MHz sinusoid at a repetition rate of 300-500 Hz applied to power and a signal I/O port at power (WRNM).

A Fourier Transform Analysis was performed on the above described signals to develop the amplitude vs. frequency characteristics of each applied signal. The worst case composite of the amplitude vs. frequency characteristics, thus developed, forms the basis of the conducted susceptibility analysis.

Figure 4-16 shows the power line conducted susceptibility analysis. Plotted on Figure 4-16 are the applied susceptibility signal spectra in terms of dBuA so as to be directly comparable to the conducted emission data. The susceptibility signal spectra represent the signal levels injected into the GE NUMAC (not in the LDM configuration) via its power

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4.0 ANALYSIS (continued)

4.4 Susceptibility Analysis (continued)

4.4.1 Power Line Conducted Susceptibility (continued)

lines (Reference GE EMI Analysis Report, dated January 1993). Also plotted on this figure is the power line conducted emission data measured during the site survey tests at Brunswick Plant, Units 1 and 2. It can be seen from the data presented on Figure 4-16 that the composite of the spectra from the susceptibility signals injected into the GE NUMAC equipment, via its prime power lines, is at least 7 dB greater than the emissions found on the site prime power lines. This shows that the GE NUMAC will not be susceptible to noise existing on the site prime power lines with at least a 7 dB safety margin.

The conducted susceptibility tests previously performed by GE on the NUMAC equipment is much more rigorous than the recommended CS01 testing (30 Hz to 15 kHz). With respect to the higher frequency range (above 15 kHz) the recommended CS02 test levels are more rigorous than the testing previously performed by GE. The rationale for recommending a more rigorous requirement over this frequency range is twofold:

1. To allow for an increase in the safety margin from 7 dB to a larger safety margin, and

2. To impose a standard (MIL-STD-461C, Test Method CS02) which is universally recognized and easy to implement.

4.4.2 Magnetic Field Radiated Susceptibility

The following magnetic field radiated susceptibility tests were performed on the GE NUMAC equipment:

4.0 ANALYSIS (continued)

4.4 Susceptibility Analysis (continued)

4.4.2 Magnetic Field Radiated Susceptibility (continued)

Continuous-wave radiated magnetic field susceptibility tests with 300V oscillations at 0.5-1 Hz repetition rates with damped oscillations of 6-7 Hz at 100, 200, 300, 400 and 500 kHz and with 5V oscillations from 0.5 -100 MHz at a rate of 1-5 MHz/sec. (LRM, SRM, WRNM, DCWRM, RBVRM).

Figure 4-17 shows the magnetic field radiated susceptibility (Reference GE EMI Analysis Report, dated January 1993). The radiated magnetic field susceptibility tests performed on the GE NUMAC equipment did not cover the same frequency range as the magnetic field emission testing at the site. This does not pose a problem in that the magnetic field emissions measured on site are extremely low, approaching normal background ambient noise. The existing on site equipment or the GE NUMAC equipment will not be adversely affected by the introduction of the GE NUMAC into the on site system.

The magnetic field radiated susceptibility tests previously performed by GE on the NUMAC equipment are much more rigorous than the RS01 testing recommended in Section 4.3. Although the frequency range of coverage of the previously performed GE tests is above the frequency range of the recommended test, compliance with the applied signal levels at these higher frequencies will ensure with a high degree of confidence compliance with the recommended RS01 test levels.

4.0 ANALYSIS (continued)

4.4 Susceptibility Analysis (continued)

4.4.3 Electric Field Susceptibility

The following electric field radiated susceptibility tests were performed on the GE NUMAC equipment:

> Continuous-wave radiated electric field susceptibility tests at 65 V/m from 20-990 MHz (RBVRM) and at 10 V/m from 27-500 MHz (WRNM).

Figure 4-18 shows the electric field radiated susceptibility analysis (Reference GE EMI Analysis Report, dated January 1993). Plotted on Figure 4-18 is the applied susceptibility signal spectra. The susceptibility signal spectra represents the signal levels injected into the GE NUMAC via radiated electric fields. Also plotted on this figure is the radiated electric field emission data measured during the site survey tests at Brunswick Plant, Units 1 and 2. It can be seen from the data presented on Figure 4-18 that the spectra from the applied susceptibility signals injected into the GE NUMAC equipment is as least 56 dB greater than the emissions found on site. This shows that the GE NUMAC will not be susceptible to noise existing at the site point of installation with at least 56 dB safety margin.

The electric field radiated susceptibility tests previously performed by GE on the NUMAC equipment are much more rigorous than RS03 testing recommended in Section 4.3. Although the frequency range of coverage of the previously conducted GE tests covers only the higher frequency portion of the recommended RS03 requirement, the levels of the

4.0 ANALYSIS (continued)

4.4 Susceptibility Analysis (continued)

4.4.3 Electric Field Susceptibility (continued)

previously applied test signals are so much greater than the recommended test levels that compliance with the recommended RS03 test levels is ensured with a high degree of confidence.

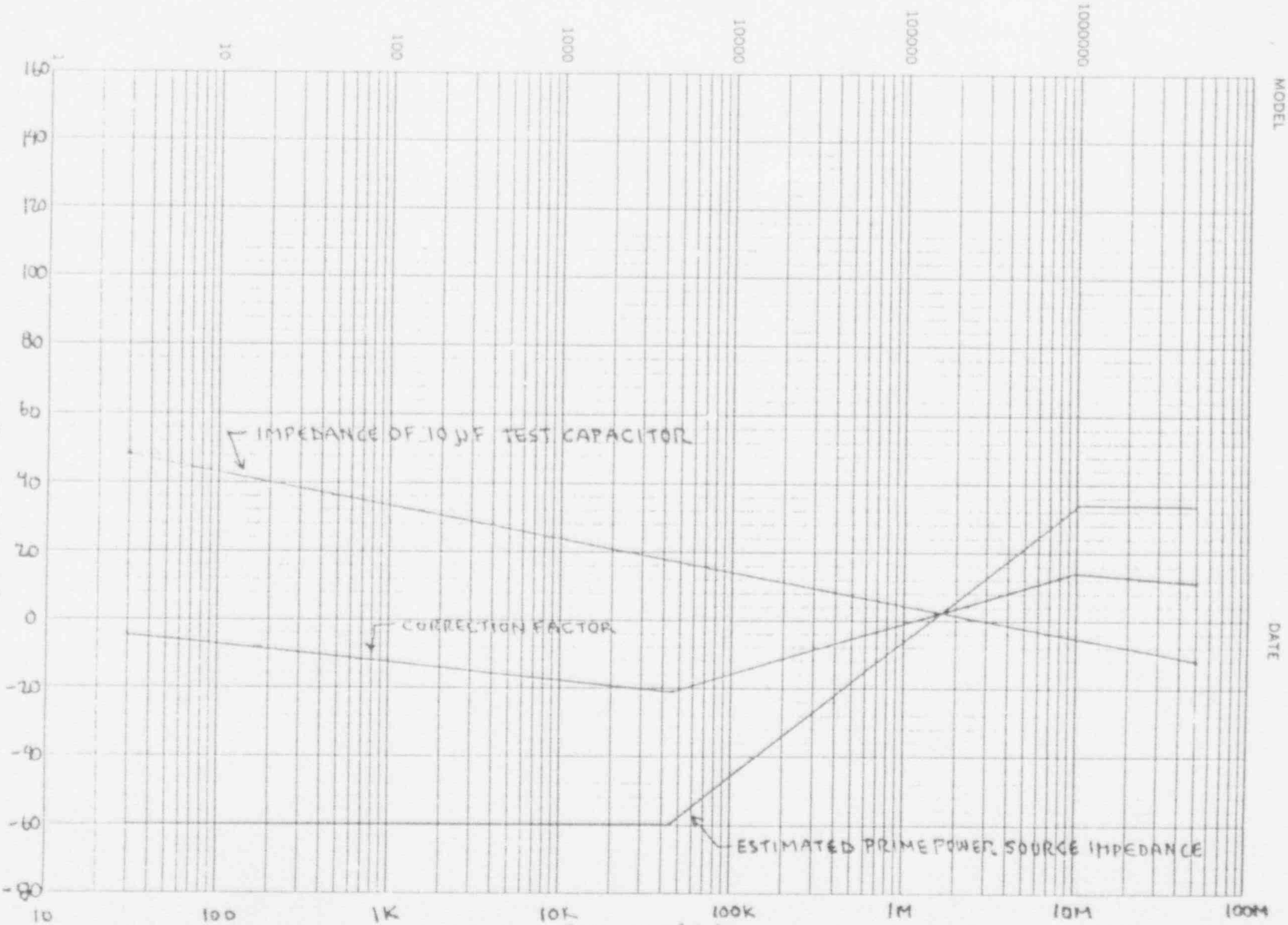

Figure 4-1 Estimate of Prime Power Source Impedance and Correction Factor

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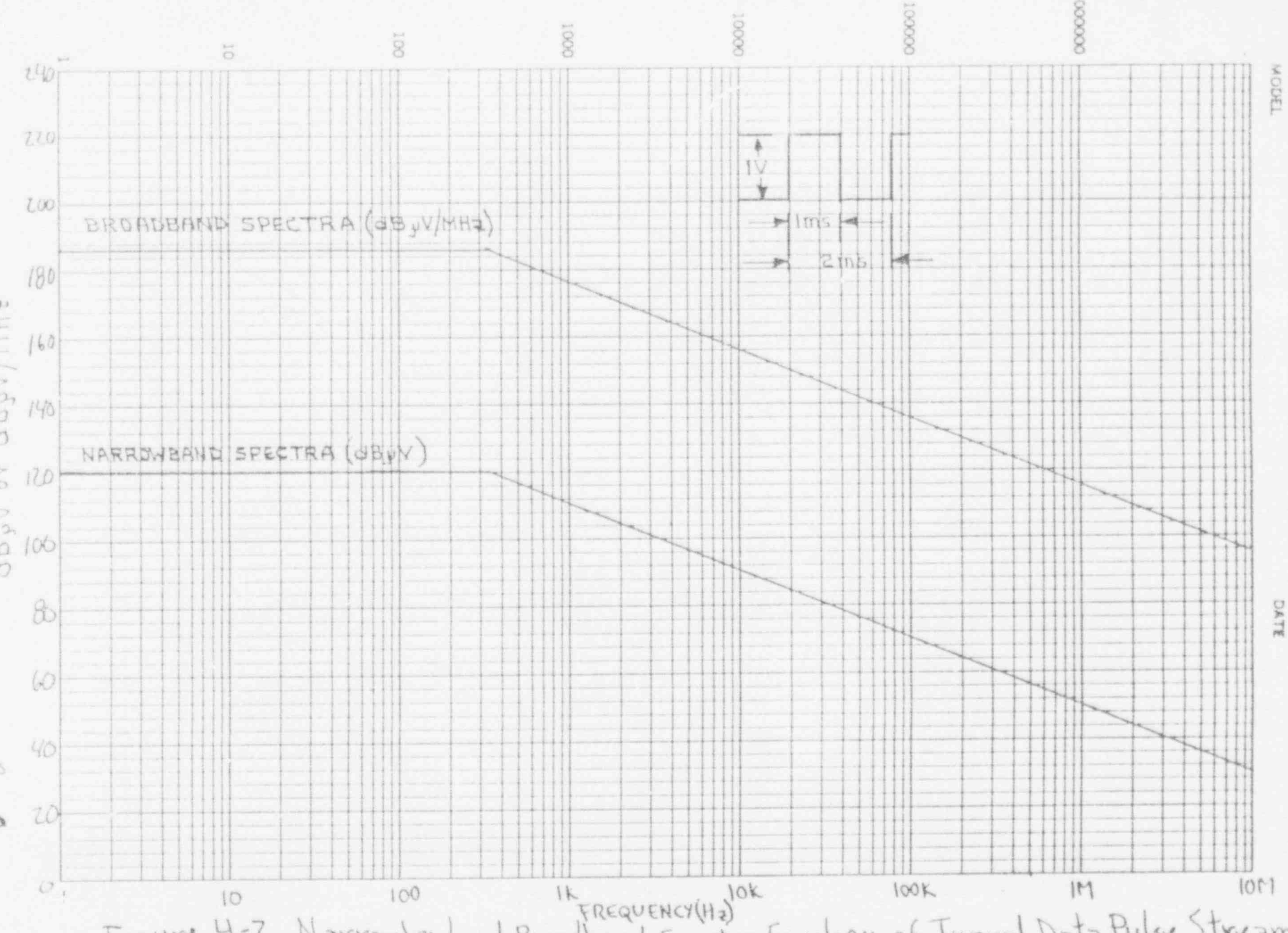

Figure 4-2 Narrowband and Broadband Spectra Envelopes of Typical Data Pulse Stream

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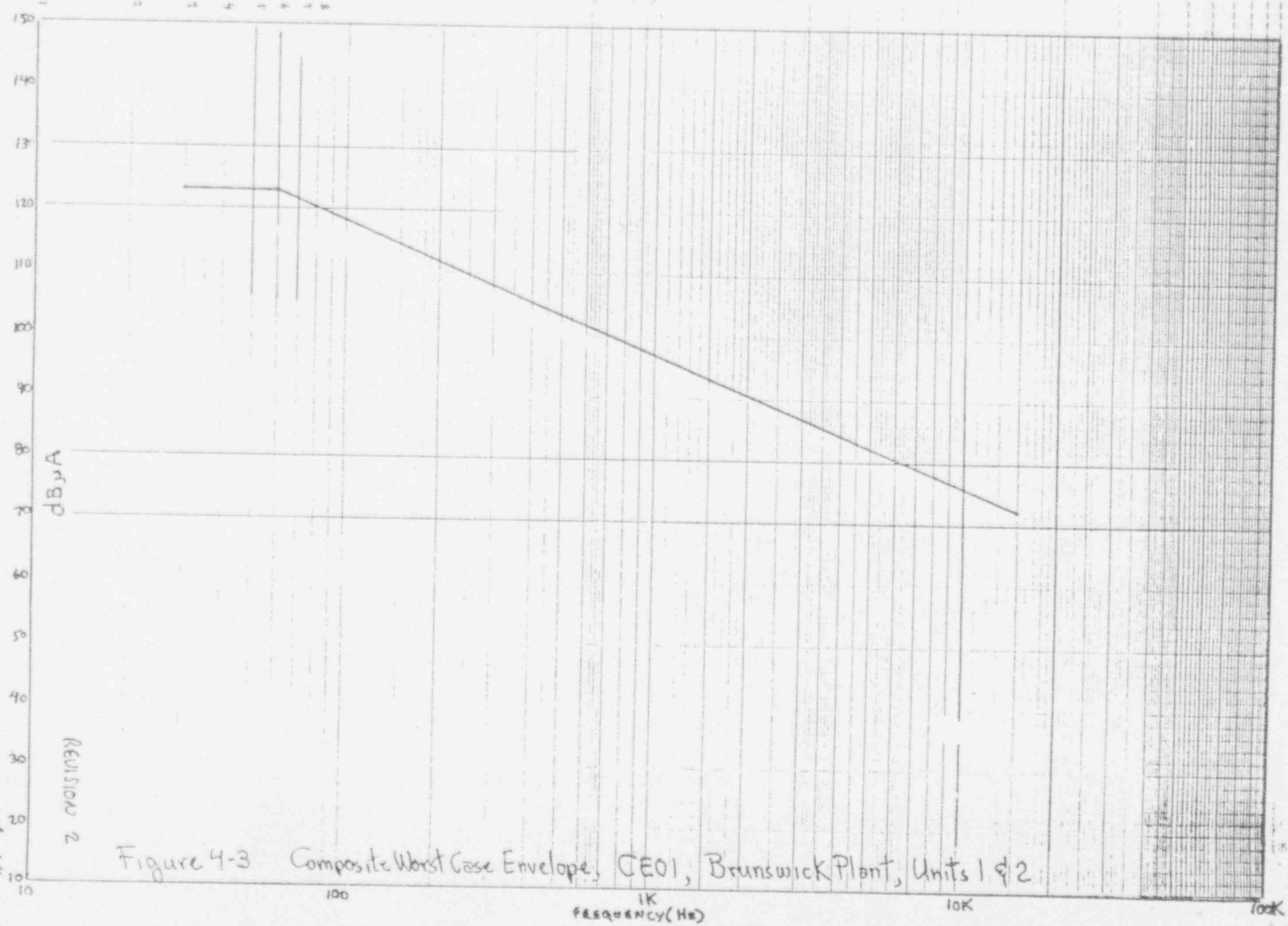

Figure 4-3 Composite Worst Case Envelope, CE01, Brunswick Plant, Units 1 & 2

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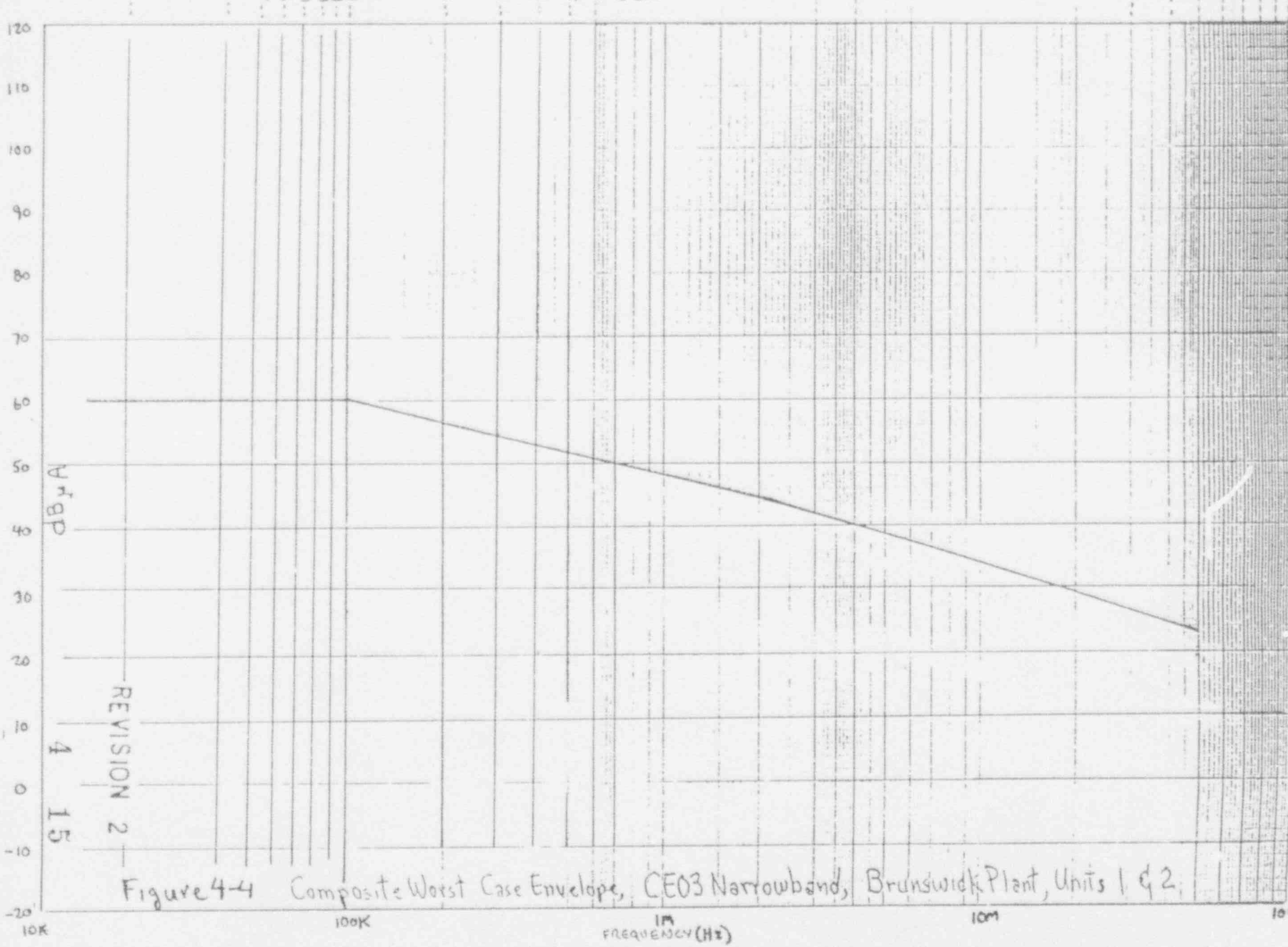

Figure 4-4 Composite Worst Case Envelope, CE03 Narrowband, Brunswick Plant, Units 1 & 2

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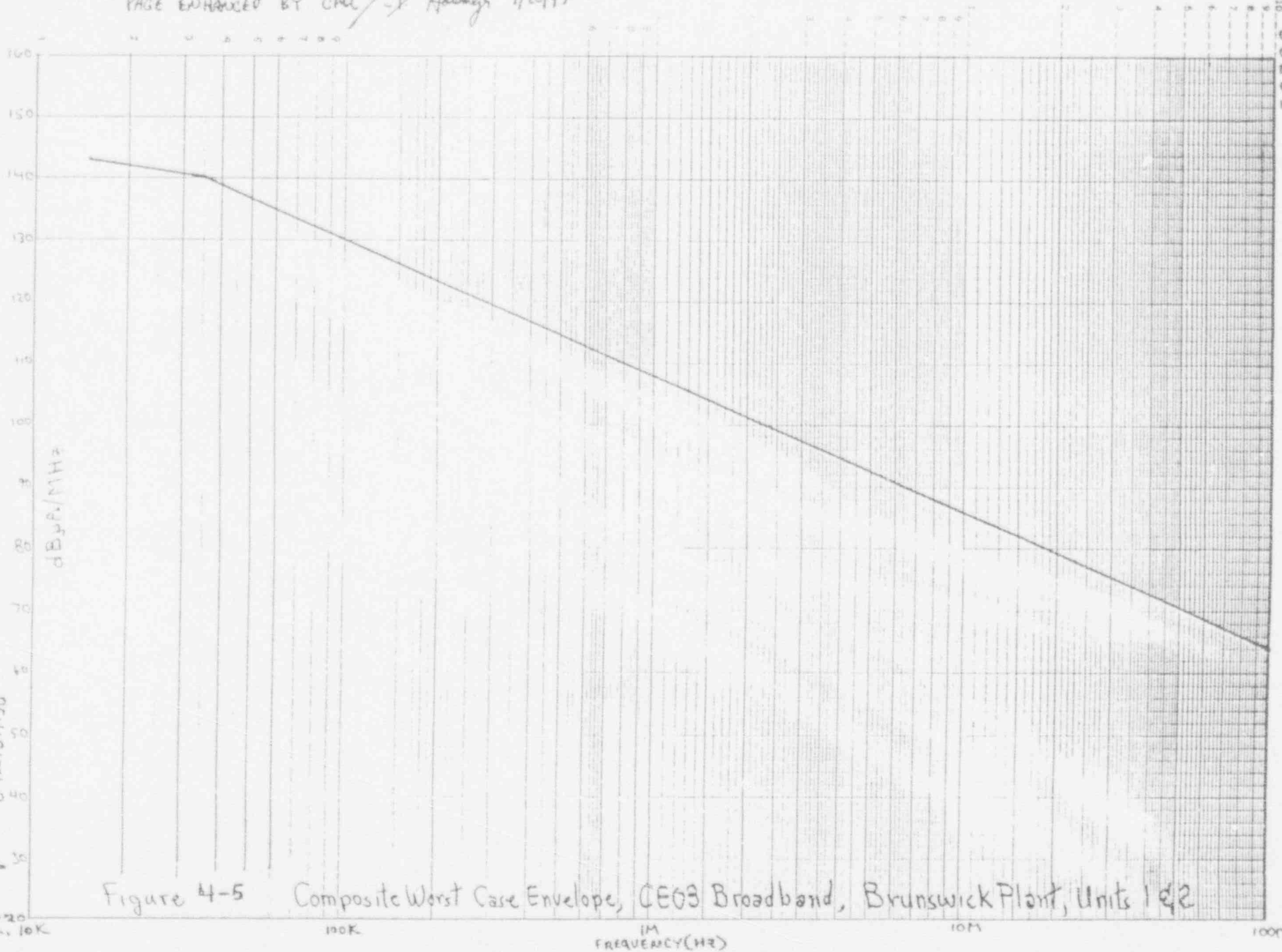

Figure 4-5 Composite Worst Case Envelope, CE03 Broadband, Brunswick Plant, Units 1 & 2

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K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 6012

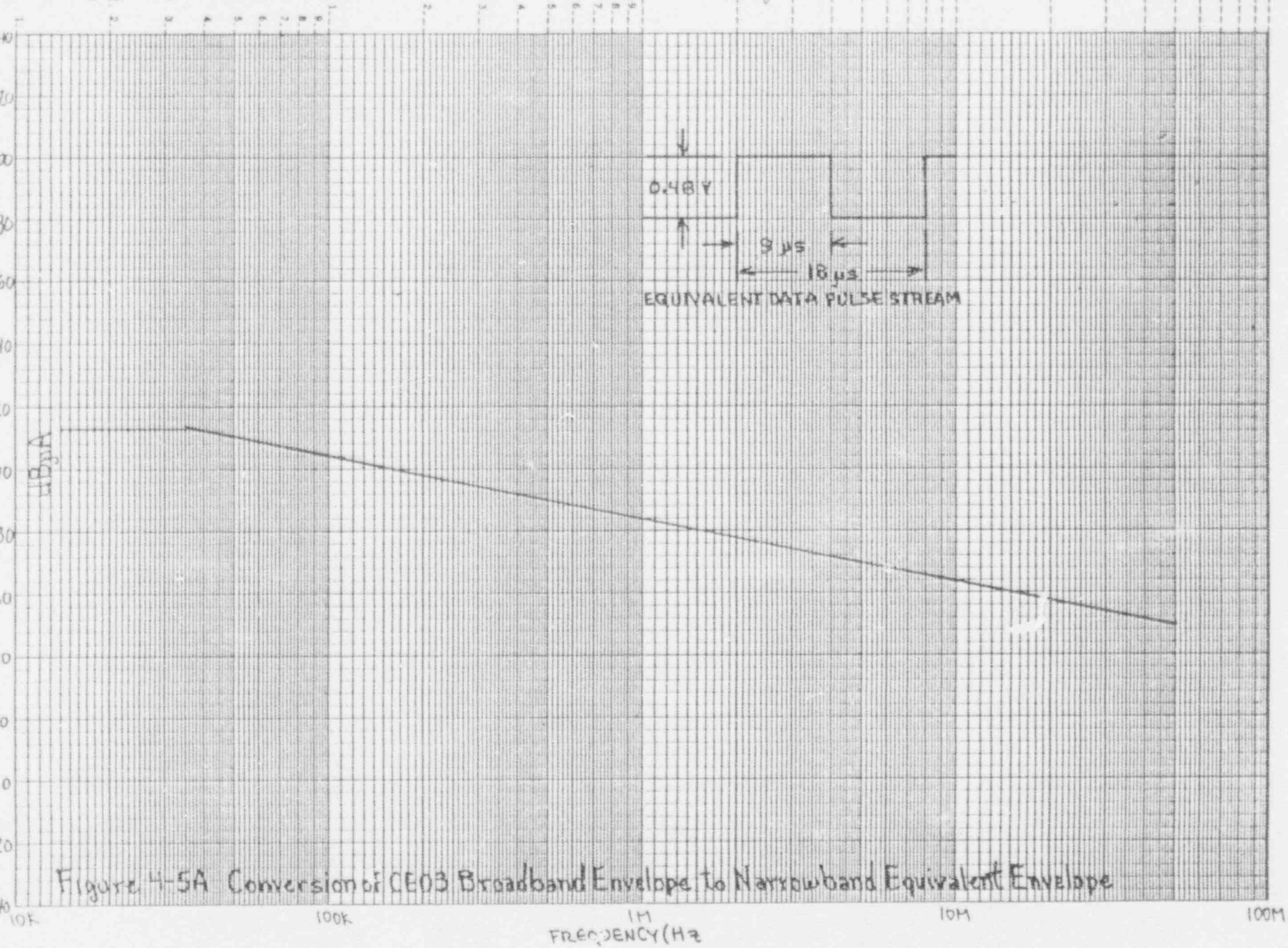

Figure 4-5A Conversion of CE03 Broadband Envelope to Narrowband Equivalent Envelope

K+E SEMI-LOGARITHMIC 7 CYCLES X 60 DIVISIONS KEUFFEL & ESSER CO.

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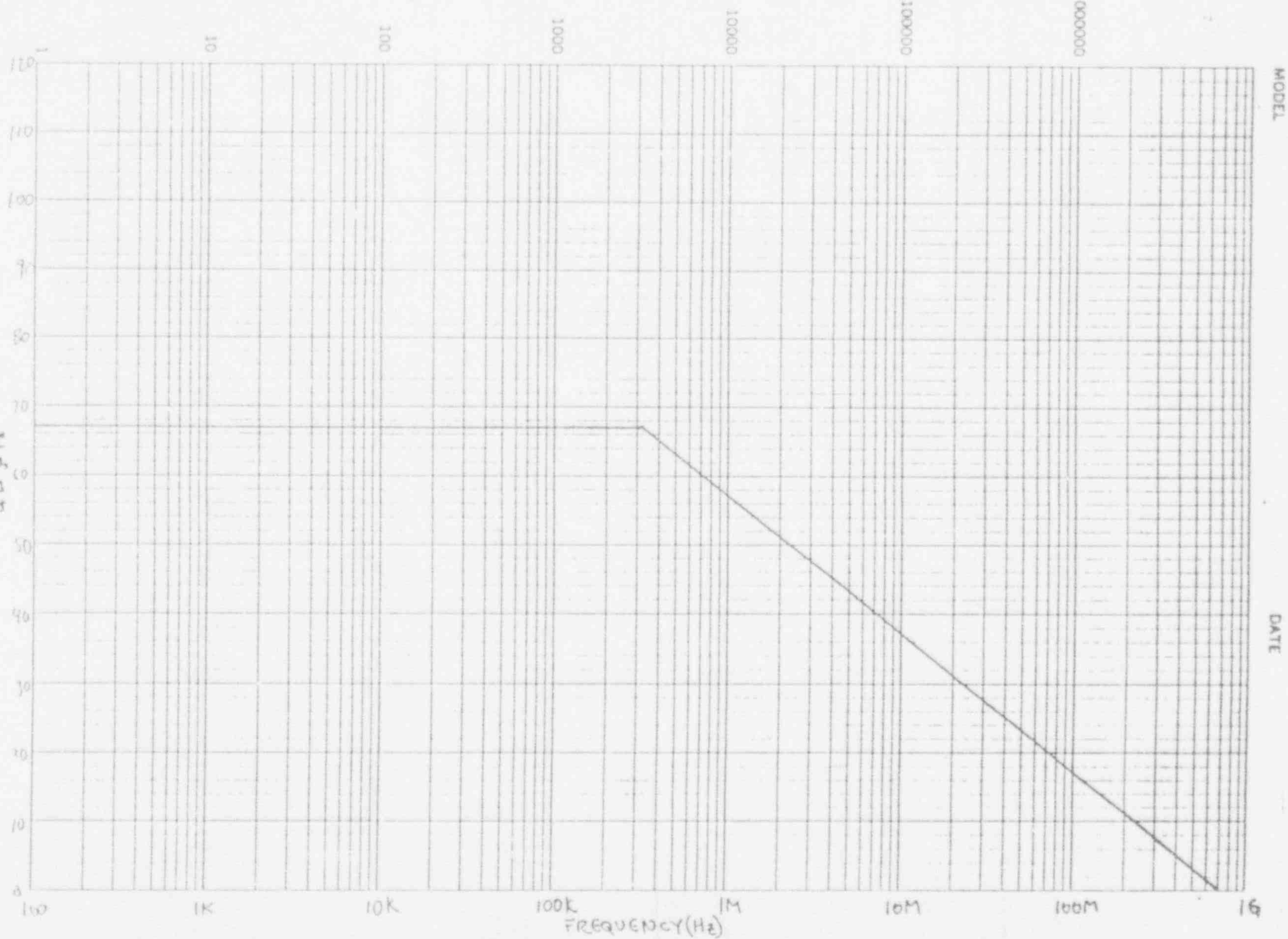

Figure 4-6 Composite Worst Case Envelope, Conducted Transients, Brunswick Station, Units 1 & 2

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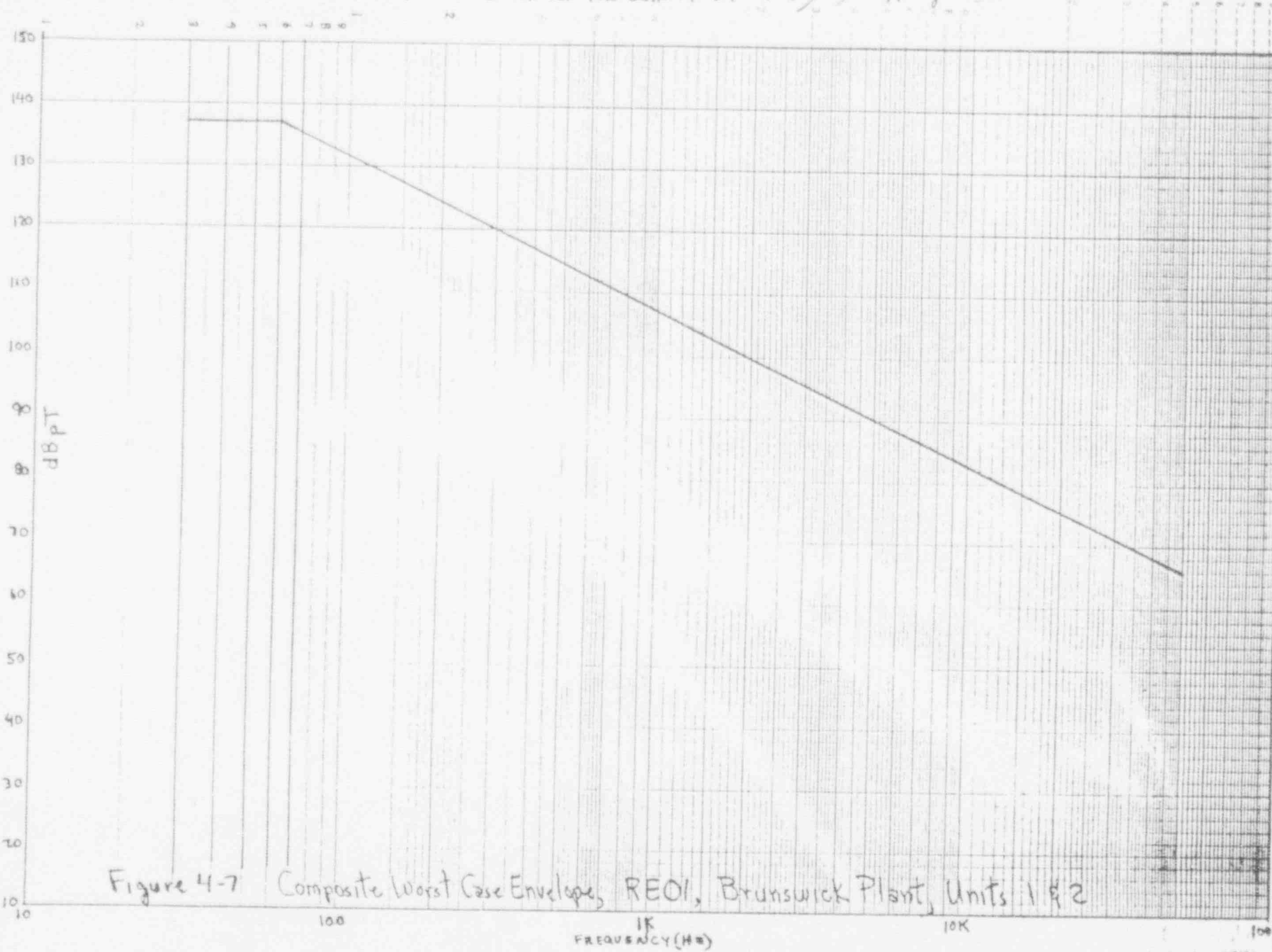

Figure 4-7 Composite Worst Case Envelope, RE01, Brunswick Plant, Units 1 & 2

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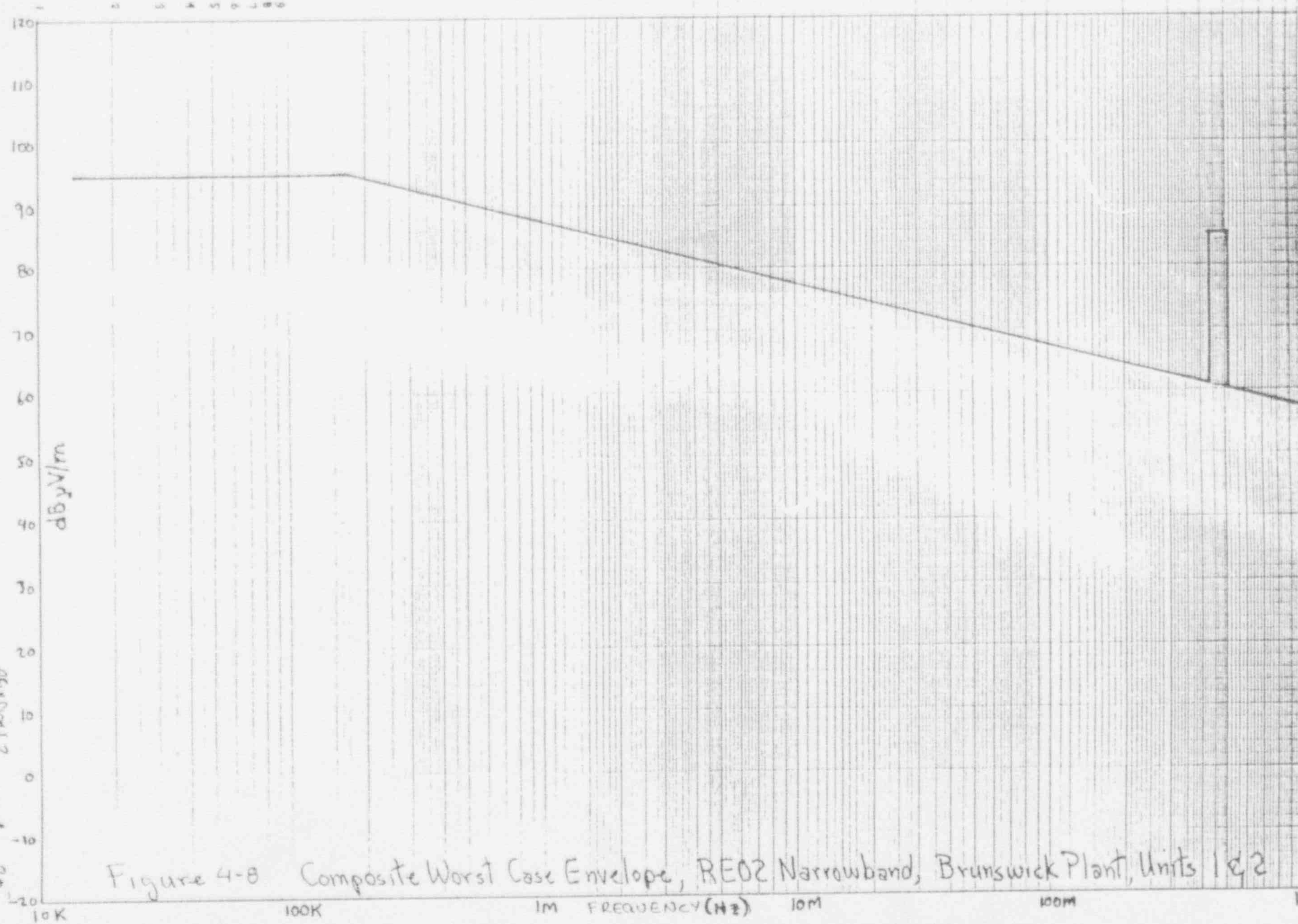

Figure 4-8 Composite Worst Case Envelope, RE02 Narrowband, Brunswick Plant, Units 1 & 2

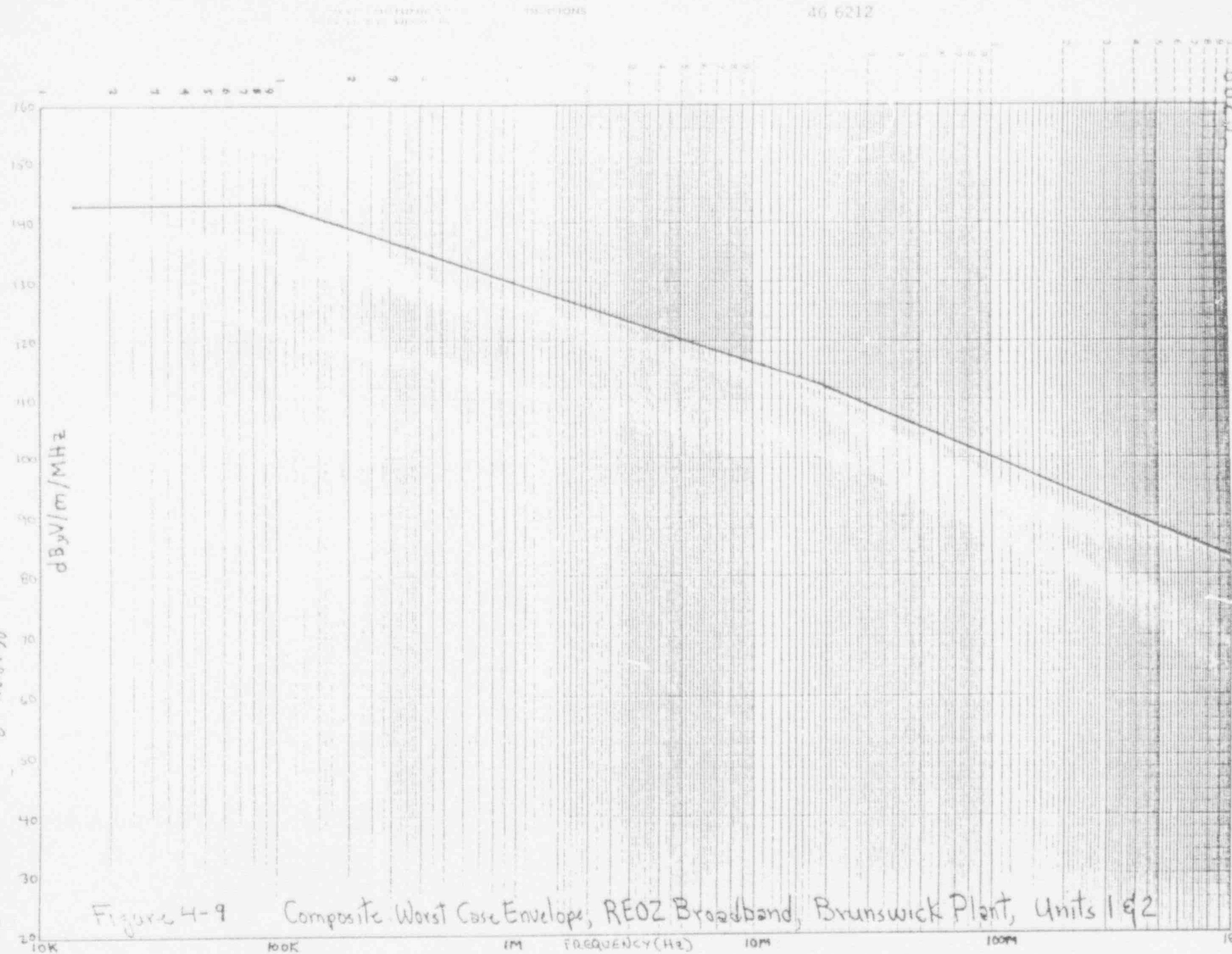

Figure 4-9 Composite Worst Case Envelope, RE02 Broadband, Brunswick Plant, Units 1 & 2

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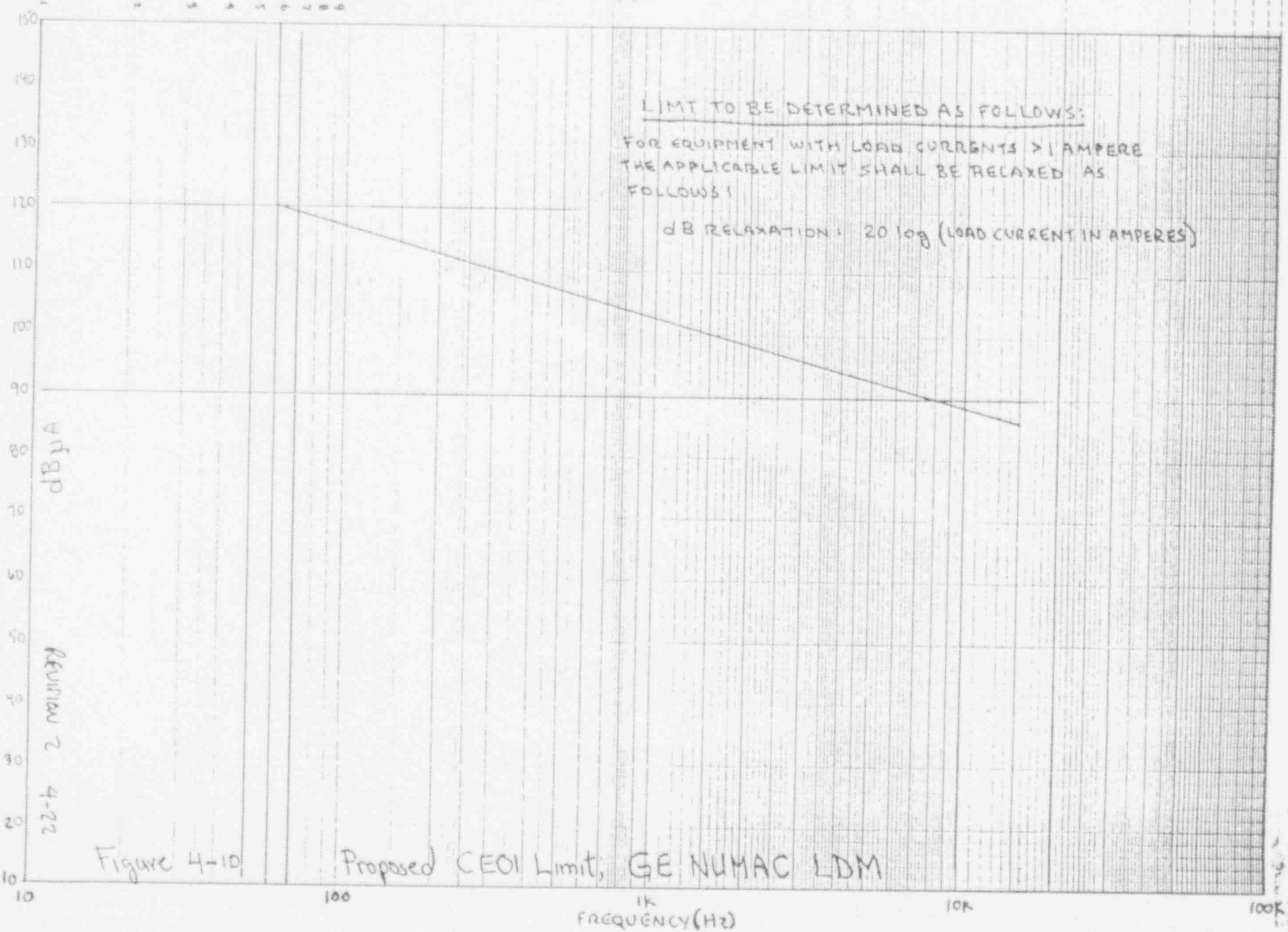

Figure 4-10 Proposed CE01 Limit, GE NUMAC LDM

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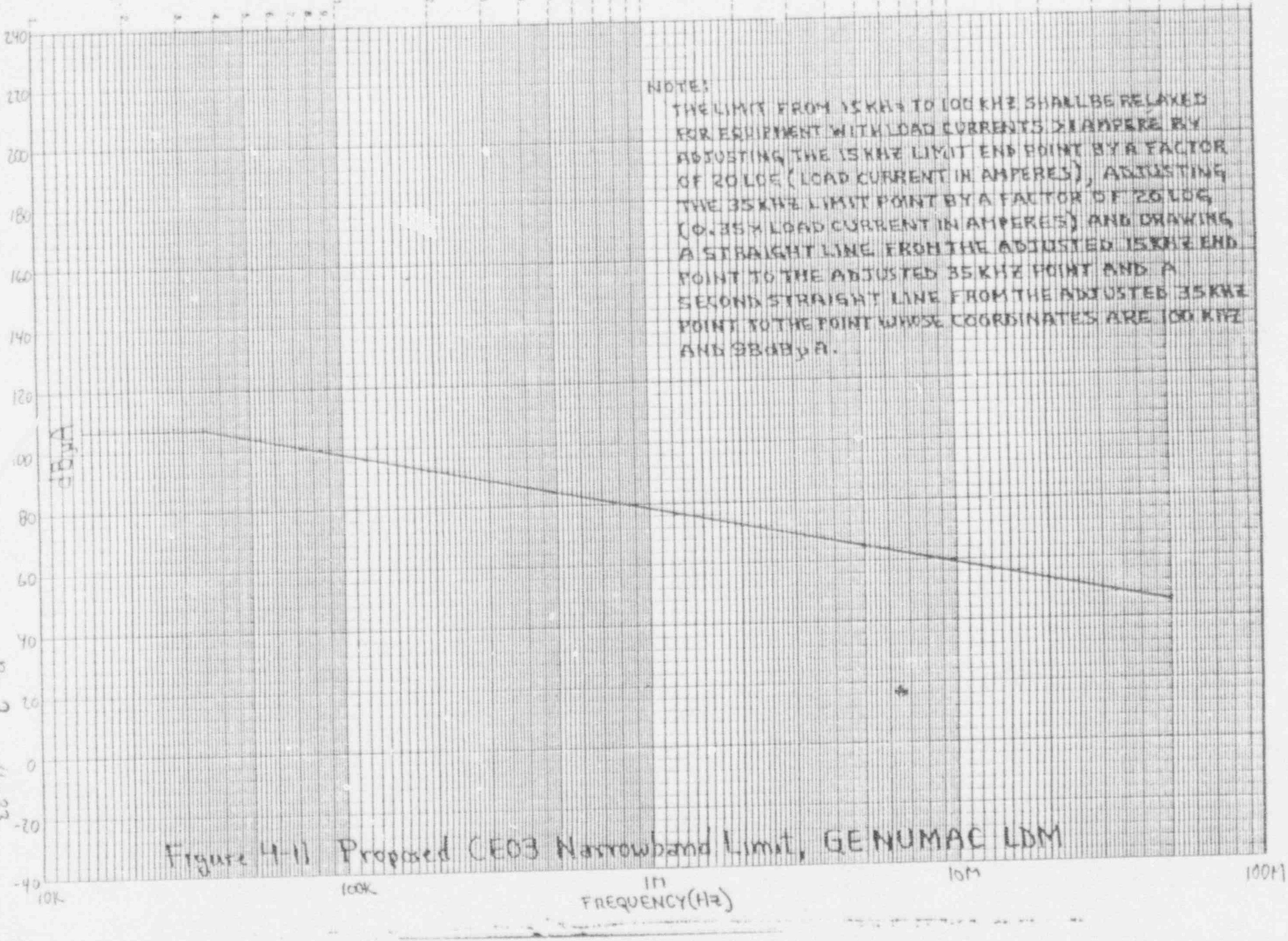

Figure 4-11 Proposed CE03 Narrowband Limit, GENUMAC LDM

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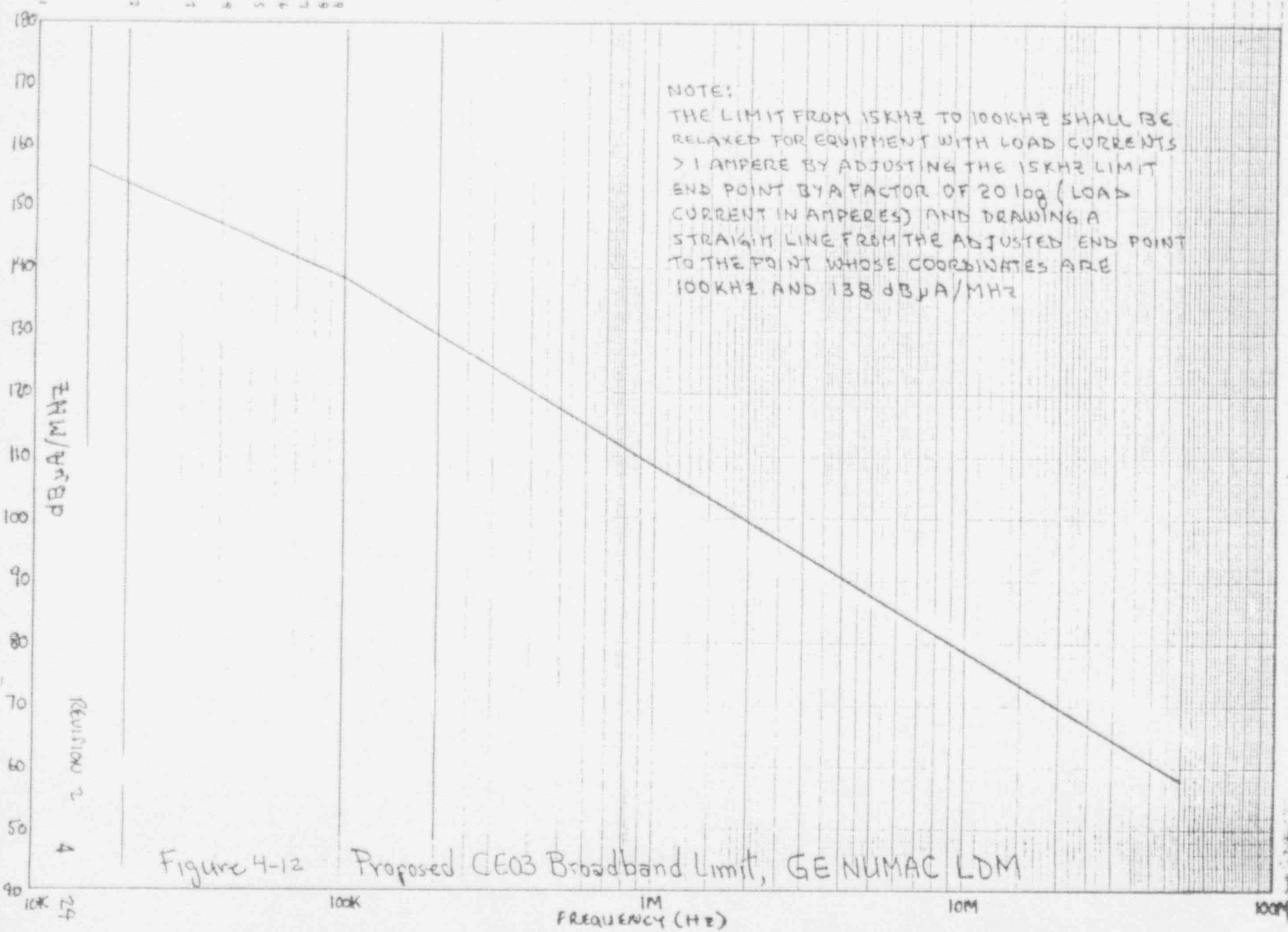

Figure 4-12 Proposed CE03 Broadband Limit, GE NUMAC LDM

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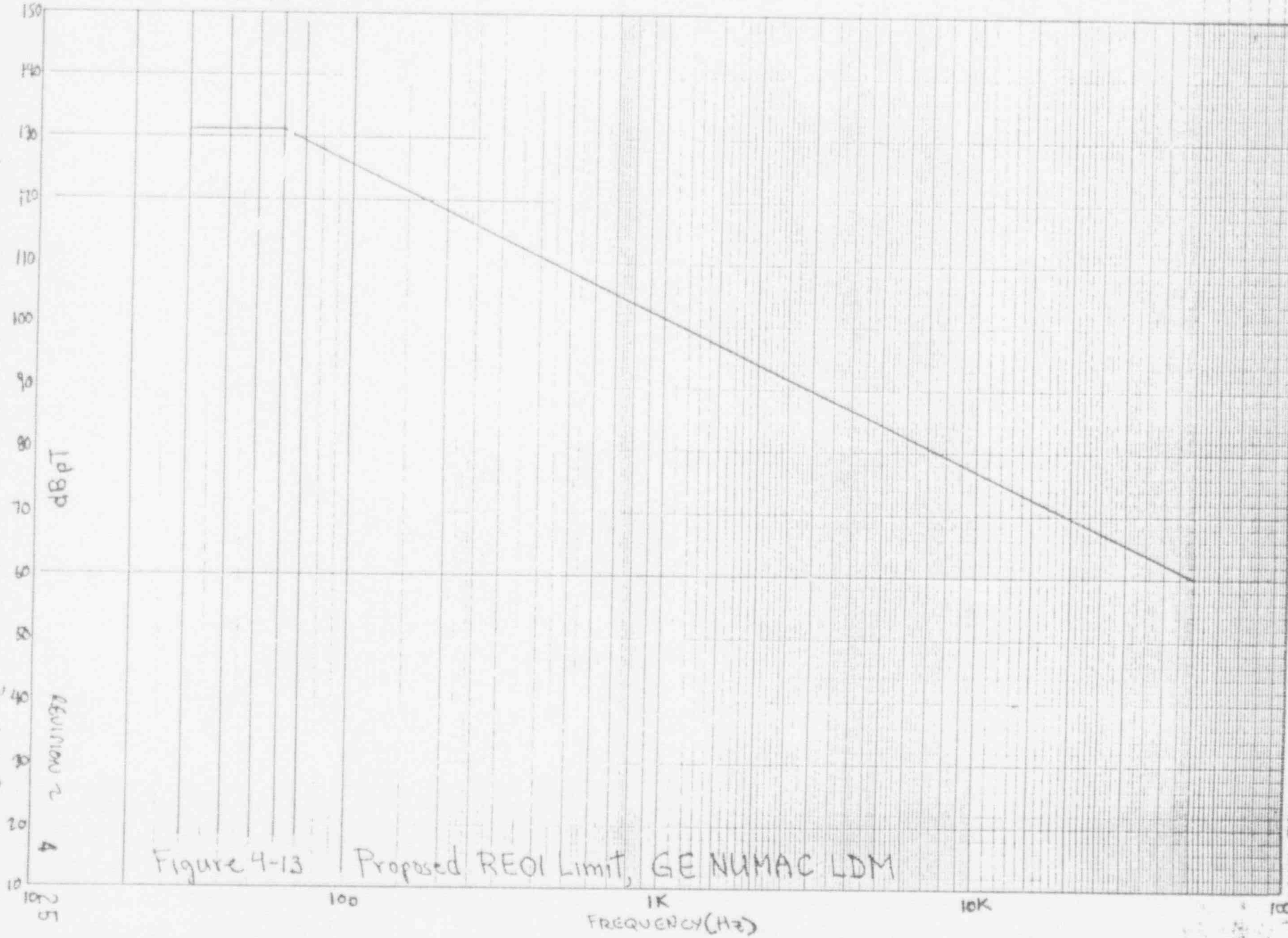

Figure 4-13 Proposed RE01 Limit, GE NUMAC LDM

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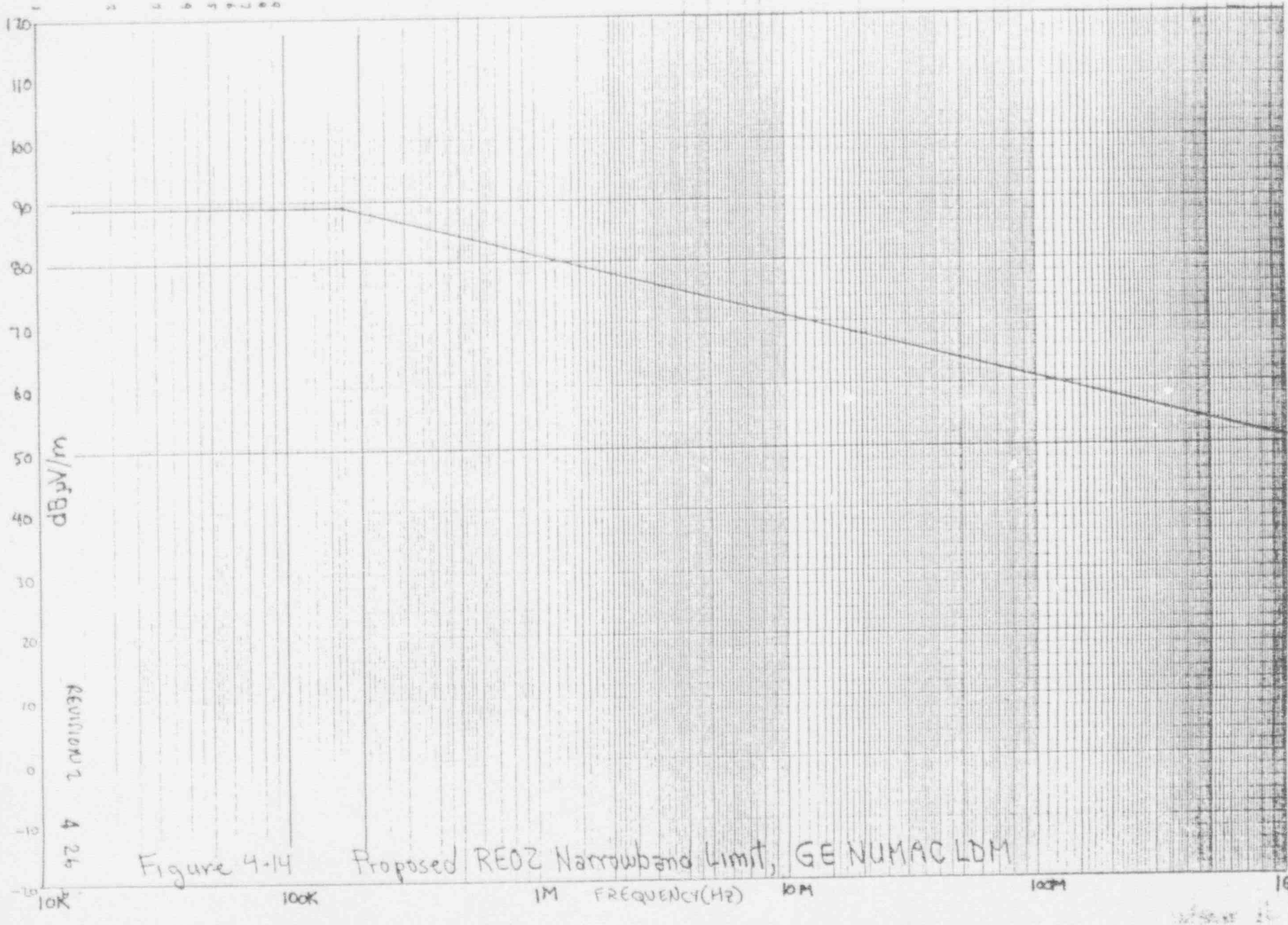

Figure 4-14 Proposed RE02 Narrowband Limit, GE NUMAC LDM

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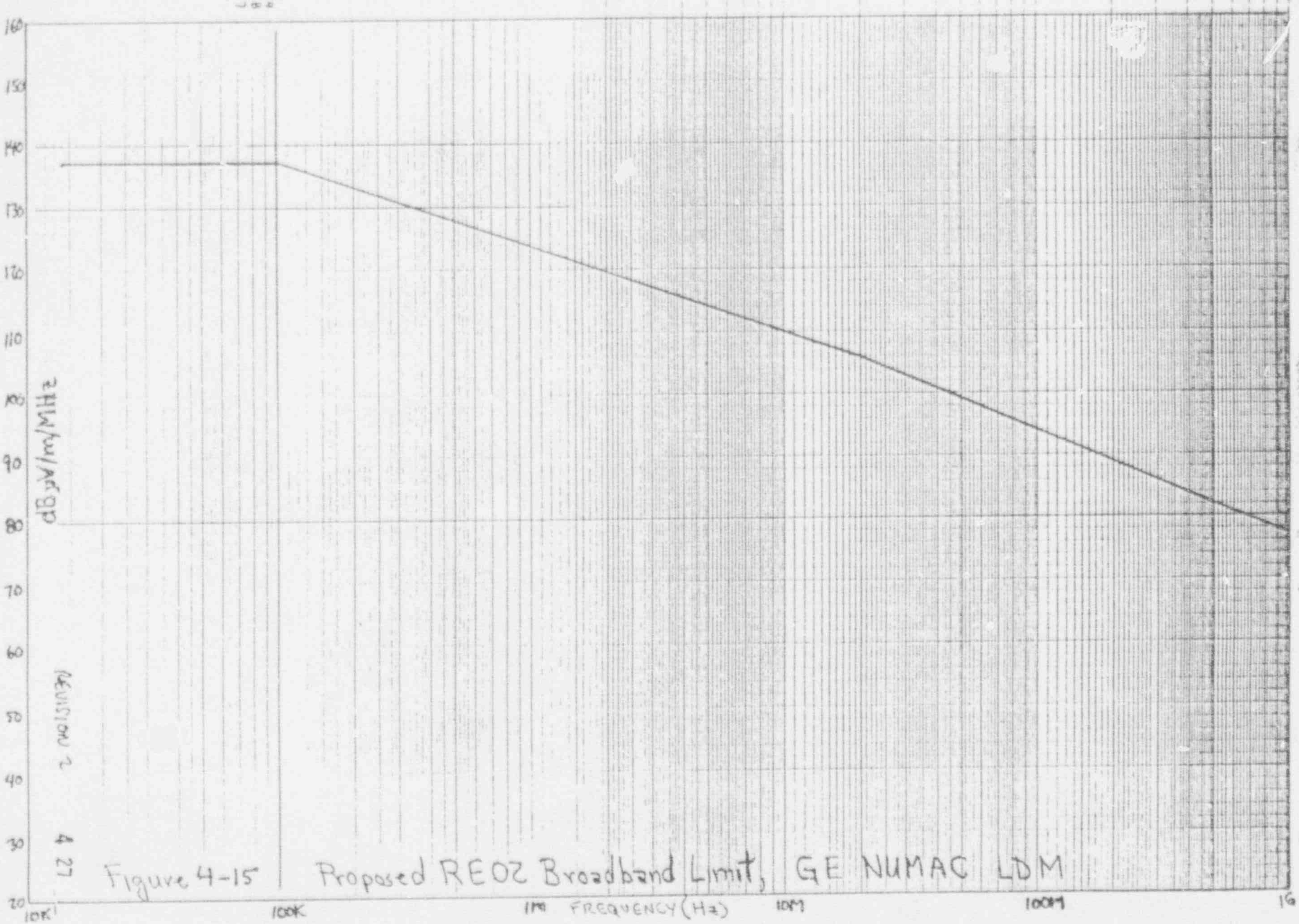

Figure 4-15 Proposed RE02 Broadband Limit, GE NUMAC LDM

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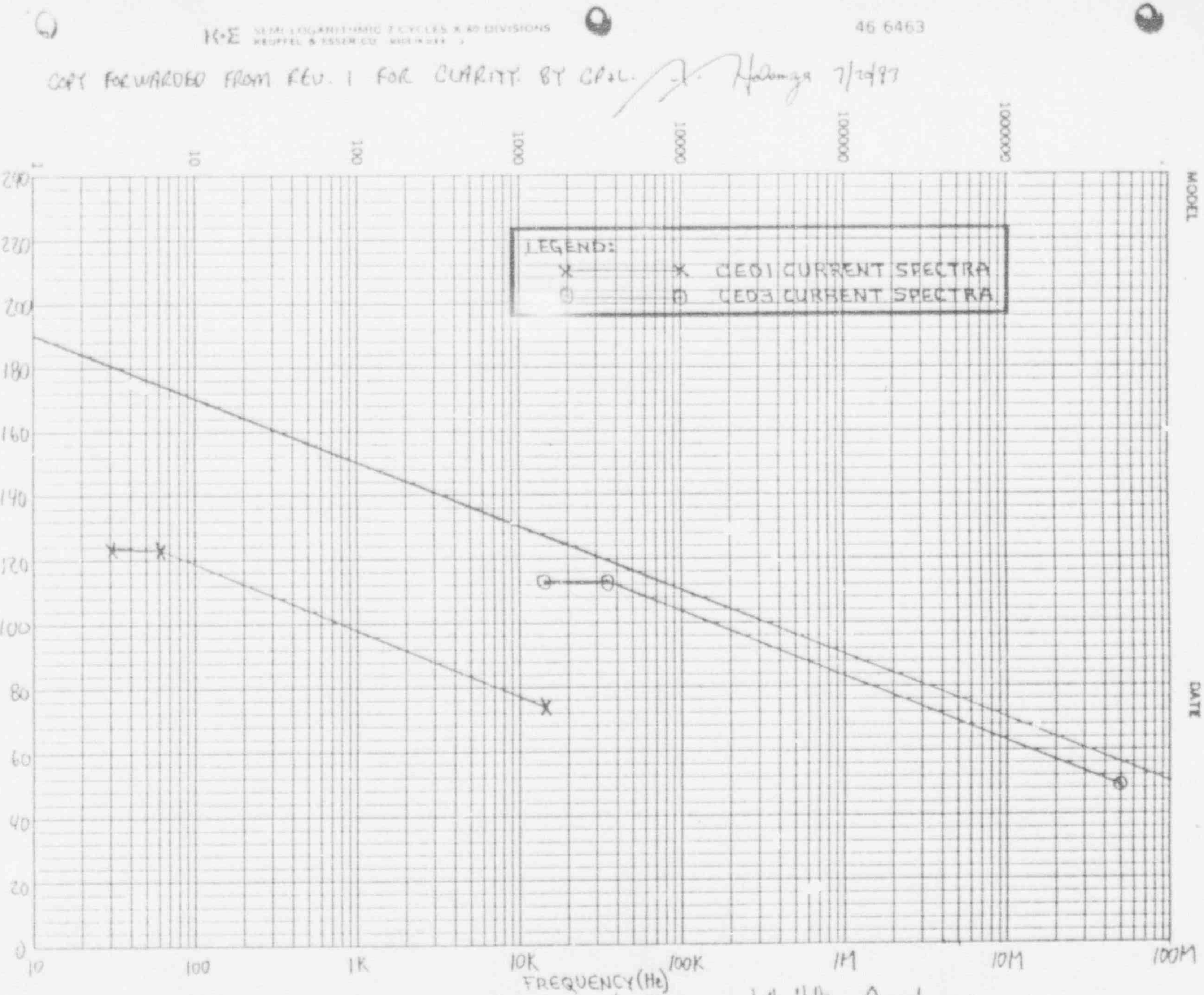

Figure 4-16 Conducted Susceptibility Analysis

K+E SEMI-LOGARITHMIC 7 CYCLES X 60 DIVISIONS 46 6463

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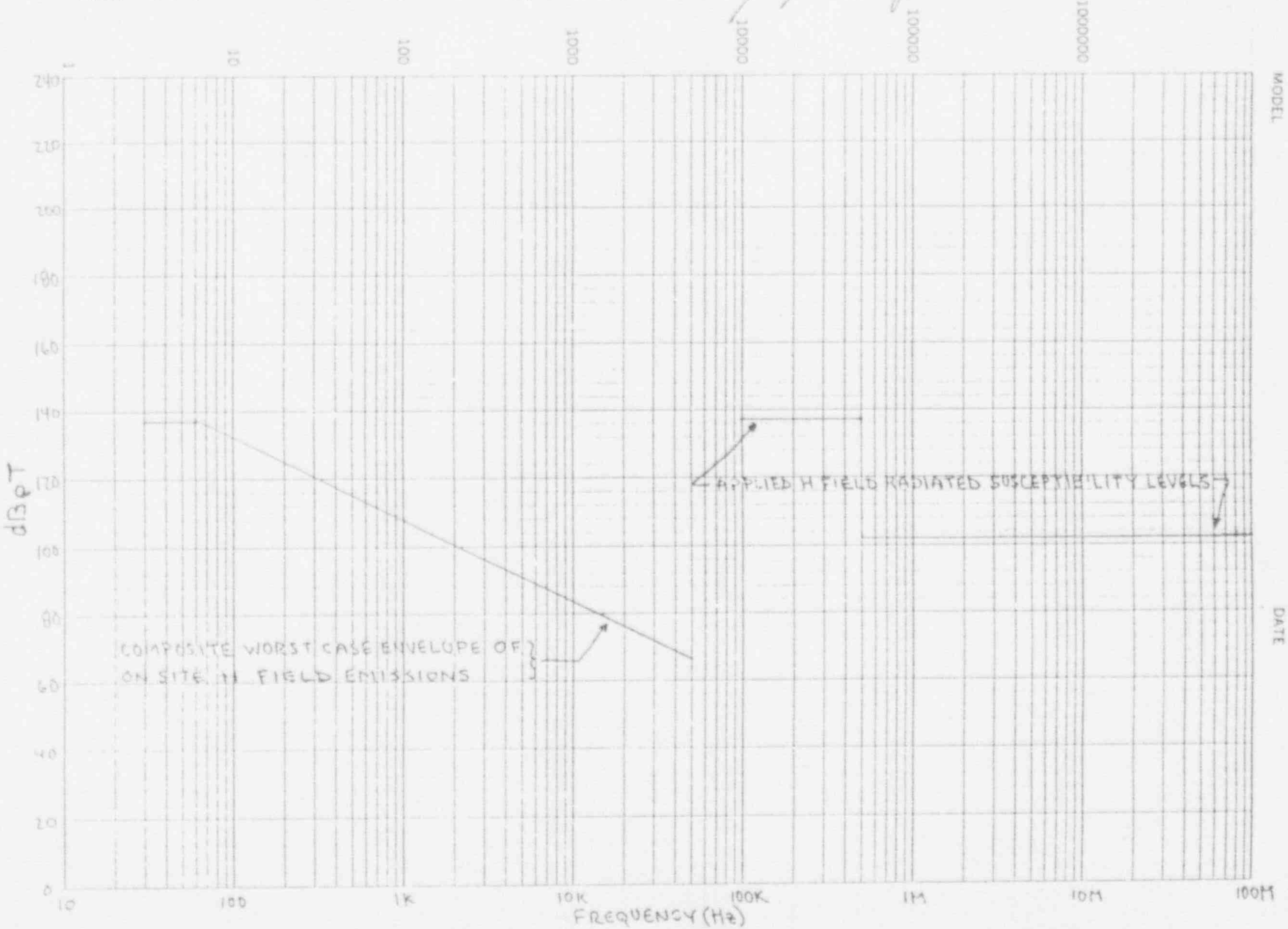

Figure 4-17 Magnetic Field Radiated Susceptibility Analysis

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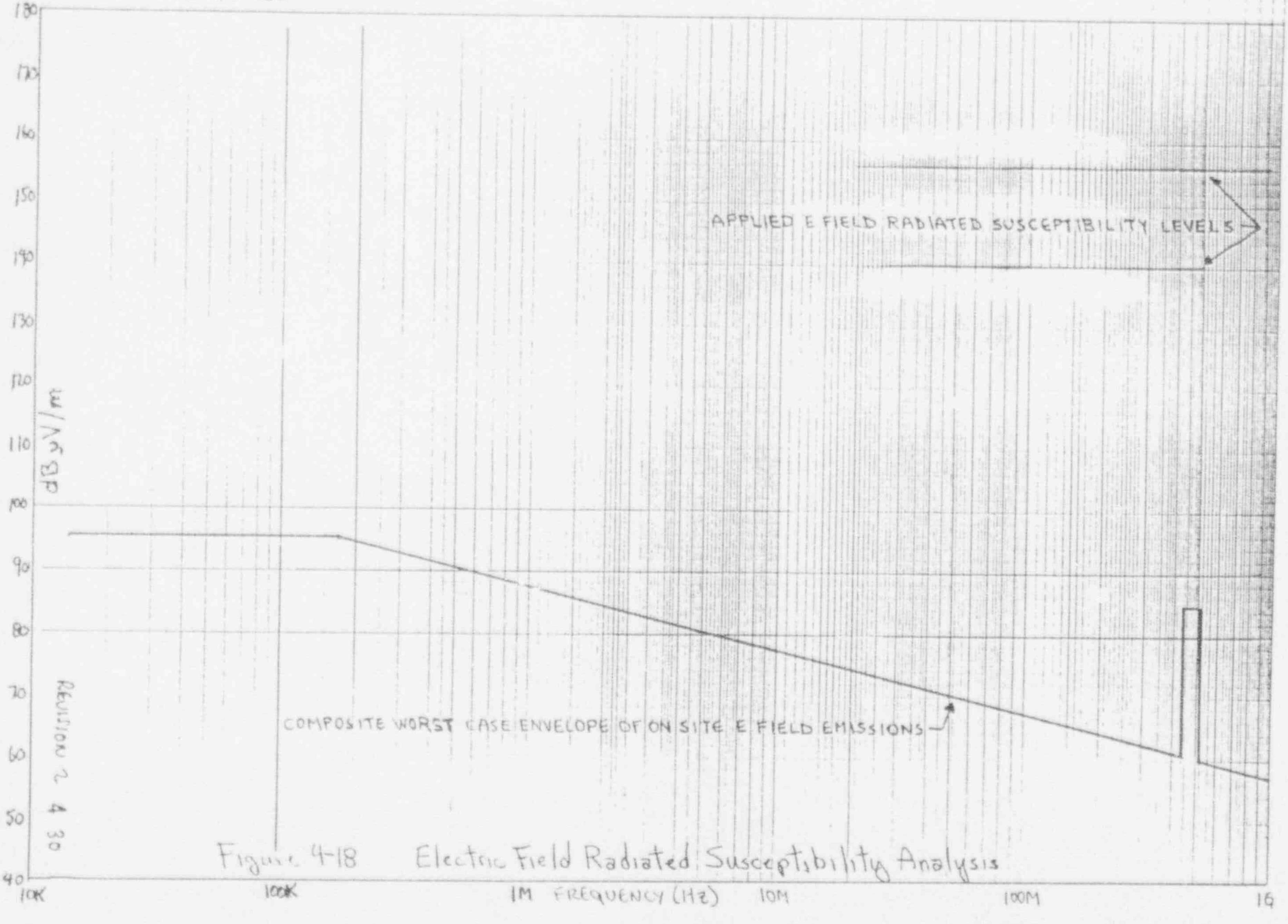

Figure 4-18 Electric Field Radiated Susceptibility Analysis

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5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Analysis of the test data shows:

1) The measured site electromagnetic environment is what one experienced in EMI design, analysis and testing would expect to measure in a site such as this. No unusual measurement data was encountered.

2) The EMI emission and susceptibility test limits, developed herein and listed below for the General Electric NUMAC Leak Detection Monitor, are realistic and readily achievable limits:

Proposed GE LDM EMI Limits

Conducted Susceptibility

CS01	30 Hz to 15 kHz	5 Volts
CS02	15 kHz to 50 MHz	1 Volt

Magnetic Field Radiated Susceptibility

RS01	30 Hz to 50 kHz	144 dBpT

Electric Field Radiated Susceptibility

RS03	14 kHz to 1 GHz	1 V/m

Conducted Emissions

See Figures 4-10, 4-11, and 4-12

Magnetic Field Radiated Emissions

See Figure 4-13

Electric Field Radiated Emissions

See Figures 4-14 and 4-15

5.0 CONCLUSIONS AND RECOMMENDATIONS (continued)

5.1 Conclusions (continued)

3) Similarities in design and comparative analysis of the site emissions data and the available GE NUMAC equipment susceptibility data provide a high level of confidence that the NUMAC LDM unit will not adversely affect the present on site equipment nor be adversely affected by these same on site equipment.

5.2 Recommendations

It is recommended that EMI/EMC testing be performed on the GE NUMAC Leak Detection Monitor. The scope of this testing should cover the Conducted Emissions, Conducted Susceptibility, Radiated Emissions and Radiated Susceptibility testing recommendations and their limits as outlined in Section 4.3 as a minimum.