ATTACHMENT 2

NTS

Test Report No. 33069-97N
NTS Job No. 60789-97N
Revision 1

TEST REPORT FOR FOURIER TRANSFORM

FOR

TENNESSEE VALLEY AUTHORITY
POST OFFICE BOX 2000
DECATUR, AL 35609

Purchase Order Number: TV-96218V

The program outlined within this report (Attachment A) was conducted in accordance with the NTS/Northeast Quality Manual, Revision 3, dated July 14, 1992. This insures that the applicable provisions of 10CFR, Part 21 and Part 50, Appendix B are fulfilled.

Reviewed and Approved by: ______________________ **Date:** 6/3/96
Independent Reviewer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: ______________________ **Date:** 6/3/96
Quality Representative, Nuclear Services
NTS/Northeast

JED/6078997.RV1

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ATTACHMENT A

TEST REPORT NO. 33069-97N

NTS

REVISION RECORD				
REVISION NUMBER	PAGE NUMBER	PARA NUMBER	CHANGES OR ADDITIONS	APPROVED BY
0----------------------------FIRST-ISSUE------------------------------				
1	Cover	---	Changed "Revision 0" to "Revision 1".	6/3/96
	Attachment A, 4 & 5	3.0	Added text.	6/3/96
	Attachment A, A-3	Figure 3	Replaced Figure 3.	

NTS

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TEST REPORT
FOR
FOURIER TRANSFORM

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Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

REVISION PAGE

Rev.No.	Date	Page No.	Para.No.	Description
Original	21 May 1996			
1	31 May 1996	4-5	3.0	Added Text
		A-3	Figure 3	Replaced Figure

NTS

Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

SIGNATURES

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Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

TABLE OF CONTENTS

APPENDIXES

NTS

Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

1.0 INTRODUCTION

To solve many engineering problems, one needs to know the response of a Linear Time Invariant system to some input signal. If the input signal can be broken up into simple signals and one knows how the system responds to these simple signals, then one can predict how the system will behave to this complex input signal. Therefore anything that can break a signal down into its constituent parts would be very useful. One such tool is the Fourier Series.

2.0 REFERENCES

2.1 Tennessee Valley Authority Purchase Order Number TV-96218V.

2.2 NTS Interdivision Transfer Form and Interdivision Job Request dated 5 April 1996.

2.3 NTS Quality Program Manual dated 17 October 1995.

3.0 THE FOURIER SERIES/TRANSFORM

With the exception of some mathematical curiosities, any periodic signal of period T can be expanded into a trigonometric series of sine and cosine functions, as long as it obeys the following conditions:

1. f(t) has finite number of maxima and minima within T
2. f(t) has finite number of discontinuities within T, and
3. It is necessary that the integral from 0 to T of the function f(t)dt be less than infinity. i.e.:

$$\int_0^T |f(t)|\,dt < \infty$$

If all of these are true then the signal can be represented as:

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\frac{2\pi n t}{T} + \sum_{n=1}^{\infty} b_n \sin\frac{2\pi n t}{T}$$

and the coefficients are:

$$\frac{a_n}{2} = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)\cos\left(\frac{2\pi n t}{T}\right) dt$$

$$\frac{b_n}{2} = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)\sin\left(\frac{2\pi n t}{T}\right) dt$$

$$\frac{a_0}{2} = \int_{t_0}^{t_0+T} f(t)\, dt$$

Any electrical signal can be viewed from either of two different standpoints:

1. The time domain
2. The frequency domain

The domain with which we are most familiar is the time domain. This is akin to the trace on an oscilloscope, where the vertical deflection represents the signals amplitude, and the horizontal deflection represents the time variable.

The second representation is the frequency domain. This is like the trace on a spectrum analyzer, where the horizontal deflection represents the frequency variable and the vertical deflection represents the signal amplitude at that frequency.

Any give signal can be fully described in either of these two domains. We can go between the two domains by using a tool called the Fourier Transform.

Any integrable function f(t) uniquely defines its Fourier coefficients or its Fourier Transform. Conversely, a complete set of Fourier coefficients or a Fourier Transform uniquely defines the corresponding function f(t).

The Fourier integral expansion describes f(t) as a "sum" of infinitesimal sinusoidal components with frequencies "f" or circular frequencies "W" (where W = s(PI)f (f>0)); the functions 2[c(f)] and arg c(f) respectively define the amplitudes and the phase angles of the sinusoidal components. The treatment of Fourier integrals has been unified through the introduction of generalized (integrated) Fourier Transforms. These Fourier Transforms allow for the ready calculation of the amplitudes and phase angles of the various harmonic components that make up the frequency domain representation of the time domain signal under investigation. Many engineering and mathematics handbooks tabulate the Fourier Transforms for various commonly encountered signal waveforms.

In the field of EMI/EMC emissions and/or susceptibility analysis our main concern usually is not with the actual frequency domain representation of a digital signal, but in the overall envelope of the frequency domain representation. Rarely does one worry about the individual sine/cosine components (harmonics) of the digital signal.

Figure 1 in Appendix A shows a segment of a generic digital communications signal pulse stream in the time domain.

Figure 2 in Appendix A shows, qualitatively, the frequency representation of this same digital signal pulse stream.

SAMPLE CALCULATION

The IEC 801-4 conducted susceptibility analysis has been selected as the vehicle for presenting a sample calculation. Since the IEC 801-4 test is performed using time domain pulses the IEC 801-4 pulse train waveform must be converted to the frequency domain so as to be directly comparable to the site survey worst case conducted emissions envelope. The vehicle used for this time domain to frequency domain conversion is the Fourier Transform.

The susceptibility pulse used in the conduct of a IEC 801-4 test is as shown on Figure 3 found in Appendix A.

The current waveform is identical in shape to the voltage waveform as it is inserted into the equipment via a 50 Ohm termination. The Fourier Transform for this pulse configuration is:

$$C_n = 20 \log \left[2A \frac{d+T}{T} \left| \frac{\sin n\pi\, t/T}{n\pi\, t/T} \quad \frac{\sin n\pi \frac{t+d}{T}}{n\pi \frac{t+d}{T}} \right| \right] + 120 \ \text{dB}\mu\text{A}$$

Inserting the values for the various parameters we can calculate the amplitude of the fundamental of the sinusoidal components (158 dBuA). The envelope of the sinusoidal components is flat up to the first breakpoint frequency given by $f_1 = 1/(pi)d$ (6.3 MHz where d = 50 ns). From the first break point frequency the envelope drops off at a rate of 20 dB/decade until the second breakpoint frequency (given by f2 = 1/(pi)t, 63.3 MHz in this case where t = 5 ns), after which the envelope drops off at rate of 40 dB/decade. Similarly, we can calculate the envelope for the pulse bursts which has the effect of reducing the frequency of the flat portion of the spectral envelope down to a frequency of approximately 3 Hz. Figure 4 in Appendix A, shows, quantitatively, the envelope of the frequency representation of this IEC 801-4 pulse stream. The previously described analytical procedure, applicable to the IEC 801-4 pulse train conversion from the time domain to the frequency domain, is equally applicable to any and all conversions from the time domain to the frequency domain wherever tests were performed using time domain procedures.

Calculating the amplitude value of 158 dBuA is accomplished by inserting the 40 Amp amplitude value (2 KV ÷ 50 Ω = 40A) and the pulse train waveform parameters (from Figure 3) into the equation given above for C_n. Note that the terms within the absolute value bars are the form $\sin x/x$ and for small values of x the term $\sin x/x$ is equal to 1. Therefore the equation for C_n reduces to: $C_n = 20 \log \left[2A \frac{d+T}{T} \right] + 120 \ \text{dBuA}$

Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

Inserting the proper values into this equation (for $n = 1$) yields an amplitude value for the fundamental frequency component of 158 dBuA.

The formulas for f_1 and f_2 ($f_1 = \frac{1}{\pi \tau_d}$ and $f_2 = \frac{1}{\pi \tau_t}$) are emperically derived and well known within the EMI/EMC community.

Knowing the formula for both f_1 and f_2 allows one to arrive at the complete frequency domain representation by only calculating three items, namely, C_n at the fundamental and frequencies f_1 and f_2.

NTS

Report Number	33069-97N
P.O. Number	TV-96218V
IJO Number	60789-97N
Date	21 May 1996

APPENDIX A

Figures

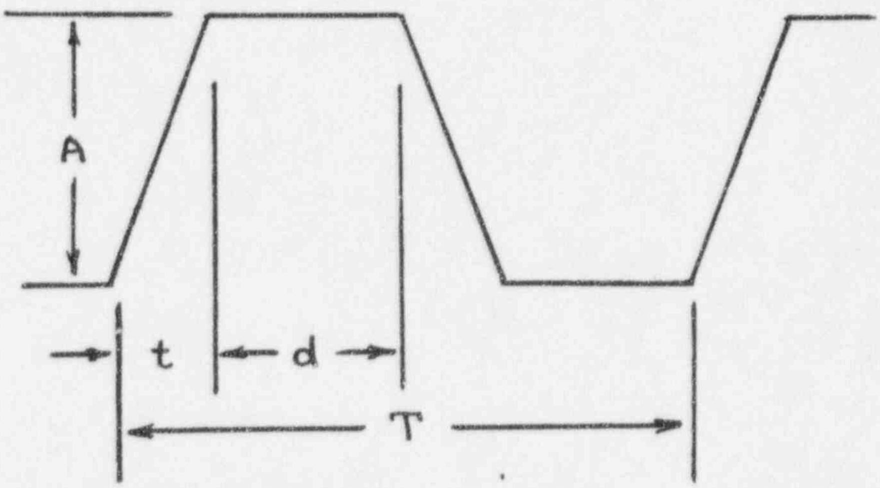

FIGURE 1: Segment of Generic Digital Signal Pulse Stream

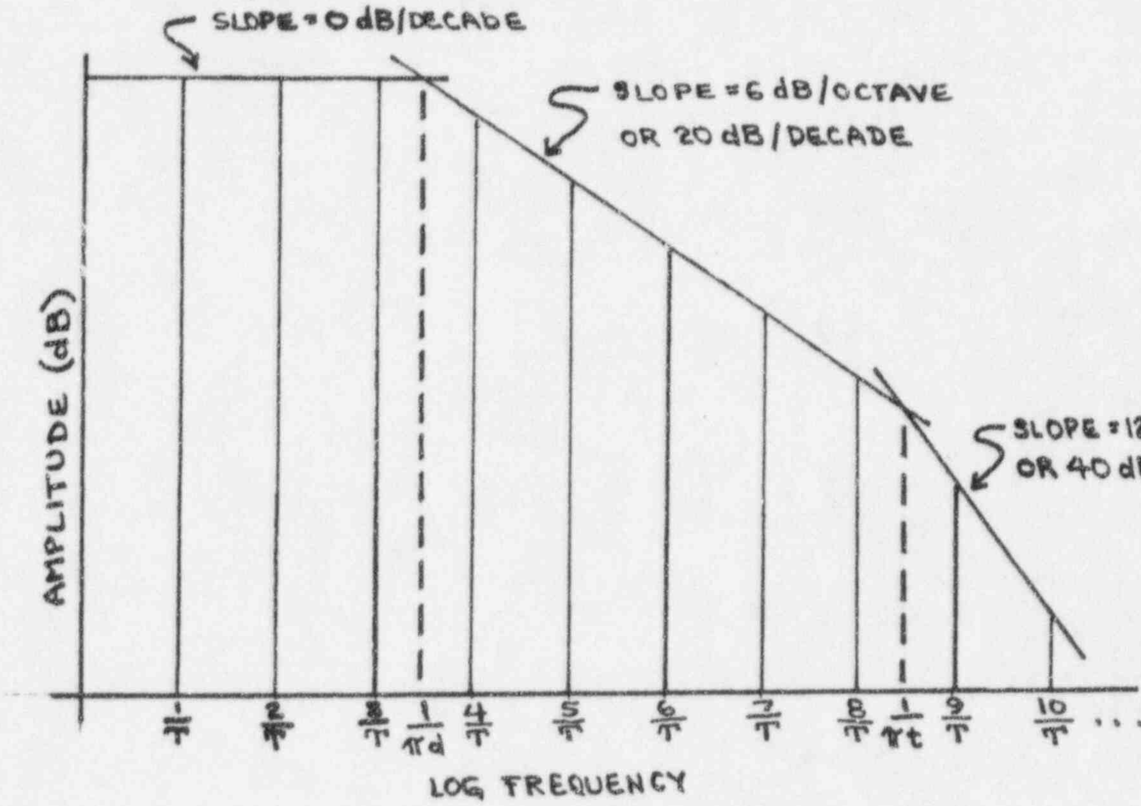

FIGURE 2: Frequency Domain Representation of Generic Digital Signal Pulse Stream

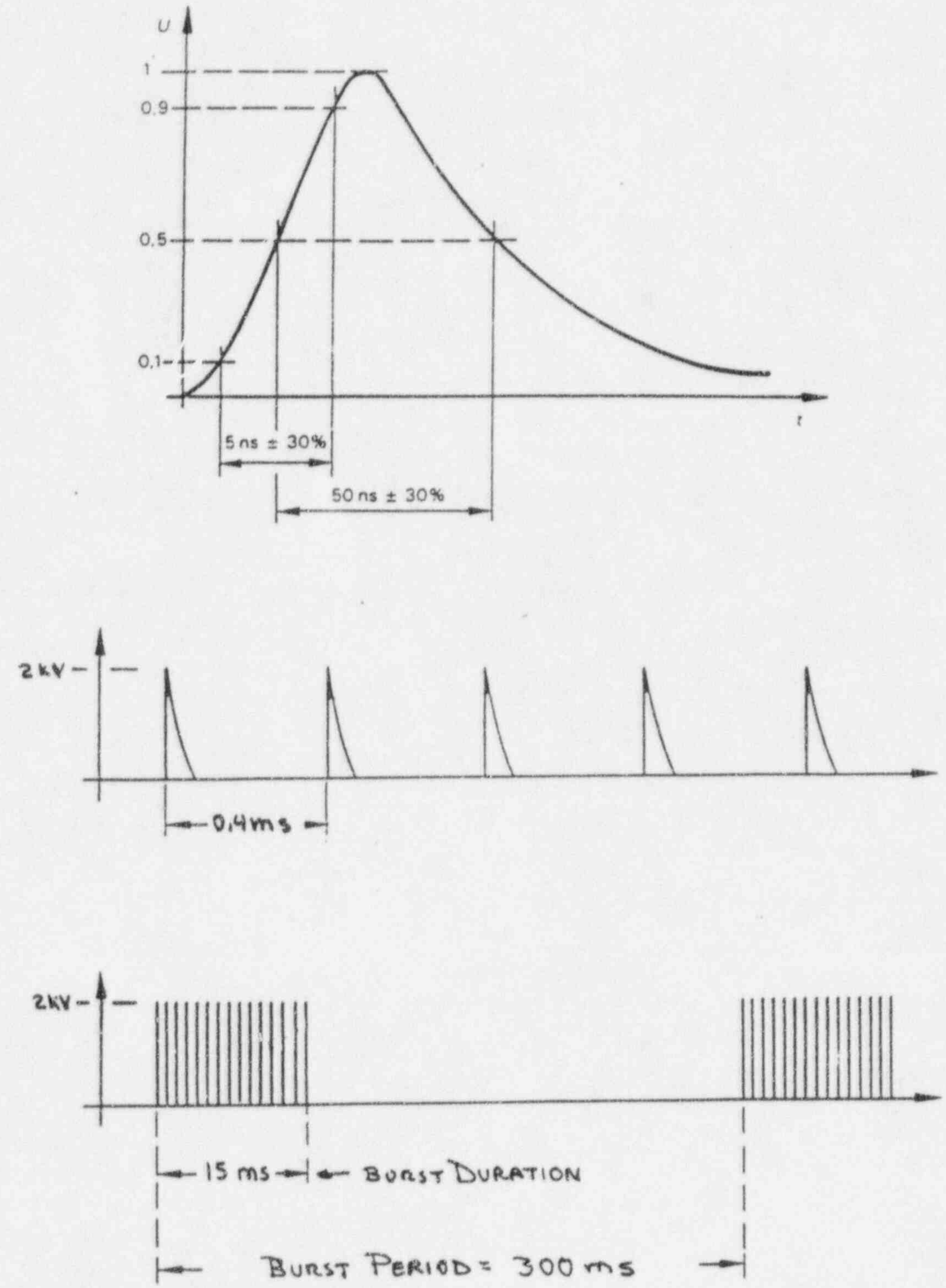

FIGURE 3: IEC 801-4 Susceptibility Pulse Train

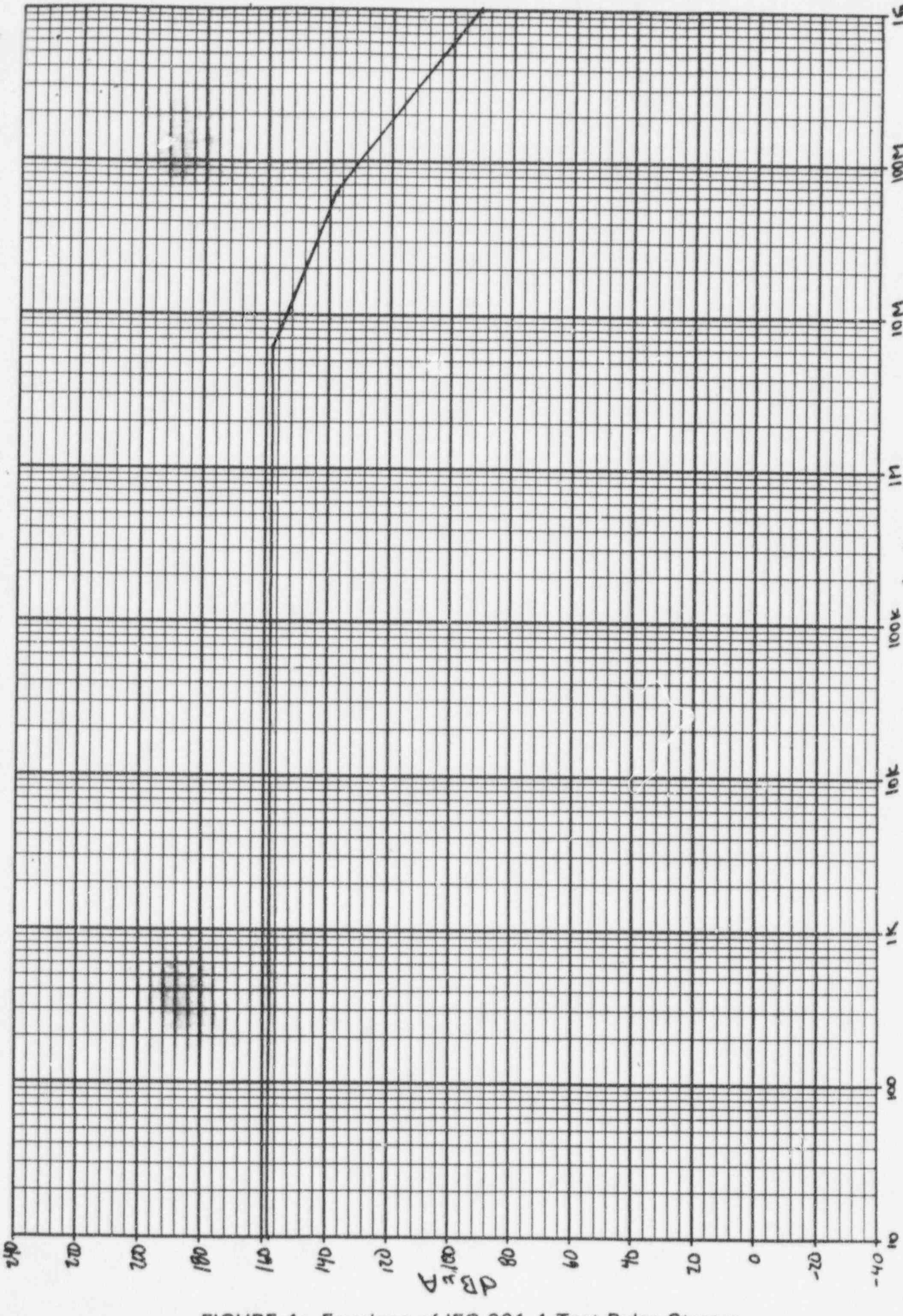

FIGURE 4: Envelope of IEC 801-4 Test Pulse Stream