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DISCLAIMER

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ABSTRACT

In this paper a phase-compensated distributed parameter electromagnetic delay line suitable for the readout of the positions of ionizing tracks in multi-wire proportional chambers is described. Delay lines with delays of 40 to 200 nanoseconds/cm having a rectangular cross section have been designed. The rectangular cross section enables them to be capacitatively coupled to the wire chamber simply by clamping them on the wire chamber external leads. The coupling coefficients between the chamber and delay line are approximately 3 to 10%. The electronic readout accuracy is better than ± 0.1 mm due to the delay line.

INTRODUCTION

It was shown in previous papers[1,2] that a readout scheme for a wire-proportional chamber using an electromagnetic delay line can be made which was considerably simpler and cheaper than the amplifier array method. A basic block diagram of the proportional-wire chamber and the associated electronics used for the pulse time determination is shown in Fig. 1a. Timing pulses can be obtained from both ends of the delay line. After amplification, both signals are applied to separate zero-crossing discriminators. The discriminator output pulses are applied to time-to-height converters. The conventional pulse-to-height analyzer is used for measurement of the position of the ionizing track and for the determination of the position accuracy.

Delay-line readout also offers significantly higher reliability than the amplifier per wire method, under actual operating conditions of wire-proportional chambers. Furthermore, the delay-line readout has the desirable ability to enhance the measurement accuracy by means of position information interpolation between discrete wires of the chamber[2].

In the above mentioned papers we have described the use of commercially available delay lines. Since these delay lines were designed primarily for the purpose of delaying electrical signals in a compact device, it soon became apparent that they did not have an optimized geometrical configuration and optimum electrical characteristics for wire-chamber readout. Consequently, a delay line whose geometrical configuration and electrical properties would be more suited for this purpose could be designed. The following criteria have been used in our development: (a) rectangular cross section with a sufficiently large area so that a high-capacitative coupling coefficient would be obtainable, (b) a design that could be readily built for wire chamber lengths of 50 to 100 cm, (c) delays between 40 to 200 nanoseconds per cm of delay line length, with very uniform delay dependence on the delay-line length, (d) delay-line effective bandwidth greater than 2 MHz, with low and uniformly distributed losses per delay-line length, (e) generally, the delay line should be designed without any ferrite or magnetic material in it, to allow its usage in the presence of magnetic fields of any intensity.

DELAY LINE DESIGN

Taking the above given criteria into account, delay lines having a rectangular cross section have been designed. Details of the delay line design are shown in Fig. 2. In this paper we describe a specific

delay line made on a plastic core, 2.5 cm x 0.3 cm in cross section and 55 cm in length. The internal conductor which is grounded consists of a mylar foil with longitudinal copper bands on one side. The metallic strip side is cemented on to the plastic core. A mylar backing, 25 microns thick, serves to provide the capacity between the metallic bands and the external conductor. The copper bands are approximately 2 mm wide. They are connected at both ends to the ground pins on the plastic core. The outer conductor consists of a closely wound helix of #30 gauge copper Formvar wire. In order to reduce the phase distortion as described in the following section, phase compensation is provided. This is done by means of a mylar strip with etched metallic bands of copper or aluminum, which is cemented onto one of the flat sides of delay line. The other flat surface is left free so that it can be used to couple onto the wire leads of the proportional chambers.

ELECTRICAL CHARACTERISTICS

It is well known that a delay line with one conductor consisting of a helix suffers from an appreciable degree of dispersion, because the effective inductance of the helix decreases with frequency[3]. In the commercial type "mini-lines"[4] which we have used previously, this dispersion is compensated by using a zig-zag winding on a small diameter ceramic former. Alternative methods of phase compensation are the use of skewed turns on a helical winding[5] and the use of floating patches[6]. In the present design the floating patch method has been used, since it allows the use of a simple helical winding. Also, the compensation can be made with a high degree of uniformity along the total delay line length. This is done by cementing onto the delay line a long strip of mylar with thin metallic bands on it. The amount of compensation is adjusted by varying the pitch of the compensating bands.

Figure 3 shows the response of the delay line to a step function input with a rise time of 50 nanoseconds to simulate the chamber response. The traces (a) and (b) were taken with the delay line uncompensated; (a) shows the output when the pulse is fed in as in a conventional delay line. The oscillations seen in the output are due to the higher frequencies propagating with a larger velocities than the lower frequencies. The trace (b) was taken with the input pulse fed in capacitatively in a chamber configuration. The capacitative input has the effect of differentiating the input step function; this combined with the dispersion produces the resultant effect seen in Fig. 3b. The traces 3c and 3d were taken with the delay line compensated. From this it can be seen that the compensation produces a clean pulse whose arrival can be timed to an accuracy of 1 nanosecond.

As mentioned above, the compensation for the dispersion is obtained by use of the mylar strip with the aluminum bands. The angle of the bands is selected empirically by observing the effect on input step functions. For the best compensating effect the angle between the longer axis of the delay line and metallized bands turned out to be 45± 3 degrees, for the particular line described here. The amplitude response as a function of frequency of this line is shown in Fig. 4 with compensating bands at the optimum angle and with a resistive terminating impedance $R_0 = 620\ \Omega$.

PROPORTIONAL CHAMBER APPLICATIONS

In the proportional chamber readout applications the signal is not fed from one end as in conventional delay line use, but it is coupled capacitatively from each wire of the chamber to the helix. The connection to the chamber is shown schematically in Fig. 1b. The coupling coefficient of such a line is approximately from 3 to 4% for signals injected from any one wire. A somewhat higher coupling, in the range from 5 to 10% can be obtained if the delay line is coupled onto the wire leads by means of a glycerine or a TiO_2-epoxy mixture layer since they have dielectric constants of 40 and 14 respectively.

Figure 5 shows the delay of the pulse as a function of the distance between this input--fed in capacitatively--and the end of the line. The linearity depends on the uniformity of inductance, shunt capacity and compensating capacity per unit length. In our line, aside from a region 2 cm long at either end, the deviations from linearity are less than ± 0.2 mm. The end deviations are due to the fact that the mutual inductance which is uniform along the line becomes rapidly smaller where the helical winding begins and ends.

The amplitude of the output pulse as a function of the input pulse position is shown in Fig. 6. In 6a we plot the attenuation of the amplitude as a function of the distance from a chamber wire to the end of the delay line. In 6b we plot the attenuation of the area of the pulse as a function of distance. The reason for doing this is that timing discriminators which operate by a comparison of integrated pulses[7] can be used and give a more accurate determination of pulse positions than the more conventional zero crossing discriminators. In 6c we show the change in pulse shape as a function of position.

CONCLUSIONS

It is shown that use of distributed parameter electromagnetic delay lines offer a very satisfactory method for proportional-wire chamber readout. The readout delay line has been designed with the following mechanical and electrical parameters:

Core Length	58.3 cm	
Winding Length	57 cm	#30 wire, 34 turns/cm
Width	2.6 cm	
Thickness	0.9 cm	
Ground Strip Width	3 cm	
Ground Strip Area	170 cm^2	

Total Capacity	4.73 nF
Capacity per cm	83 pF/cm
Total Inductance L	1.9 mh @ 10 KHz
Inductance per cm	33.3 μh
Total Delay	2.7 μs
Delay per cm	47.7 ns
$Z_o \cong 620\ \Omega$ (experimental datum)	
Rise Time	220 ns
Delay/Rise Time Ratio ≅	12.5

The main disadvantage of the delay line described here for proportional chamber readout is that two pulse resolution is not satisfactory, although it may be compensated for by timing the arrival of the pulses to the two ends of the line. However, this method will not be effective for three pulses or more. A very important exception to this is in the location of showers, where the following data can be obtained: (a) the position of the centroid of the shower (b) the width of the shower (c) the total energy deposited by the shower in a given chamber gap. The integrating type timing discriminators mentioned previously can be used to obtain this information[8].

FOOTNOTE AND REFERENCES

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FIGURE CAPTIONS

Fig. 1 (a) Basic Block Diagram of the proportional chamber and associated electronics used for the pulse time determination.
(b) Cross section of chamber showing rectangular delay line, capacitatively coupled to chamber leads.

Fig. 2. Details of rectangular cross-section delay line with floating patch, phase-compensation.

Fig. 3. Output pulses from delay line showing effects of phase compensation. The input pulse is a step function with a rise time of 50 nsec to simulate the chamber input.
(a) Uncompensated line -- output pulse at far end.
(b) Uncompensated line -- output pulse for input fed capacitatively to simulated chamber input.
(c) Output pulse from compensated delay line.
(d) Output pulse from compensated delay line for input fed in capacitatively as in (b).

Fig. 4. Frequency response of delay line shows band pass at 3 db = 2.5 MHz.

Fig. 5. Linearity response of delay line showing end effects.

Fig. 6. Response of delay line to simulated chamber inputs fed in capacitatively.
(a) Output pulse amplitude as a function of distance of input pulse.
(b) Output pulse area as a function of distance of input pulse. The attenuation is smaller than (a) indicating the preferential use of integrating discriminators.
(c) Shape of output pulses as a function of input pulse position.

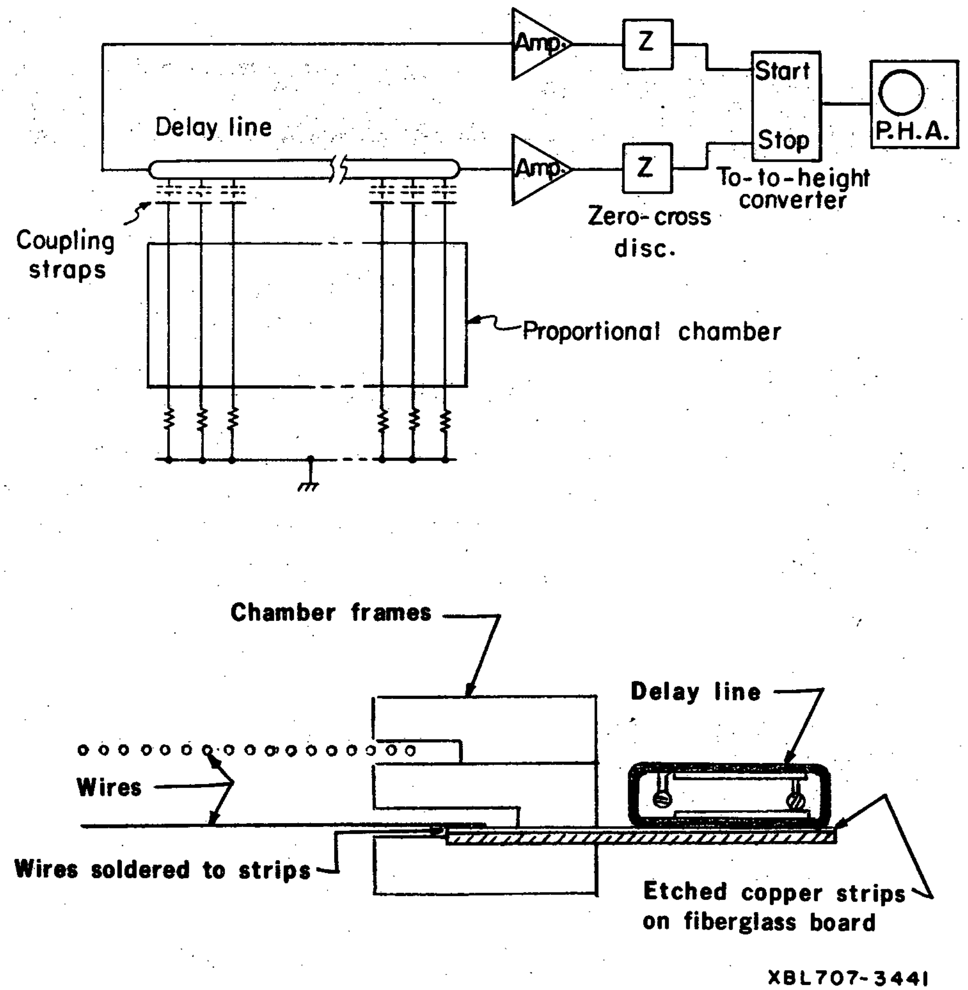
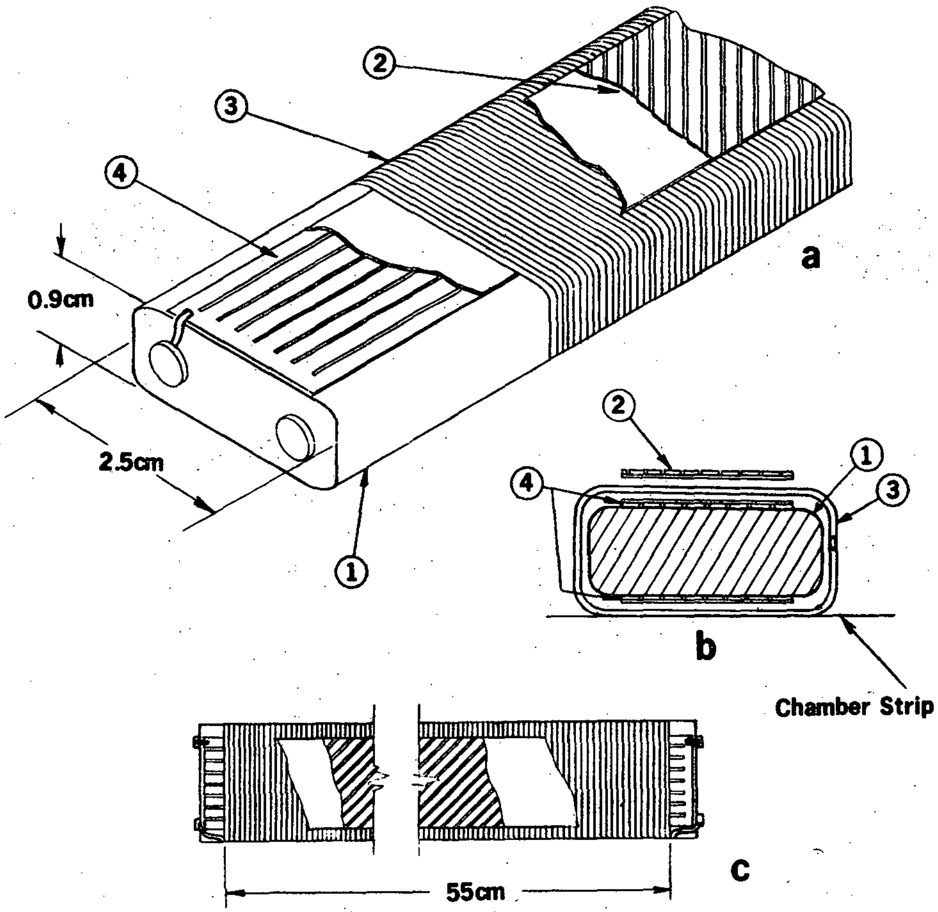


Fig. 1



① Plastic Core

② Floating Metal Strips On Mylar Base: Strips = 1.8mm Wide; Gaps = 0.3mm Wide; Mylar = 25 Microns Thick

③ Winding = #30 Formvar Wire

④ 8 Copper Strips On Mylar Base: Strips = 1.8mm Wide; Gaps = 0.3mm Wide; Mylar = 25 Microns Thick

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Fig. 2

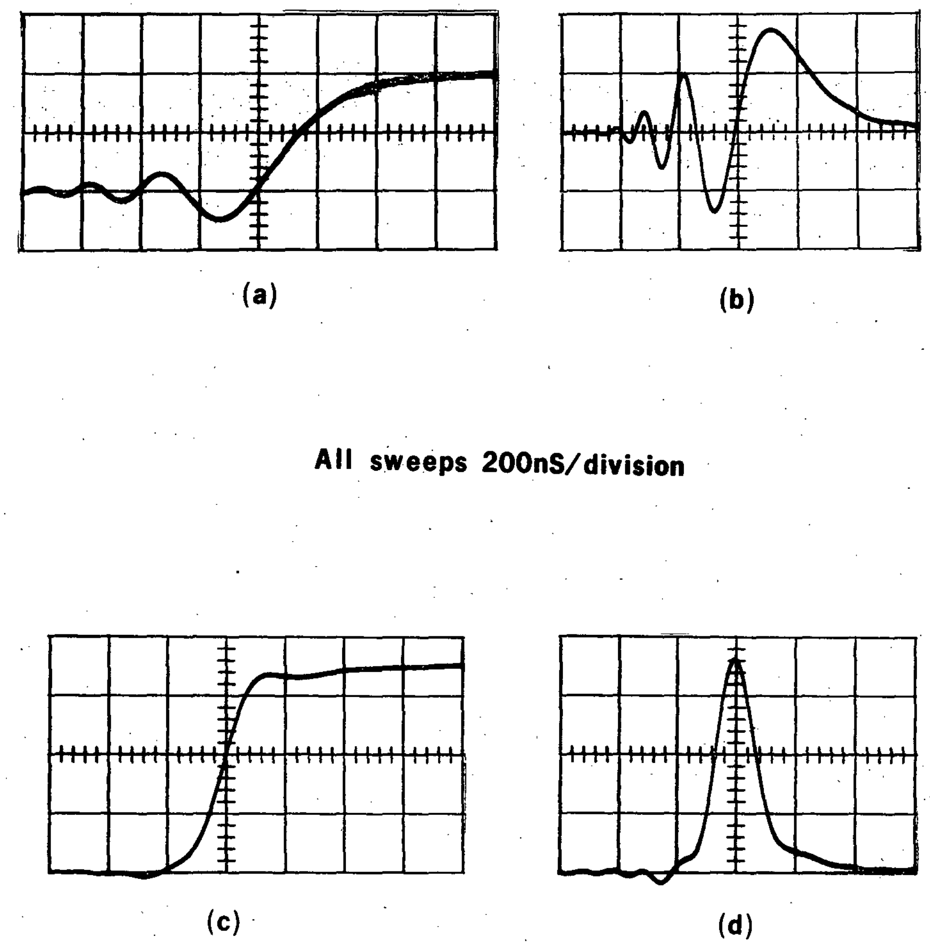

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Fig. 3

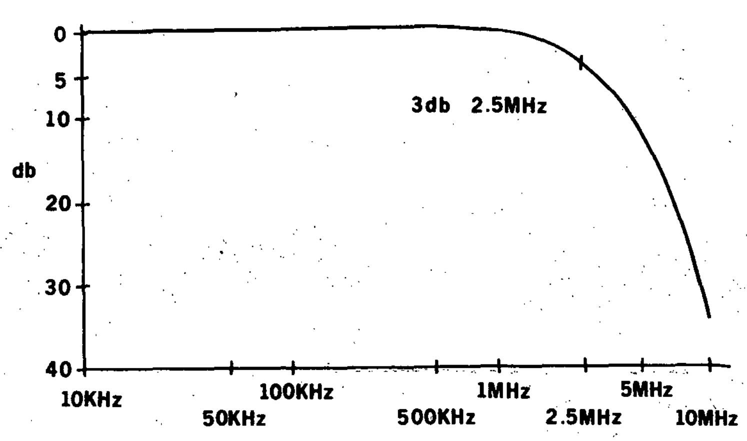

Fig. 4

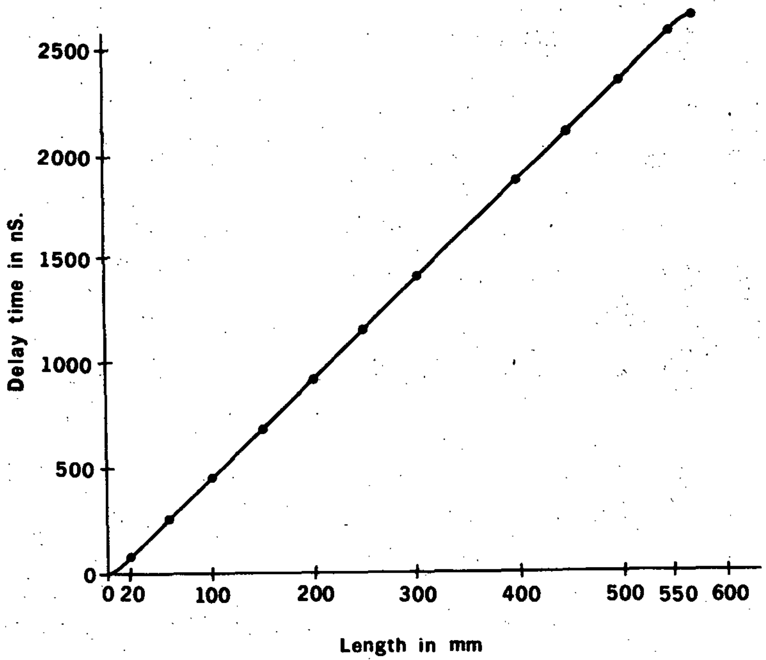

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Fig. 5

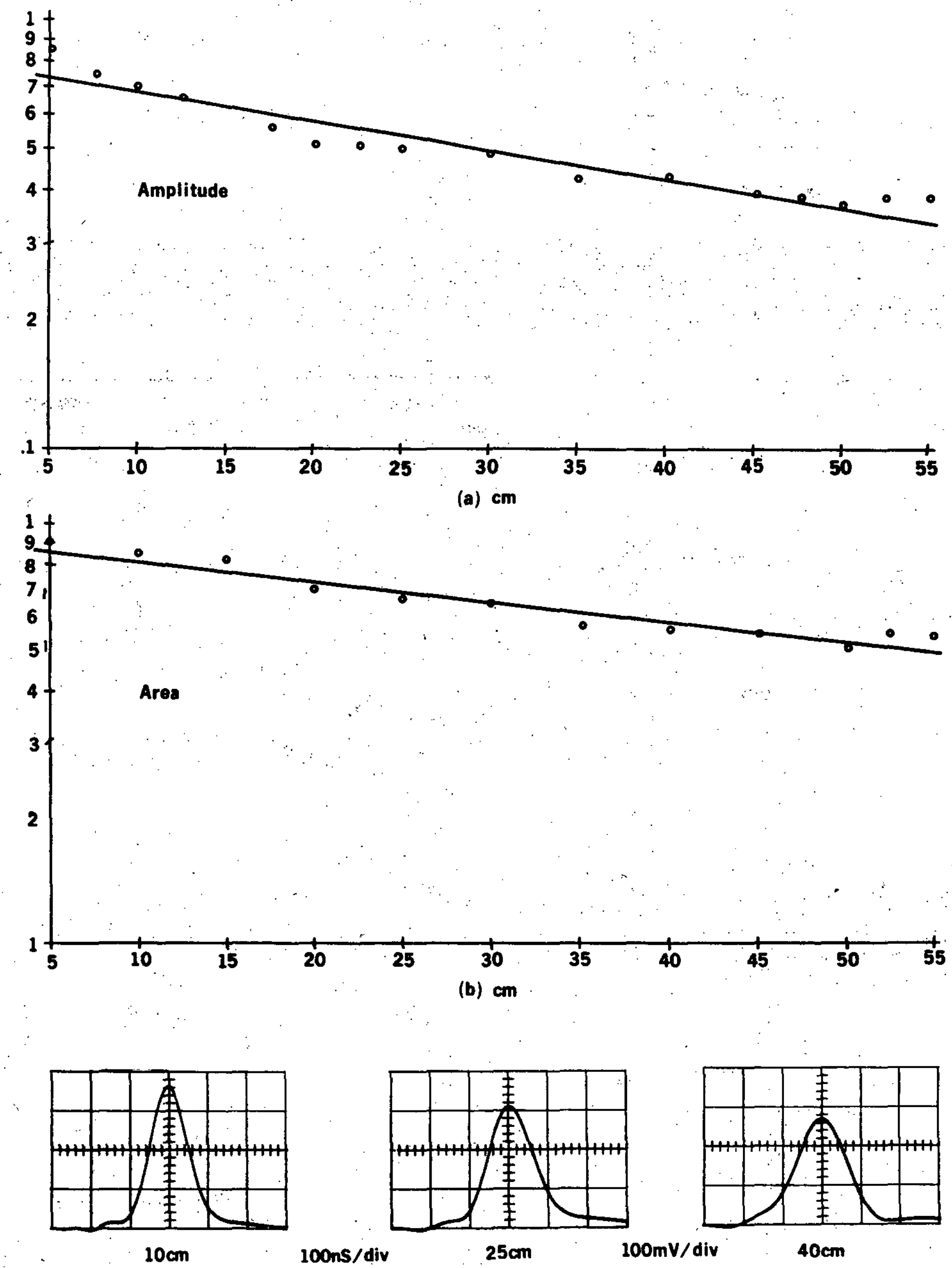

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Fig. 6

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