IMPROVED DELAY LINES FOR PROPORTIONAL WIRE CHAMBER READOUT*

R. Grove, V. Perez-Mendez and J. Sperinde

Lawrence Berkeley Laboratory

Berkeley, California

August 1972

ABSTRACT

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Various modifications to the electromagnetic delay lines used for wire chamber readout are described. These modifications consist of changing the cross-sectional area of the lines and decreasing the eddy current losses and the dielectric losses. Also, the characteristic impedance of the lines is increased. The effect of these modifications is to increase the coupling efficiency to the chamber wires and to make the delay-to-risetime ratio equal to 30 for a 50 cm. long delay line.

INTRODUCTION

In previous papers¹ a readout scheme for wire-proportional chambers using electromagnetic delay lines has been presented. This method has the advantage of being both simpler and cheaper than the amplifier array

MASTER

* Work done under the auspices of the U. S. Atomic Energy Commission.

method as well as providing higher spatial resolution. The construction and electrical characteristics of phase-compensated distributed parameter electromagnetic delay lines suitable for use with proportional wire chambers were also described.² The criteria that we have used in the delay line development are as follows:

a) The bandwidth of the delay line should be approximately matched to the risetime of the proportional chamber pulses. Typically the chamber pulses have a risetime of ~ 100 ns for minimum ionizing particles traversing a 0.5 cm gap in 90% Argon - 10% Methane at one atmosphere pressure. Under the same conditions, the risetime for pulses produced by localized ionization such as the photoelectric conversion of 6 keV photons in the gas is about 30 ns.³

b) The coupling to the chamber should be simple and the coupling efficiency should be high. The lines are made with a large area rectangular cross-section and the desired coupling efficiency is obtained by placing the line on a flat surface with plated metallic bands which are connected to the chamber wires.

c) The impedance should be high to allow good coupling without loading the chamber pulse.

d) There should be uniform delay dependence on delay line length.

e) The delay per unit length should be $\sim 50 - 100$ ns/cm so that timing electronics with a minimum time jitter of 1 ns is sufficient to localize the pulse origin to a fraction of a millimeter.

f) The attenuation should be moderate for a line $\gtrsim 1$ m.

g) The two pulse resolution should be as good as possible.

All of the above criteria are not independent. The delay per unit length is given by $\sqrt{LC}$, the impedance by $\sqrt{L/C}$ and the bandwidth is proportional to $\sqrt{\frac{1}{LC}}$ where L is the inductance per unit length and C is the capacitance per unit length. In practice the delay per unit length is made as large as is possible without causing unacceptable attenuation of the signals due to the decrease in bandwidth. The desired high impedance is obtained by making L relatively large and C relatively small. The best overall performance is obtained when the minimum rise time of the delay line is approximately equal to the rise time of the chamber pulses.

Modifications in Delay Line Construction

The changes described below were made in order to increase the high frequency response of the lines and to increase the coupling efficiency to the chamber.

First the thickness of the line has been made smaller. This increases the effective number of sections, since the distributed delay lines can be considered as consisting of a number of sections with the section length determined by the thickness of the lines.⁴ A well known property of lumped-section delay lines⁵ is that the delay-to-risetime ratio increases as $n^{2/3}$ where n is the number of sections. In order to maintain the delay per unit length at the desired value of 50 - 100 ns/cm, the quantity $\sqrt{LC}$ has to be maintained at the desired value. This can be done by increasing the width of the line as well as the number of turns/cm of the helical winding.

Eddy current losses in the distributed ground strip have been reduced by making it of copper-plated lines on Mylar or Kapton with strips of

1 mm or less in width. The eddy current losses in the compensation pads have been eliminated by making them of aluminum plated Mylar with thin enough platings so that the resistance is of the order of 1 Ω /square. The compensating pads could have been made of the same material as the ground strip without affecting the performance of the line. Eddy current losses also occur in the coupling pads and they likewise can be reduced by dividing each pad into narrow strips or making the pads of resistive material.

Dielectric losses in the distributed capacitance of the delay line have been minimized by making the plastic former of Nema G-7 (a glass-fibre plastic impregnated with low-loss silicone resin) and the dielectric spacer between the ground plane and the helical winding of Polyethylene.

The coupling efficiency of the delay line to the chamber wires has been increased primarily by raising the characteristic impedance of the line as well as by increasing the coupling capacity between the line and wire pads. This latter increase occurs primarily from the increased width of the delay line which is in close proximity to the chamber pads.

That these changes produce better coupling can be understood in the following way. Define a coupling capacity C_c between the metallic strip and the delay line. Then for signals of a given frequency (say typically 3 MHz) the capacity acts as an impedance given by $Z_c = \frac{1}{2\pi f C_c}$ where f is the frequency. This impedance is in series with one half of the delay line impedance. The reason that the signal sees only half the full impedance is that a signal entered at a midpoint of the line sees two lines, one in each direction, and thus sees the two characteristic

impedances in parallel. The coupling capacity and delay line behave as a voltage divider and the fraction of the input voltage transmitted in each direction is given by $(Z_d/2)/(Z_c + Z_d/2)$ or $Z_d / (2Z_c + Z_d)$ where Z_d is the line characteristic impedance. From this expression it is evident that both the increased coupling capacity and the increased characteristic impedance improve the coupling efficiency. As an example, suppose $C_c = 20$ pf, $f = 3$ MHz and $Z_d = 1500 \Omega$. Then $Z_c = 2650 \Omega$ and $Z_d/(2Z_c + Z_d) = .22$. These numbers are typical for our recent delay lines. Note however that further increases in C_c do not produce comparable increases in the delay line signal amplitude obtained from a chamber. This is because the chambers are current limited sources and increasing the coupling efficiency merely loads the signal on the chamber producing only slight gains in the output signal from the delay line. Schemes in which the chamber wires are directly coupled to the delay line can increase the amplitude of the output signal by at most about 50%.

The construction of the delay line is shown in fig. 1. The electrical characteristics, from measurements described below, are given in Table 1. For comparison, the characteristics of the old line are included also.

Table 1

Mechanical and electrical parameters of the delay line.

Parameter	New	Old
Length	51 cm	57 cm
Width	3.2 cm	2.6 cm
Thickness	.33 cm	.9 cm
Windings (#38 wire)	78 turns/cm	34 turns/cm
Ground Strip Width	2.5 cm	3.4 cm
Compensation Strip Width (45°)	≈ 1 cm	1.8 cm
Inductance	77 μ h/cm	30 μ h/cm
Capacity	36 pf/cm	49 pf/cm
Impedance	1500 Ω	750 Ω
Delay	52 ns/cm	39 ns/cm
Coupling efficiency	18%	5%
Attenuation	5 db/m	6.5 db/m
Band pass	-3 db @ 3 MHz	-3 db @ 2.5 MHz
Delay/Risetime	30:1	15:1
D. C. resistance	590 Ω	300 Ω

From the table, taking the delay-to-risetime ratio as a figure of merit, it is seen that the new line with a value of 30 is appreciably better in its overall frequency response than the previously described line. The coupling efficiency and attenuation are determined by measuring the voltage response of the line to a 100 ns rise time step function input from a voltage source. The signal is capacitively coupled to the delay line using a printed circuit board with 5 strips/cm of the same type as is used on the wire chambers. Typical pulses are seen in fig. 2a. The delay-to-risetime ratio is obtained by directly coupling a short rise time step function in one end of the line and measuring the time delay and risetime (10% - 90%) of the step function at the other end. To measure the corresponding two pulse resolution, two equal amplitude pulses are simultaneously entered on the line via a coupling board as

described above, again using step functions with a 100 ns rise time. The two pulses are said to be resolved when the dip between the two peaks is a quarter of the peak amplitude. Some pulses showing the line response versus the two pulse separation at the distance of 25 cm from the end of the line are shown in fig. 2b.

Conclusions

The coupling efficiency of the electromagnetic delay lines to multi-wire proportional chambers has been increased to approximately twenty percent by increasing the chamber to delay line coupling capacity and increasing the delay line characteristic impedance. Further increases in coupling efficiency are probably not justified since very little additional output signal is obtained due to the loading effect of the delay line on the chamber pulses. The two pulse resolution of the lines has been significantly improved as is evidenced by the delay-to-risetime ratio of 30. This improvement has been obtained by making the lines thinner thereby increasing the number of sections in the equivalent lumped constant delay line and by reducing eddy current losses and dielectric losses.

REFERENCES

1. R. Grove, K. Lee, V. Perez-Mendez, and J. Sperinde, Nuc. Inst. & Methods, 89 (1970) 257.
2. R. Grove, I. Ko, B. Leskovar, V. Perez-Mendez, Nuc. Inst. & Methods, 99 (1972) 381.
3. Sherwood Parker, private communication.
4. M. J. E. Golay, Proc. IRE 34 (1946) 138.
5. W. C. Elmore and M. Sands, Electronics, (McGraw-Hill Book Company, Inc., New York, 1949), p. 39.

FIGURE CAPTIONS

- Fig. 1. Details of rectangular cross-section delay line with floating patch phase-compensation.
- Fig. 2. Response of delay line to simulated chamber inputs fed in capacitively. (a) Output pulse amplitude and shape as a function of distance of input pulse. (b) Output pulse shape as a function of distance between input pulses at 25 cm down the line.

1. G-7 Fiberglas core (silicone resin binder).
2. Winding (#30 wire, 8 turns/mm).
3. Ground Strips (10 strips/cm of 25 μ m Cu. Strip width = 0.5 mm, gap width = 0.5 mm).
4. Compensating Strips (metalized strips on plastic).
5. Terminating Resistor.

Fig. 1

DELAY LINE PULSES

Fig. 2a

DELAY LINE PULSES FOR TWO SIMULTANEOUS EQUAL-AMPLITUDE INPUT PULSES

Fig. 2b