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# THE DELAY LINE READOUT TECHNIQUE APPLIED TO PROPORTIONAL CHAMBERS USING ELECTRONEGATIVE GAS MIXTURES

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SUMMARY

The delay line readout technique was adapted to proportional chambers using electronegative gas mixtures. This requires lines with improved rise time, but allows somewhat shorter delays; at the same time, we improved the two-pulse resolution. Our new line is 55cm long, has a delay to rise time ratio of 50 for a delay of 2.1 μs; two pulse resolution in the middle of the line is of the order of 15mm for equal amplitude pulses.

We also investigated aluminum core and printed circuit delay lines. We found that the first ones are well suited for low to medium delays with medium two pulse resolution; the second ones are adapted to low delays and may have extremely good delay to rise time ratio in the differential stripline configuration.

## INTRODUCTION

The electromagnetic delay line readout of proportional chambers has been described in previous papers.[1,2] This method is cheaper than the one amplifier per wire technique and, when applied to cathode planes, provides higher spatial resolution, if delays of 10 to 100ns/cm are used, depending on the performances of the associated electronics. For large chambers, the resulting dead time may become prohibitive, so a value of the delay as low as possible is preferred. On the other hand, the intrinsic two pulse resolution of the chamber may be degraded by the line; to limit this effect, delay lines with high delay to rise time ratio are needed when the chamber must detect more than one track at a time; in any case a high delay to rise time ratio allows the discriminators to work under better conditions.

Due to its simplicity, we favor capacitive coupling of the delay lines to the chamber, the lines having a wide rectangular cross-section and being pressed against a flat surface supporting metallic strips connected to the chamber wires. The impedance of the delay line should then be high to obtain a good coupling efficiency; this is also necessary because the attenuation along the line is determined by the ratio of its resistance to its impedance.

Wherever an electronegative gas is used in a proportional chamber, shorter pulse rise times are obtained, usually with much larger amplitudes and reduced dynamic range. Then, the coupling efficiency is less important, especially with low noise amplifiers[3]; then it becomes possible to obtain better rise time, lower delay and improved two pulse resolution.

Of course, the optimisation of the line depends on the particular application as well as on the available electronics: It may for example be worthwhile to sacrifice two pulse resolution or even some spatial accuracy in order to obtain a very short dead time.

## OPTIMISATION OF THE DELAY LINE

Proportional chambers are often used to detect several simultaneous tracks, so we consider two pulse resolution as the most important factor; therefore our primary goal is to obtain a high delay to rise time ratio.

In lumped circuit delay lines, the ratio increases as $n^{2/3}$ with increasing number n of cells. For distributed parameters lines, n is defined by the distance at which a significant mutual inductance between turns exists, so n increases when the thickness of the line is diminished. Therefore we must make n large, with low mutual inductance between cells but with high self inductance in each cell; n is limited by mechanical considerations and the maximum self inductance by the tolerable attenuation since, as more turns of thinner wires are used, the resistance increases and therefore the output signal decreases as,

$$V_{out} = V_{in} e^{\frac{-R}{2Z}} \qquad \text{with } Z = \sqrt{\frac{L}{C}}$$

The inductance of the line being defined, the upper limit of the capacity is given by $Z = \sqrt{L/C}$ and by the acceptable value of $R/2Z$, keeping in mind that the delay must allow good spatial accuracy with the timing discriminators that are available. The lower practical value of C may also sometimes be determined by the capacity of the coupling board or by the sensitivity of the line to parasitic capacitances.

## DESCRIPTION OF THE LINE

As the mutual inductance is decreased, less compensation is needed. We designed the line so that it doesn't need compensation when used with our standard coupling board. Otherwise, it requires a very small amount of compensation.

The mechanical and electrical parameters of the line are:

| | |
|---|---|
| Length | 55cm |
| Width | 3.3cm |
| Thickness | 0.15cm |
| Winding (#36 wire) | 60 turns/cm |
| Ground strip width | 1.5cm |
| Delay | 2.1μs |
| Impedance | 800Ω |
| Delay/rise time | 50 |
| DC resistance | 300Ω |

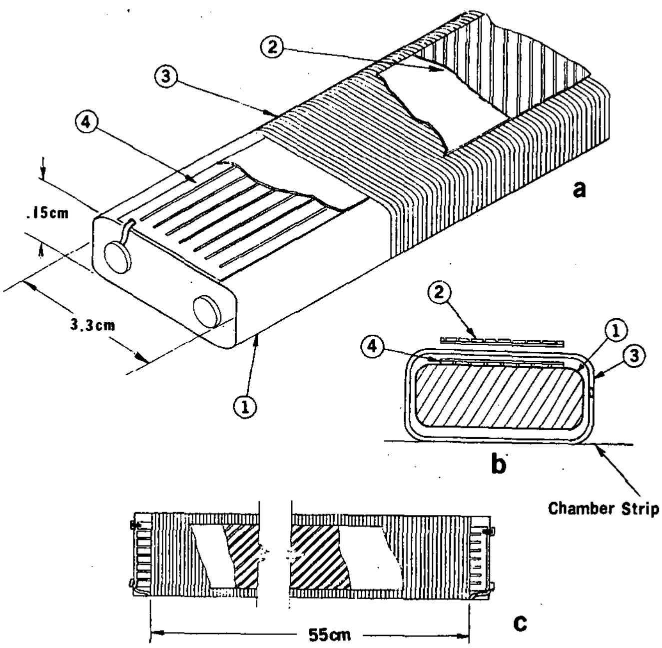
The mechanical construction appears in fig.1. The rise time is measured with simulated chamber pulses, as can be seen on fig. 2a). The attenuation and deformation of the pulse along the line are obtained by comparing pulses fed at 10 and 40cm from the output. The two pulse resolution is shown on fig. 2b).

## ALTERNATE SOLUTIONS

Following a suggestion of D.M. Lee and others[4], delay lines with aluminum cores were also tested and reasonably satisfactory results were obtained with short delays. Since there are image currents induced in the core, the inductance of the line is essentially the self inductance of the wire itself. With delay lines of this type, we were not able to achieve delay to rise time ratios better than 25 with delay of the order of one microsecond. Delay lines of this type tend to have low inductance, moderate to high capacity, therefore relatively low impedance and fairly high DC resistance, with, a resulting large attenuation.

As the number of cells seems in first approximation to be defined by the thickness of the insulation between wire and aluminum core, the cross section of the core itself is not critical. These lines seems to be a satisfactory solution where some deterioration of the two pulse resolution and low to medium delays are acceptables.

Strip delay lines[5], especially the differential strip[6], have a promising potential use in wire chamber readout. These lines can be made by printed circuit techniques on copper-clad mylar and hence are easily produced in large numbers, with good uniformity of characteristics. Their delay to rise time ratio can exceed 60(ref. 5). For long delays, we experienced some difficulties in keeping the attenuation low enough; this problem is enhanced by the low impedance of these lines, typically 50-100Ω. Satisfactory lines made by etching zig-zag patterns 38mm wide, with a pitch of 1.75mm on copper plated Kapton 100 microns thick, have a delay of 3.5 ns/cm over a length of 60 cm. Of course, this delay is still too low to provide good spatial accuracy, but due to their low mass, these lines are useful for reading the second coordinate along the wires of a drift chamber with medium accuracy.




① Plastic Core

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

③ Winding = #36 Formvar Wire

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

Fig. 1. Structure of the delay line.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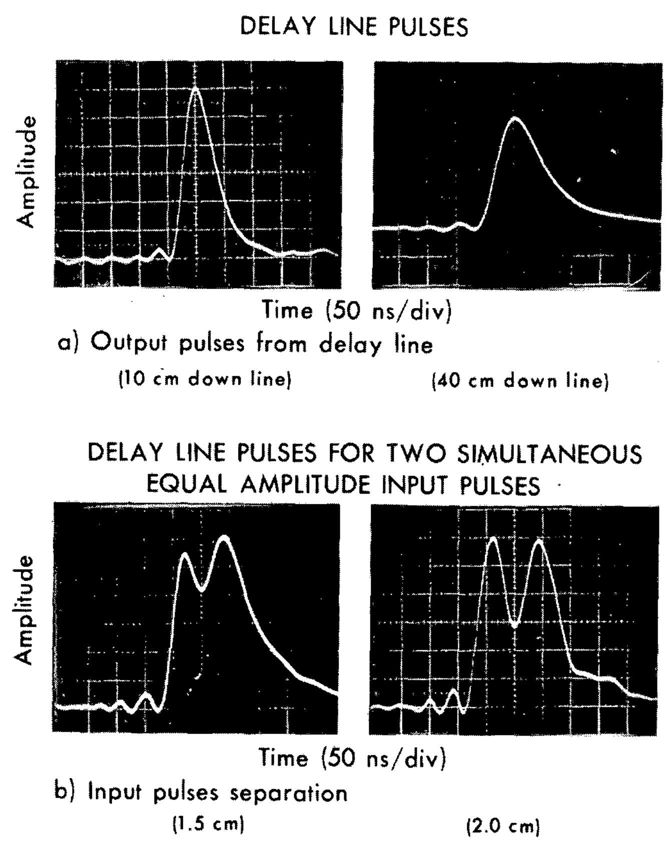


Fig. 2. Response of delay line to simulated chamber pulses fed in capacitively.

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