DELAY LINE FOR MEASURING THE WAVE-FORM OF ATMOSPHERICS

Akira IWAI and Yukihiro SUGIYAMA

Summary—Several trials have been made to obtain a suitable delay line for measuring the wave form of atmospherics, but sufficient characteristics have not been obtained. Recently, a supersonic delay line is manufactured in Japan. An excellent result which had not been attained is now obtained by using this supersonic delay line. The delay time obtained at present is 250 micro-seconds, but the value of 500–600 micro-seconds is reached without any trouble.

I. Introduction

Up to the present, a time sweeping system of start-stop has been employed to display the waveform of atmospherics on a cathode ray tube screen for the purpose of saving films and synchronizing to a cathode ray direction finder. This sweeping system has a defect in that initial parts of waveforms are missed and orders of pulses on the cathode ray tube screen are obscure. Several trials have been carried out by both foreign workers and us to solve this trouble, but sufficient characteristics to employ in the waveform recorder have not been yet obtained, because for a straight delay system, the specific band width is too wide to pass through the waveform of atmospherics. The imperfect delay circuits constructed by many lumped L, C, R constants have, however, been used from necessity described above, but their delay time is several 10 micro-seconds at the most. It has been concluded that a carrier frequency delay system may be expected to yield good characteristics because of the compression of the specific band width, but suitable delay media have not been obtained for improving this old delay system. Recently, the supersonic delay line is also manufactured in Japan with the developments of electronic computers and the solution of this problem was urgent with the advance of studies of waveforms. So, we carried out an experiment using a supersonic delay line and obtained an excellent result.

II. Delay Line for Measuring the Wavefrom of Atmospherics

1. Delay System

A signal to be delayed is modulated by a carrier wave of suitable high frequency and transformed to a narrow band width to pass through the supersonic medium. Then, the modulated signal passed through the delay line is amplified and detected. This detector output is the signal to be recorded. On the one hand, the signal introduced from a previous stage of the delay line, is used to operate the sweep start circuit and the brilliance modulation circuit. A block diagram of this system is shown in Fig. 1.

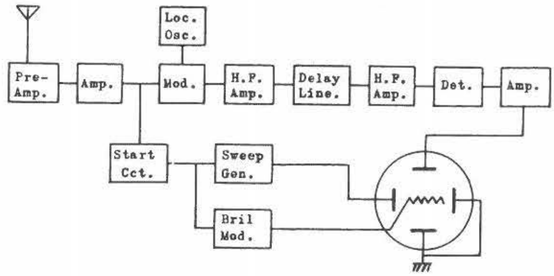


FIG. 1. Block diagram of delay system.

2. Delay Line

The delay line used in this system is MS-4 supersonic delay line manufactured by Kinsekisha Laboratory Ltd, which has been developed for use in electronic computers. Its appearance, internal construction and electric characteristics are shown in Photo. 1, Fig. 2 and Table 1, respectively. In the case of the pulse modulation system, spurious and leakage signals are out of question, but they must be suppressed to the highest degree for the amplitude modulation which is used in this delay line by reason of simplifying the apparatus. It is difficult to obtain an extremely long delay time. So, the value of 250 micro-seconds is employed, but it is multiplied by about ten for those of the conventional delay system.

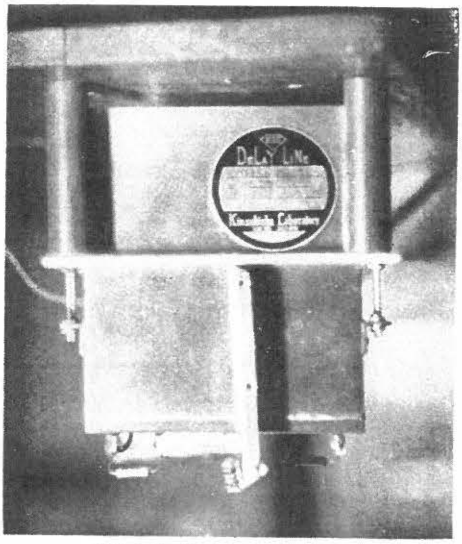


PHOTO. 1. Appearance.

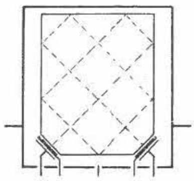


FIG. 2. Internal constrution of MS-4 type delay line.

TABLE 1. Electrical Characteristics of Delay Line

MS-4 Type Delay Line							
Freq.	Delay Time	Insertion Loss	Spurious	Terminal Impedance	Cap. Input	Cap. Output	Dimension
15 Mc/s	250 μsec	32 db	35 db	1,000 Ω	35 pF	34.5 pF	125×145×25 m/m

3. Circuit System

As shown in Table 1, the carrier frequency of this delay line is 15 Mc/s, while the frequency band of the waveform of atmospherics ranges from 50 c/s to 300 kc/s. So, it is necessary to transform 50 c/s-300 kc/s to 15 Mc/s by the amplitude modulation system. In the range of 15 Mc/s ± 300 kc/s, the characteristics of the delay line are nearly constant. The suppressor grid modulation of 6 AU 6 is used, its output signal being supplied to the delay line through an amplifier stage. The output signal from the delay line is amplified by two amplifier stages and is detected by a germanium diode. The detected output signal is introduced to the final amplifier stage of the waveform recorder. All this amplifing circuit system must be covered throughout the operating range by sufficiently linear characteristics. The input voltage of the delay line is about 4.9 V, the output 0.12 V, the input voltage of the detector 11.5 V.

4. Distortion

This delay line makes use of the multiple reflections in a square block of vitreous silica, while the directivity of two transducers used in this delay line is shown in Fig. 3. So, long delay times produce high spurious signals which are found out at unexpected places. This spurious signal must be reduced as little as possible, because it is difficult to distinguish between the atmospherics and the spurious signals of them. To measure the spurious signal ratio, the pulse modulated carrier wave is applied to the delay line and its output pattern is shown in Photo. 2. In this pattern the spurious signal ratio measures about −35 db. In addition, the spurious signal generates also from the capacitive coupling between input and output terminals of this delay line. This spurious signal may be separated easily from the former one by varying the repetition frequency of test pulse, because the interval between the spurious of leakage and the main pulse always equals the delay time. The latter spurious signal ratio measures less than −40 db in the pattern of Photo. 2. To reduce the leakage, the input and output terminals must be shielded strictly to each other, and the earth terminals of both transducers must be earthed separately to each circuit.

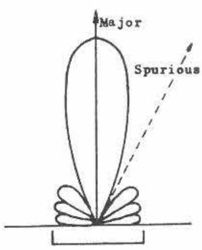


FIG. 3. Directivity of transducer.

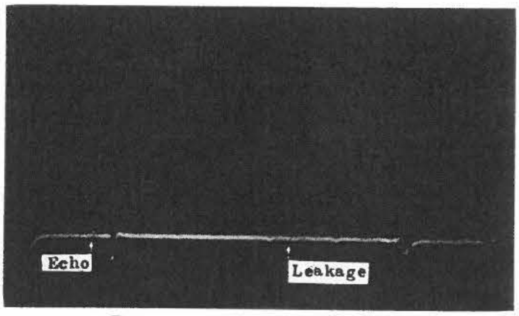


PHOTO. 2. Spurious pattern

Besides the distortions described above, some distortions originate from the modulator and the detector. These distortions are nonlinear and are divided into the amplitude distortion and the harmonic distortion. The harmonic distortion must be reduced as little as possible, because the distortion is very harmful to the frequency analysis. It is to be desired from the accuracy of frequency analysis that the distortion caused by the modulation system is less than 3%. Most distortion originates from the modulator. Fig. 4 shows the modulating characteristics of 6AU6 used in this apparatus. It is advisable that the operating range of the average modulation input to the suppressor grid is less than 3 V.

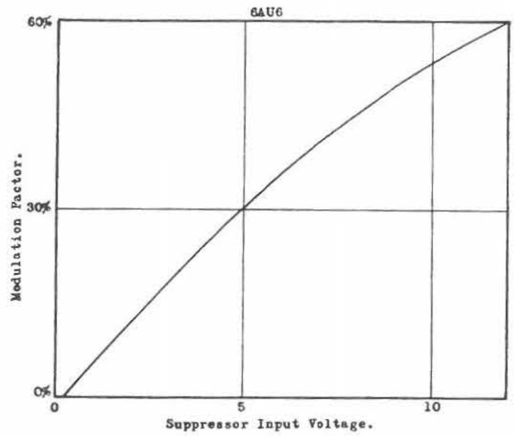


FIG. 4. Modulating characteristics of 6AU6.

If the characteristics of the amplifier used in this system is not a fully wide enough band to pass the signal through, the amplifying distortion generates in this amplifier. Of course, it is possible to compensate the characteristics of the delay line in the amplifier stage. The characteristics of the stagger amplifier used in this system is shown in Photo. 3 and the overall characteristics inserting the delay line in Photo. 4. It is shown that the band width of this amplifier is much wider than that of the delay line.

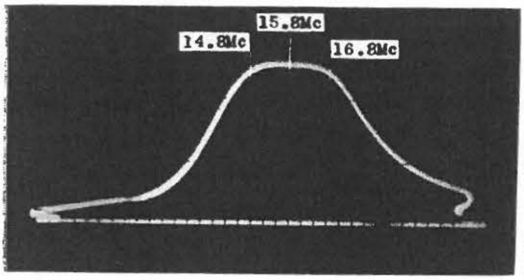


PHOTO. 3. Stagger Amp. characteristics.

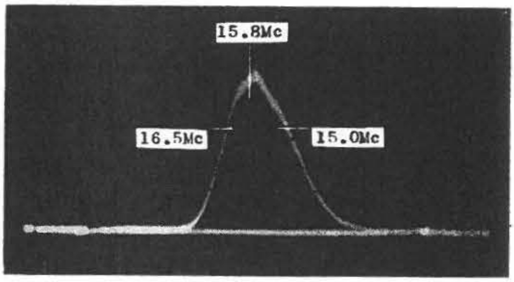


PHOTO 4. Overall characteristics.

III. Experimental Results

1. Delay Characteristics

The delay time t_0 is shown by

$$t_0 = \frac{d\beta}{d\omega}$$

where β is the phase characteristics of the transmission circuit and ω the angular frequency. If t_0 is constant over the pass band required to transmit the signal, the waveform free from distortions is obtained in the output of this circuit after the time of t_0. It is very difficult to measure directly the phase characteristics of the delay line and it is sufficient to know only the delay characteristics of the modulation signal. Therefore, the phase characteristics against the frequency between the input modulation wave and the output detection one was measured by means of Lissajous' figure, from which was obtained the equivalent characteristics of overall retardation. The band width of the amplifier, the modulator and the detector is so wide that the obtained result is governed only the delay line. The phase difference vs frequency characteristics is shown in Fig. 5, the delay time vs frequency characteristics in Fig. 6 and the amplitude vs frequency characteristics in Fig. 7. From these results, this delay line is applicable to the signal ranged to 300 kc/s and this range may be spread out by using compensation networks. But, it was not necessary to use the compensation networks for our purpose.

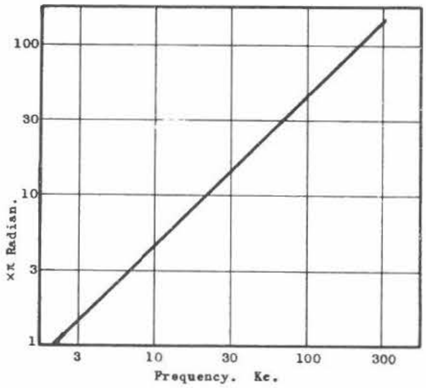


FIG. 5. Phase difference vs frequency characteristics.

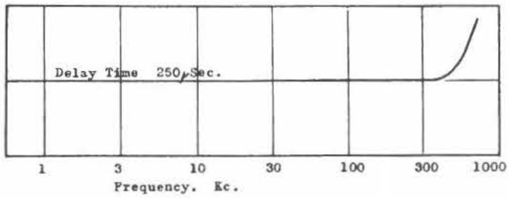


FIG. 6. Delay time vs frequency characteristics.

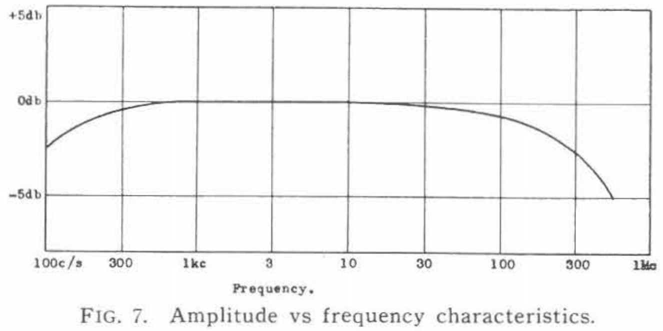


FIG. 7. Amplitude vs frequency characteristics.

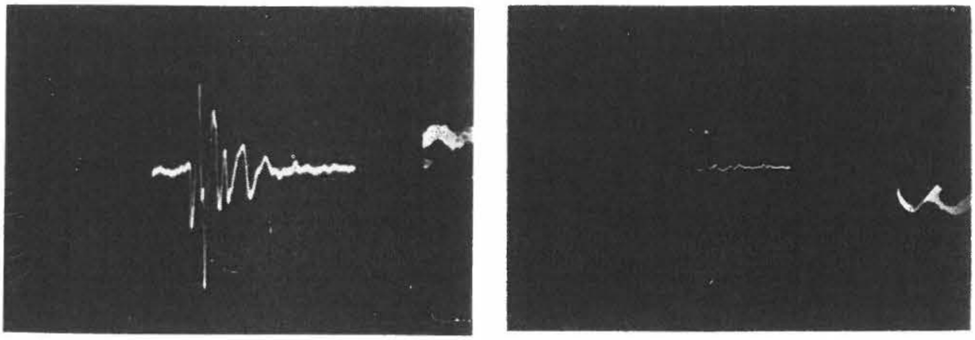
2. Results Obtained

The waveform received by using this delay line is shown in Photo. 5, together with the one obtained simultaneously by the conventional method. The left photograph shows the waveform passed through the delay line, the right is photographed without the delay line. There is a remarkable agreement between the two photographs.

The result analysed by a frequency analyser is shown in Fig. 8 to find out any difference between the data shown above.

3. Circuit Diagram

The details of this circuit is shown in Fig. 9.



(*a*) (*b*)

PHOTO. 5. Wavefrom
(*a*) Through delay line
(*b*) No delay line

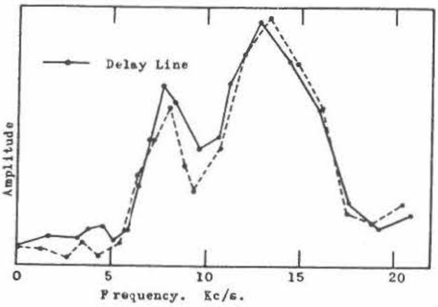


FIG. 8-(*a*). Frequency spectrum.

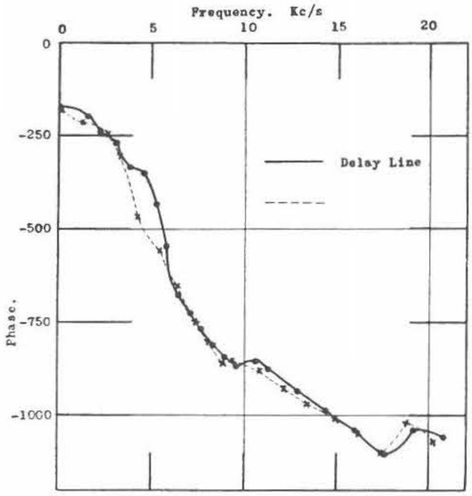


FIG. 8-(*b*). Phase spectrum.

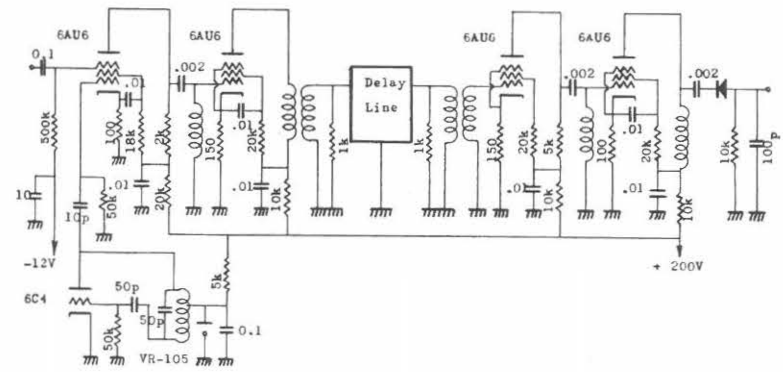


FIG. 9. Circuit diagram.

IV. Conclusion

The result obtained is so excellent that the distortions of waveforms passed through this delay line are hardly appreciable.

The delay line of the waveform recorder of atmospherics which is an outstanding problem from the beginning of the study of atmospherics is almost accomplished by using this supersonic delay line. The delay time obtained at present is 250 micro-seconds; however, the value of 500–600 micro-seconds is reached without any trouble.

V. Acknowledgements

We wish to express our thanks to Professor A. Kimpara, Director of our Research Institute, for his constant guidance and to Mr. T. Shinada of the Kinsekisha Laboratory Ltd. for the loan of the supersonic delay line in the course of this work. We are also indebted to Assistant Professor K. Sao for analysis of waveforms obtained by this delay line and to Messrs. T. Murata, T. Kato and M. Yamamoto for their technical assistance.