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Oct. 13, 1959 H. A. FAIRHURST 2,908,746

VARIABLE DELAY LINE

Filed Oct. 24, 1955 2 Sheets-Sheet 1

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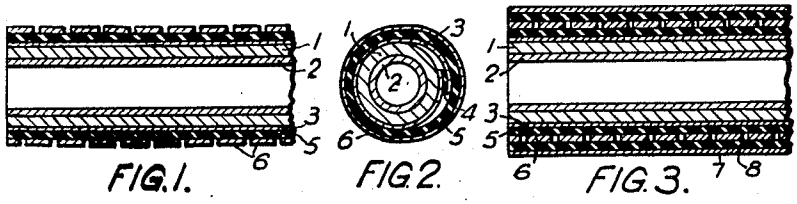

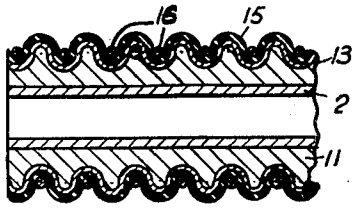

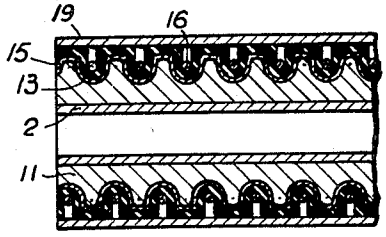

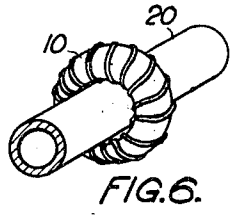

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VARIABLE DELAY LINE

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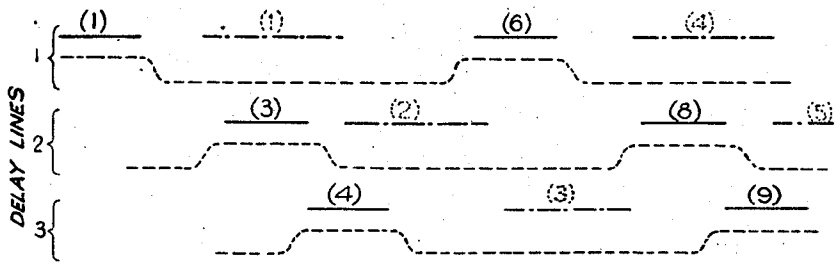

FIG. 7.

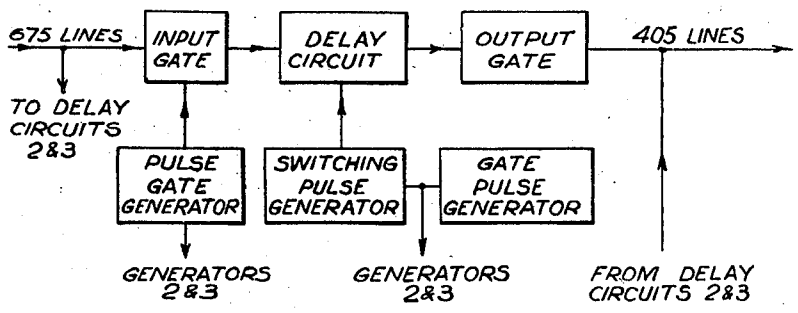

FIG. 8.

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VARIABLE DELAY LINE

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4 Claims. (Cl. 178—5)

This invention relates to means for varying the duration of received lines of a television signal by aid of an electric circuit element of readily variable distributed reactance and to circuits based thereon.

The delay line comprises a helical coil of wire, ordinarily of copper, encircling a magnetisable core, a metal sheet, commonly of foil, also surrounding the core, interrupted circumferentially to avoid eddy currents and separated by insulation of small thickness from the helical coil, and an exciting conductor associated with the core to produce magnetic flux in it when the conductor carries current. The exciting conductor is most conveniently a wire or tube passing axially through the core and so serving to produce a magnetic flux encircling the axis of the core. Where heavy exciting current is needed the tubular form of conductor will admit of cooling by circulation of water or other cooling medium.

A unit of such a delay line of substantial length is capable of momentarily storing the whole of a complex wave form and delivering it at a speed different from that at which it was received into the circuit. If the wave form enters while the core is unexcited and leaves while the core is excited it will be much reduced in duration, and conversely. The requisite switching of the exciting current may be effected electronically.

Examples of the construction of circuit elements according to the invention and of their application are illustrated in the accompanying drawings.

Fig. 1 is an axial section and

Fig. 2 a cross section of one construction,

Figs. 3, 4 and 5 are axial sections of modified constructions,

Fig. 6 a diagrammatic perspective view of another modified construction,

Fig. 7 is a timing diagram, and

Fig. 8 a circuit diagram explaining the application of the circuit element.

In Figs. 1 and 2 a tubular core **1** of ferrite or other highly magnetisable material has within it a solid or tubular conductor **2**, and is metal sheathed, for instance wrapped with metal foil **3**. It is preferable that, as shown in Fig. 2, the foil wrapping should completely surround the core, but it should not be conductively continuous circumferentially or it will be the seat of heavy eddy currents and will largely shield the core from the winding described below; the overlapping edges of the foil wrapping should therefore be separated by insulation **4**. The foil wrapping **3** is covered in turn by a sheathing of insulation **5** of a material which has but low dielectric losses, for example mica or polythene. Upon this sheathing is wound the helix **6** which constitutes the principal electrically conductive component of the circuit element. This is shown in Fig. 1 as a bare metal tape, helically wound with its turns spaced apart.

The helically wound tape **6** and the magnetic core **1** form the inductance of the circuit element; its capacitance is formed by the tape **6** and the foil **3**; both are distributed uniformly along the element. The radial thicknesses of the several components are not shown to scale; the principles of design involved in determining them are familiar; the cross-section of the tape **6** must be adequate to carry the circuit current; the thinner the insulation the greater will be the capacitance per unit length; but the insulation must be adequate to withstand the potential differences arising between the several parts of the tape **6** and the foil **3**; the core **1** must be of adequate cross section to carry without saturation the flux produced by the coil **6**, but it may need to be brought to saturation by the flux produced by current flowing in the conductor **2**. When there is current flowing in the conductor **2** and the core **1** is thereby nearly saturated the inductance of the coil **6** will be diminished.

If desired the core **6** may be covered by a further layer of insulation **7** as shown in Fig. 3, and that in turn by a foil wrapping **8**, thereby increasing the capacitance per unit length. The remainder of Fig. 3 is the same as Fig. 1.

It may be found that the mutual inductance of the turns of a coil wound, as is **6**, upon a cylindrical core, is so great as to severely limit the frequency of the current that can pass along the coil; thus, for example, it may not be possible to make of the unit a filter with a sufficiently high cut-off frequency. This can be remedied by interposing magnetisable material between the turns of the coil. In Fig. 4 the simple cylindrical core **1** of Figs. 1 to 3 is replaced by a core of ferrite or the like **11** on the outer surface of which a screw thread has been formed. The outer surface of the core is then metallised by any usual process for the deposition of metal, so producing a conductive layer **13**. This should be scored longitudinally at one or more points around the circumference to break up the eddy current path. The metal layer is covered by insulation **15**, and upon this there is wound in the trough of the screw thread a wire helix **16**.

If desired a sleeve of ferrite **19** may surround the coil **16** as shown in Fig. 5 thereby still further increasing its inductance. Or an additional sheathing of metal may be provided as explained with reference to Fig. 3 to increase the capacitance; or both additions may be made, the metal layer following but being insulated from the conductor **16**, and being circumferentially interrupted, and the magnetic sheathing covering the metal.

The circuit element described may be of any convenient length, and where considerable delay is required several units may be joined in series with alternate coils **6** reversed.

The core need not be straight; it is better if it is magnetically closed. This is shown in Fig. 6 where the delay circuit is built up of any desired number of toroidally wound cores such as **10** threaded upon a common exciting conductor **20**. In detail the unit **10** may resemble any of the constructions of Figs. 1 to 5 except for the omission of conductor **2** which is replaced by **20**.

A delay line may be formed capable of receiving the whole of a wave form of short duration, for instance a line of a television signal, before any part of the wave emerges from the line. By changing the exciting current in the exciting conductor, which may readily be done by electronic means, while the wave form is traversing the delay line, it may be made to emerge at a different rate from that at which it entered.

The invention thus affords a means of converting the signals of one television system electronically into signals appropriate to a different television system. For example, signals on a 675 line system may be converted into signals acceptable by the receivers of a 405 line system by selecting, say, the first, third and fourth lines in every five lines of the high definition system, lengthening them by variable delay circuits of the kind above described to the length of low definition lines and timing

their issue from the delay circuits so that they follow in due sequence.

The timing diagram, Fig. 7, shows in full lines the duration and time relation of the lines of the high definition system, and in dot-dash lines the duration and time relation of the lines of the low definition system, and the lines are number in sequence. There are three variable delay circuits. It will be seen that high definition line **1** passing through the first delay circuit becomes low definition line **1**, high definition line **2** is omitted, high definition line **3** passing through the second delay circuit becomes low definition line **2**, high definition line **4** passing through the third delay circuit becomes low definition line **3**, and high definition line **5** is omitted, and so on. The several dotted lines show the periods during which the respective delay lines offer great delay and small delay, and the instants at which their characteristics are changed.

Fig. 8 is a simplified block diagram of one delay circuit. The incoming signals are "gated" in well understood manner into the respective delay lines, and the delay lines are successively "gated" to the output circuit.

All of the delay circuits, when their cores are saturated, or at least magnetized, by current in the exciting conductor, delay signals by somewhat more than the duration of a line of the high definition standard, the original signal, so that the end of a line will have entered the delay circuit before the beginning of it emerges. All of them, when their cores are not saturated, slow the passage of signals to such an extent that the emergence of a line occupies the duration of a line of the new standard. But though the delay circuits are alike in respect of the rate of travel of a voltage wave through them, both when their cores are unsaturated and again when their cores are saturated, they are not alike in the delay they impose. For the lines selected from the original signal are not evenly spaced in time, but yet have to make evenly spaced lines on the new standard.

The exact timing of the switching on and off of the magnetising current is of importance, for upon it depends the total time of travel of a picture wave form through the delay circuit, partly at a high speed and partly at a low speed, and the time of travel determines the instant when the line begins to emerge. By adjustment of the time of switching the lines may be made to follow regularly one upon the other.

I claim:

1. Means for varying the duration of received lines of a television signal comprising a circuit element of readily variable distributed reactance adapted to receive the television signal, including a magnetizable core, a coil winding thereon, a metallic layer surrounding said core and interrupted circumferentially, thin insulation of low dielectric loss separating said metallic layer from said coil, and an exciting conductor associated with said core to magnetize it, and electronic means for supplying to said conductor pulses of exciting current commencing when a line of the signal is traversing, and wholly within, said circuit element and continuing until the line of signal has emerged from said circuit element.

2. Means for varying the duration of received lines of a television signal comprising a circuit element of distributed inductance and capacitance including a coil wound upon a magnetizable core, an exciting conductor associated with said core for determining its degree of saturation, and electronic means for supplying to said exciting conductor pulses of exciting current each commencing when a line of the signal is traversing, and wholly within, said circuit element and continuing until the line of signal has emerged from said circuit element.

3. A method of varying the duration of received lines of a television signal which consists in delaying the transmission of the signal train corresponding to a television line signal by a delay circuit, and when the whole line is subject to delay changing the propagation velocity of the delay circuit.

4. A method of converting a television signal from one standard to a new standard which consists in selecting the signal trains corresponding to particular lines of the received television signal, delaying each in transmission, and changing the propagation velocity of each line while it is subject to delay to the extent necessary to make its duration that of a line of the new standard, said changes being effected at such instants that the selected lines follow immediately and evenly one upon the other.

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