

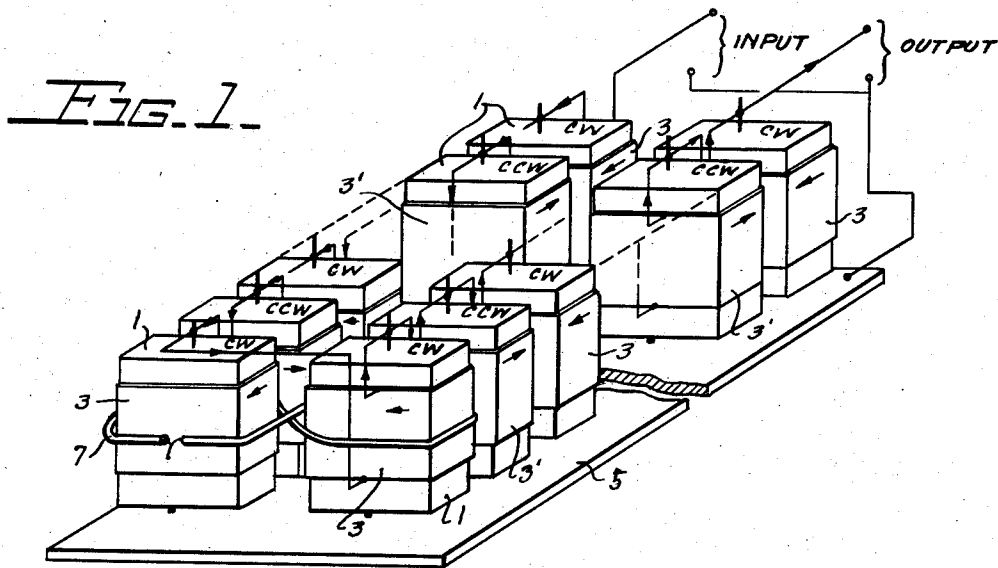
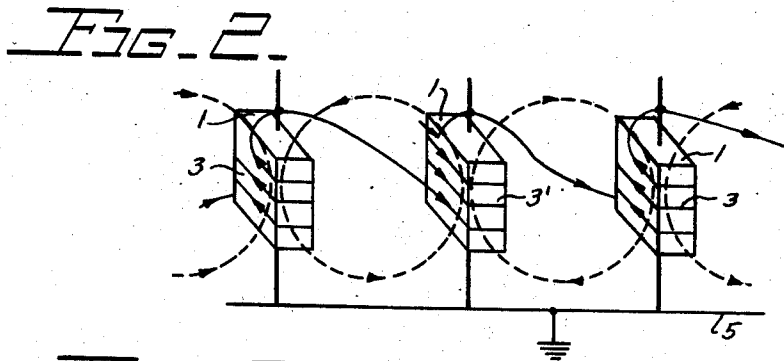
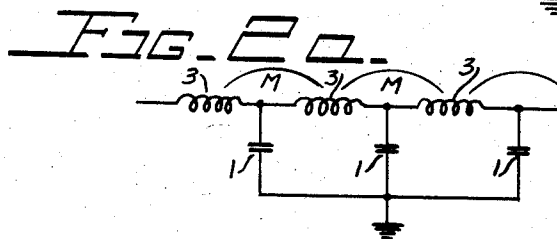
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ELECTRICAL DELAY LINES

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2 Sheets-Sheet 1



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FIG. 3.

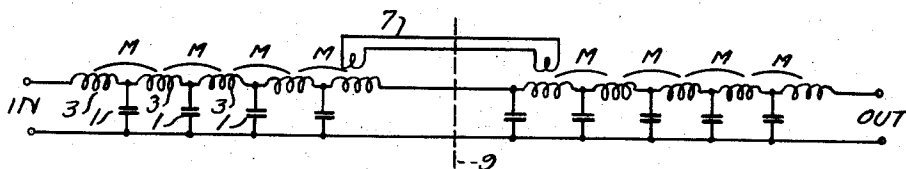


FIG. 4.

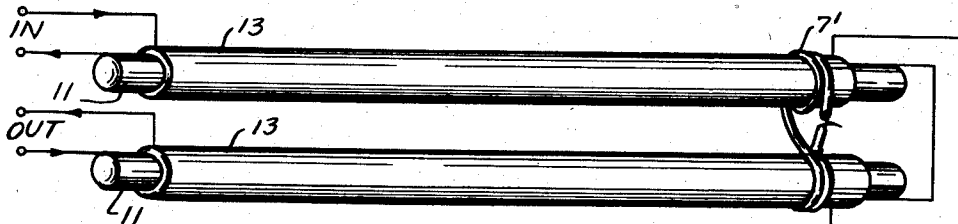
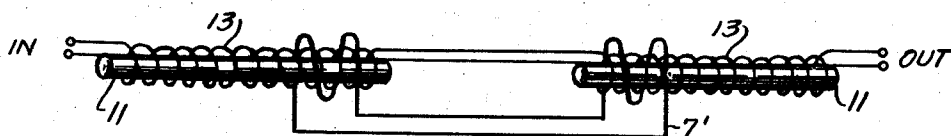


FIG. 5.



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ELECTRICAL DELAY LINES

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6 Claims. (Cl. 333—29)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to electrical delay lines and particularly to delay lines of the type shown in U. S. Patent 2,702,372, issued to James B. Hickey on February 15, 1955. This patent discloses a delay line of the lumped parameter L-C low pass m-derived filter type in which the individual L-C sections are each made up of a coil wrapped around the outside of the capacitor supplying the shunt capacitance. These sections are arranged in a row with the axes of the coils parallel so that the flux of each coil links the coils of the preceding and succeeding sections. In this way the inductive coupling between adjacent sections, required in the m-derived configuration, is provided.

In order to reduce the physical length of a line of the above type the patent shows the sections arranged in a plurality of short rows rather than a long single row. It is apparent that, in such an arrangement, the inductive coupling between adjacent sections due to the flux linkages between adjacent coils does not exist, or exists in greatly diminished form, between the last section of one row and the first section of the next row. This introduces discontinuities in the delay line which give rise to reflections resulting in a loss of energy and other undesirable effects.

It is the object of the invention to remove the above discontinuities. Briefly, this is accomplished by a conductive loop which surrounds and is inductively coupled to the coils in the two end sections of adjacent rows. The magnitude and sign of this coupling is made such as to duplicate the inductive coupling between the coils of adjacent sections in a row.

While this method is particularly adaptable to lumped constant lines of the above described type, it is also applicable to delay lines of the distributed constant type as will be seen later.

A more detailed description of the invention will be given in connection with the specific embodiments thereof shown in the accompanying drawings in which:

Fig. 1 shows a line of the type described in the Hickey patent to which the invention has been applied;

Figs. 2 and 2a show the details of several sections of the line of Fig. 1;

Fig. 3 shows the equivalent circuit of the line of Fig. 1;

Fig. 4 shows the invention applied to a distributed constant delay line; and

Fig. 5 is an equivalent circuit of Fig. 4.

Referring to Fig. 1, a delay line of the type disclosed in the above cited patent to Hickey is made up of a plurality of cascaded sections each of which, as shown more clearly in Fig. 2, consists of a small capacitor 1, such as a molded mica capacitor, around which is wound a coil 3 or 3' depending upon whether the coil, as viewed from the top, is wound clockwise or counterclockwise.

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The upper terminal of each capacitor is connected to the coil of the succeeding section and the lower terminal of each condenser is connected to a point of fixed potential such as metallic plate 5. The equivalent circuit of Fig. 2 is shown in Fig. 2a. By placing the sections adjacent one another in a row as shown in Fig. 1 the flux from each coil links the adjacent coils, as indicated in Fig. 2, and, since adjacent coils are wound in opposite directions, the resulting mutual coupling is positive. All sections are identical, except for the direction of winding of the coils, and the inductance of the coils, the coupling between the coils, and the value of capacitors 1 are made such as to satisfy the requirements for an m-derived low-pass filter.

The cascaded sections forming the delay line in Fig. 1 are arranged in two rows in order to reduce the physical length of the line. Depending upon the number of sections used and the space requirements, any number of rows may be used to achieve a desired physical dimension. It is evident that the mutual coupling between adjacent coils, indicated in Fig. 2, is uniform for all sections comprising a single row. However, this coupling is absent or greatly reduced between the coil of the last section of one row and the coil in the next succeeding section of the cascade which is located in an adjacent row. In accordance with the invention this discontinuity is prevented by coupling loop 7 which may conveniently take the form of a loop of insulated wire encircling the coils of the two end sections as shown in Fig. 1. The amount of coupling is controlled by the number of times the loop encircles the coils and is made equal to the coupling existing between adjacent coils in a row. The sign of the coupling must also be observed and made consistent with the sign of the corresponding coupling between adjacent coils in a row, which is positive. If the two end coils are wound in the same direction as in the drawing, it is necessary to cross the loop in order to achieve positive coupling, as shown.

The equivalent circuit of the delay line of Fig. 1 is shown in Fig. 3. Dotted line 9 represents the division between rows.

The above difficulty also arises when a distributed constant delay line is made in several sections. Such a line made in two sections is shown in Fig. 4. Each section of the line consists of a core 11, which may be made of a magnetic material, upon which is formed a continuous uniform winding 13. The capacity between the conductor of the winding and the core 11 is analogous to the shunt capacitors of the lumped constant line of Fig. 1. In a continuous winding of this type it is obvious that inductive coupling exists between each turn and turns adjacent thereto. When the line is in sections as in Fig. 4 such coupling does not exist between the end turns of one section and the end turns of another section connected thereto and an undesirable discontinuity is thereby introduced in the line. This condition may also be remedied by a conductive loop 7' wound around each section near the ends to be joined. As in Fig. 1, the number of turns in the loop is made sufficient to reproduce the inductive coupling that would normally exist between turns intermediate the ends of a section, i. e. across a point intermediate the ends of a section. Also the proper direction of the coupling must be preserved. Where both windings have the same directions, i. e. both in the form of right-hand or left-hand threads, the loop must be crossed as shown to obtain the proper coupling sign. An equivalent circuit of Fig. 4 is shown in Fig. 5.

I claim:

1. In an electrical delay line structure in which inductive coupling between adjacent portions resulting

from their proximity is utilized to improve the transmission characteristics of the line, and in which said line structure is divided into a plurality of physically isolated parts coupled in cascade, means for reducing discontinuities in said line due to the physical separation of said cascaded parts and the alteration of the said inductive coupling between adjacent portions of the line of that point resulting therefrom, said means comprising a conductive circuit inductively coupled to the output end portion of the line in each cascaded section, save the last, and also inductively coupled to the input end portion of the line in the next succeeding cascaded section for introducing an inductive coupling between said end portions identical to the said inductive coupling between adjacent portions within a section.

2. An electrical delay line comprising a plurality of cascaded sections each consisting of a coil providing series inductance and a condenser providing shunt capacitance in which said sections are physically arranged in rows and in which the sections in each row are sufficiently close together physically for inductive coupling to exist between the coils of adjacent sections in the cascade, means for reducing the discontinuities resulting from the greater spacing and correspondingly lesser inductive coupling between the coils of adjacent sections in the cascade located in different rows, said means comprising, in each case, a conductive loop inductively coupled to the coils in the particular adjacent sections for bringing the inductive coupling between these coils into equality with the inductive coupling between the coils of adjacent sections in the same row.

3. An electrical delay line comprising a plurality of cascaded sections each consisting of a series inductance and a shunt capacitance, in which the inductance is a coil of wire wrapped around the body of a condenser supplying said capacitance, said sections being mounted close together in each of a plurality of rows with the axes of said coils perpendicular to a reference plane whereby a predetermined amount of inductive coupling exists between adjacent coils in a row, and additional coupling means between those adjacent sections in the cascade located in different rows, said means comprising, in each case, a conductive loop inductively coupled to each of the coils in the particular adjacent sections

for bringing the inductive coupling between these coils into equality with the inductive coupling between the coils of adjacent sections in the same row.

4. An electrical delay line consisting of a plurality of physically separated sections, each section having a uniformly distributed series inductance and a uniformly distributed shunt capacitance, means connecting said sections in cascade, and additional coupling means between the connected ends of said sections, said coupling means comprising, in each case, a conductive loop conductively coupled to the series inductances of the particular connected sections near the connected ends for bringing the inductive coupling between said connected ends into equality with the inductive coupling across an intermediate point on a line section.

5. An electrical delay line consisting of a plurality of physically separated sections, each section comprising a distributed series inductive element in the form of a continuous helix and a distributed shunt capacitive element in the form of a continuous conductive element capacitively related to the turns of said helix, means connecting said sections in cascade, and additional coupling means between the connected ends of said sections, said coupling means comprising in each case, a conductive loop surrounding the series inductive elements of the particular connected sections near the connected ends for bringing the inductive coupling between said connected ends into equality with the inductive coupling across an intermediate point on a line section.

6. An electrical delay line comprising a plurality of similar line portions connected in cascade and divided into a plurality of physically isolated groups, there being in each group a predetermined additional coupling between each pair of adjacent portions in the cascade due to their proximity, and means for providing an additional coupling, equal to said predetermined coupling, between the last portion of each group, save the last group, and the first portion of said next succeeding group, said means comprising, in each case, a conductive circuit coupled to said last and first portions.

References Cited in the file of this patent

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