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ARTIFICIAL TRANSMISSION LINE

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Fig. 1.

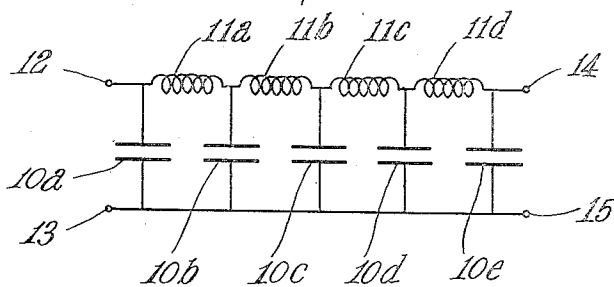


Fig. 2.

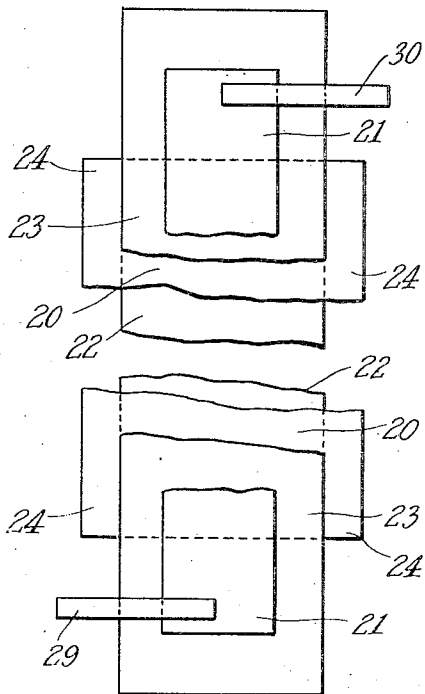
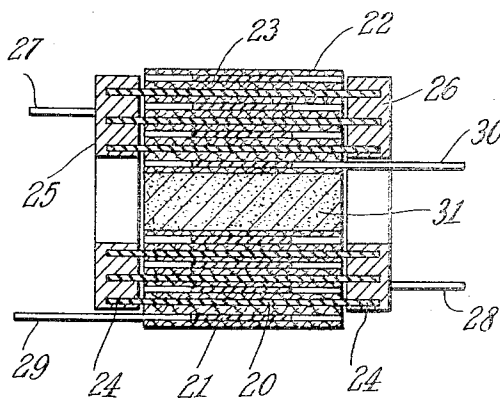


Fig. 3.



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ARTIFICIAL TRANSMISSION LINE

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This invention relates to a new and improved electrical circuit and more particularly refers to artificial transmission lines having characteristics which are highly desirable but heretofore have been practically unattainable. In certain aspects this invention is based upon modifications of the novel condenser described in abandoned U. S. patent application Serial No. 489,456, filed June 3, 1943, by Howard F. Sherman, and entitled "Improved by-pass condenser."

The classical picture of a transmission line is a network of an infinite number of sections, each consisting of a series inductance (corresponding to the inductance per unit length of the wire constituting the transmission line) and a parallel capacity (which is the capacity to ground or between adjacent wires of a unit length of the wire). Such transmission lines are very useful, particularly in high frequencies in transmitting or in rejecting signals, in matching or transforming impedances, and in delaying and modifying the wave shape of signals.

It is well known in the art to make artificial transmission lines with so-called lumped characteristics, that is to say, made up of a finite number of inductances and capacities, and these artificial transmission lines with lumped parameters have been quite successful. At high frequencies they suffer from the defect, however, that the lumped inductance has a high distributed capacity, and that the lumped capacity has a high series inductance so that it is extremely difficult to obtain the electrical equivalent of the natural transmission line. At the same time the natural transmission line to have useful qualities is so long physically that it is difficult, if not impossible, to make use of it in ordinary apparatus.

A further difficulty with the known artificial line is that it is impossible to match the behavior of the natural line at the physical start of the line. In the natural line there is actually shunt capacity appearing as part of the line from its very inception. There is likewise series inductance appearing in the natural line upon its inception. With the artificial line a choice must be made between starting with either a series inductance or a shunt capacitance and this choice necessarily makes the resulting network differ from the natural prototype.

It is an object of the present invention to overcome the foregoing and other disadvantages of the prior art.

A further object is to produce new electrical circuits having desirable characteristics.

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A still further object is to produce an artificial transmission line which combines the advantages of prior art transmission lines without at the same time including the disadvantages of these transmission lines.

A still further object is to produce artificial transmission lines which have characteristics heretofore unattainable.

Additional objects will become apparent from a consideration of the following description and claims.

These objects are attained in accordance with the present invention which comprises an electrical circuit composed of two layers of electrically conducting materials separated by layers of dielectric material and convolutely wound, one of said layers of electrically conducting materials being connected on both sides throughout substantially its entire length to terminals and the other of said layers of electrically conducting materials being connected only at one point to corresponding terminals. In a more restricted sense this invention concerns an artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of dielectric material of intermediate width and convolutely wound, the wide layer of electrically conducting material being connected on both sides throughout substantially its entire length to terminals and the narrow layer of said electrically conducting material being connected only at its extreme end to corresponding terminals. In its preferred embodiment this invention pertains to an artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of dielectric material of intermediate width, the longitudinal center line of each of said layers registering with each other and the resulting assembly being convolutely wound, the projecting ends of the wide layer of electrically conducting material being connected by low resistance electrically conducting material which is connected to terminals for the system and the narrow layer of electrically conducting material being connected only at its extreme end to corresponding terminals of the system. Additional features of the invention are concerned with the use of a magnetic core for the convolutely wound circuits previously described herein or suggested thereby and/or the use of a non-magnetic core of electrically conducting material for the aforesaid assembly; the employment of impregnating agents for improving the

dielectric characteristics of the insulating layers in said circuits; and the employment of the circuits produced as aforesaid or by equivalent methods in the electrical and related arts.

I can best describe my artificial transmission line by referring to the well-known technique of paper condensers. Here, as is well known, two continuous metal foils are rolled up with dielectric spacers between them. The condenser is rolled around a central mandrel; two types of rolling are well known. In one type the foils are displaced laterally from each other so that one foil extends from one side of the condenser and the other foil from the other side. Soldered connections are made to these foils which connections become the terminals of the condenser. This type of winding is known as "non-inductive" or "short-path" winding.

In the other type of winding the foils are parallel with each other with the dielectric spacers extending from both sides of the foil. At some points of the winding, tabs are inserted to make contact to each foil respectively, and these tabs become the terminal connections of the condenser. This type of winding is given a misnomer, namely, "inductive winding" (if the tabs are placed at the same place on the respective foils lengthwise the induced field in one foil exactly neutralizes the induced field in the other so that no residual inductance exists in the section).

In both these windings whatever the inductance of the windings themselves may be, there is present, as is evident, the inductance of the lead wires themselves. In my novel artificial transmission line I follow condenser practice in that I use two foils with dielectric spacers therebetween. Advisably, but not necessarily, one foil is wider than the dielectric spacers, and one foil is advisably, but not necessarily, narrower than the dielectric spaces. They are wound up, preferably with their center lines registering, so that the narrow foil is completely covered with the dielectric spacers and the wide foil extends beyond the spacers on both sides. With the rolled up assembly I solder or otherwise make continuous the extended foil at both sides of the winding. To the narrow foil I make contact, preferably but not necessarily, at the extreme end of it only. In this way my wide foil takes the place of one conductor of the natural transmission line, with the important difference that the cross section of the conductor is uniformly distributed throughout the mass of the assembly instead of being confined to a single wire, while the short foil constitutes the other conductor of the system and generates therewith the distributed constants desired.

It is evident that this assembly meets all requirements of the natural transmission line, including the end effects inasmuch as the short foil acts as an inductance from the point where it is connected, and also there is capacity between both foils from the point of connecting in the circuit.

The inductance of the narrow foil has a value considerably more than would be obtained by inductance of the same foil stretched out to its natural length, and this is accomplished both by the fact that the coil form itself increases the inductance, and also by the fact that these turns are so closely coupled that the mutual inductance between turns is quite high and this adds to the sum total of inductance. If desired, of course, the mandrel used for forming the final assembly

can be replaced by a magnetic core of high permeability, for example, a powdered iron core or a powdered magnetite core.

The invention may be more readily understood by reference to the accompanying illustrative drawings wherein the same parts in the various figures are similarly numbered.

In these drawings:

Figure 1 schematically illustrates the electrical equivalent of an artificial transmission line in accordance with the invention;

Fig. 2 shows a method of constructing the artificial transmission line of the invention;

Fig. 3 is a cross-sectional view of an artificial transmission line in accordance with the invention.

Referring to Fig. 1, a transmission line may be effectively represented by a series of individual condenser units 10a, 10b, 10c, etc., and a series of inductance units 11a, 11b, 11c, etc., positioned between input terminals 12 and 13 and output terminals 14 and 15. The condensers 10 and the inductances 11 represent the distributed capacitance and the distributed inductance respectively of the transmission line. Artificial transmission lines based on the equivalent circuit shown in Fig. 1 have heretofore been constructed by means of a finite number of inductors connected in series in one branch of the circuit and a finite number of capacitors connected in shunt across both branches of the line at the junction points of the individual inductors.

The inductors and capacitors themselves are characterized by distributed capacity and inductance respectively. However, at comparatively low frequencies the effects of these distributed constants are negligible and at such frequencies artificial transmission lines so constructed are electrically equivalent to their real prototypes.

At high frequencies the effects of the distributed capacitance of the inductors and of the distributed inductance of the capacitors is not negligible and because of this it has been extremely difficult to obtain the electrical equivalent of the natural transmission line.

Figs. 2 and 3 illustrate the construction of a new artificial transmission line according to the invention, which artificial transmission line is free of the disadvantages of the heretofore proposed artificial transmission lines and is capable of operating at extremely high frequencies. The device shown comprises metal bands or foils 20 and 21 convolutely wound with interposed insulating dielectric spacers 22—23 to form a roll such as shown in Fig. 3. The foil 20 has such a width that the side edge portions thereof shown as 24 extend beyond both side edges of the spacers 22—23, whereas foil 21 has such a width that its side edges are wholly enclosed within the edges of the spacers and the edges of the foil 20. The foil 21 may have a length equal to that of the foil 20 or may have a greater length as shown, for reasons later to be pointed out.

Suitable materials for the foils 20 and 21 are lead, tin, aluminum or the like, and the spacers 22—23 may consist of kraft paper, linen paper or the like, preferably uniformly impregnated with a low-loss dielectric material such as described in abandoned U. S. patent application Serial No. 475,051, filed by L. A. Brooks, on February 6, 1943, abandoned U. S. patent application Serial No. 480,137, filed by Preston Robinson on March 23, 1943, and U. S. patent application Serial No. 490,777, filed by James L. Hyde on June 14, 1943 (now U. S. Patent No. 2,377,630). The aforesaid

co-pending applications described numerous resins particularly adapted for employment as low-loss dielectric materials. These resins are for the most part obtained by the polymerization of certain monomeric materials containing ethylene linkages. An illustration thereof is polyvinyl carbazole which is obtained by the polymerization of vinyl carbazole.

The protruding edge portions of the foil 20 are electrically interconnected by means of low-resistance electrical shunts such being effected preferably by imbedding the same in solder, such as is shown at 25 and 26. Terminal wires 27 and 28 imbedded or otherwise affixed to the shunts 25 and 26 serve as two terminals of the artificial transmission line corresponding to terminals 13 and 15 of Fig. 1. By means of tabs 29 and 30 imbedded within the wound roll and connected to the ends of the foil 21, the terminals 12 and 14 of Fig. 1 are provided.

A high distributed inductance value may be imparted to the device of Fig. 3 by means of a core 31 consisting of a material of high magnetic permeability, such as powdered iron or magnetite, suitably compacted to form a self-sustaining rod which rod may also serve initially as a winding mandrel for winding the elements into the roll shown. By varying the composition of the core 31 or by adjusting its position within the roll, the inductance of the device may be adjusted over wide range which is particularly desirable in the case where a transmission line capable of operating over a range of frequencies is desired.

In some instances certain conditions existing in the circuit in which the artificial transmission line is used require that the transmission line exhibit an inductive reactance and this may be produced by making the foil 21 longer than the foil 20 as shown in Fig. 2.

As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

I claim:

1. An artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of dielectric material of intermediate width and convolutely wound, the wide layer of electrically conducting material being connected on both sides throughout substantially its entire length to terminals and the narrow layer of electrically conducting material being connected only at its extreme ends to terminals.

2. An artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of dielectric material of intermediate width, the longitudinal center line of each of said layers registering with each other and the resulting assembly being convolutely wound, the projecting ends of the wide layer of electrically conducting material being imbedded in low resistance electrically conducting material which is connected to terminals for the system and the narrow layer of electrically conducting material being connected only at its extreme ends to terminals for the system.

3. An artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of dielectric material of

intermediate width, the longitudinal center line of each of said layers registering with each other and the resulting assembly being convolutely wound upon a core of electrically conducting material, the projecting ends of the wide layer of electrically conducting material being imbedded in low resistance electrically conducting material which is connected to terminals for the system and the narrow layer of electrically conducting material being connected only at its extreme ends to terminals for the system.

4. An artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of porous dielectric material of intermediate width impregnated with substances capable of improving its dielectric properties, the longitudinal center line of each of said layers registering with each other and the resulting assembly being convolutely wound, the projecting ends of the wide layer of electrically conducting material being imbedded in low resistance electrically conducting material which is connected to terminals for the system and the narrow layer of electrically conducting material being connected only at its extreme ends to terminals for the system.

5. An artificial transmission line comprising a wide layer of electrically conducting material and a narrow layer of electrically conducting material separated by layers of porous dielectric material of intermediate width impregnated with substances capable of improving its dielectric properties, the longitudinal center line of each of said layers registering with each other and the resulting assembly being convolutely wound upon a core of electrically conducting material, the projecting ends of the wide layers of electrically conducting material being imbedded in low resistance electrically conducting material which is connected to terminals for the system and the narrow layer of electrically conducting material being connected only at its extreme ends to terminals for the system.

6. An electrical circuit useful as a transmission line and in bypassing undesired frequencies comprising the artificial transmission line of claim 1 wherein the terminal at one side of the wide layer of electrically conducting material and the terminal at one extremity of the narrow layer of electrically conducting material are connected as input terminals and the terminal at the opposite side of the wide layer of electrically conducting material and the terminal at the opposite extremity of the narrow layer of electrically conducting material are connected as output terminals.

7. An electrical circuit useful as a transmission line and in bypassing undesired frequencies comprising the artificial transmission line of claim 2 wherein the terminal at one side of the wide layer of electrically conducting material and the terminal at one extremity of the narrow layer of electrically conducting material are connected as input terminals and the terminal at the opposite side of the wide layer of electrically conducting material and the terminal at the opposite extremity of the narrow layer of electrically conducting material are connected as output terminals.

8. An electrical circuit useful as a transmission line and in bypassing undesired frequencies comprising the artificial transmission line of claim 3 wherein the terminal at one side of the wide layer of electrically conducting material and

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the terminal at one extremity of the narrow layer of electrically conducting material are connected as input terminals and the terminal at the opposite side of the wide layer of electrically conducting material and the terminal at the opposite extremity of the narrow layer of electrically conducting material are connected as output terminals.

9. An electrical circuit useful as a transmission line and in bypassing undesired frequencies comprising the artificial transmission line of claim 4 wherein the terminal at one side of the wide layer of electrically conducting material and the terminal at one extremity of the narrow layer of electrically conducting material are connected as input terminals and the terminal at the opposite side of the wide layer of electrically conducting material and the terminal at the opposite extremity of the narrow layer of electrically conducting material are connected as output terminals.

10. An electrical circuit useful as a transmission line and in bypassing undesired frequencies comprising the artificial transmission line of

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claim 5 wherein the terminal at one side of the wide layer of electrically conducting material and the terminal at one extremity of the narrow layer of electrically conducting material are connected as input terminals and the terminal at the opposite side of the wide layer of electrically conducting material and the terminal at the opposite extremity of the narrow layer of electrically conducting material are connected as output terminals.

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