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ARTIFICIAL TRANSMISSION LINE
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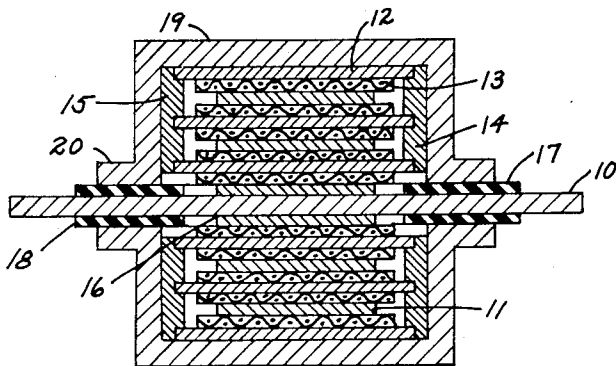


FIG. 1

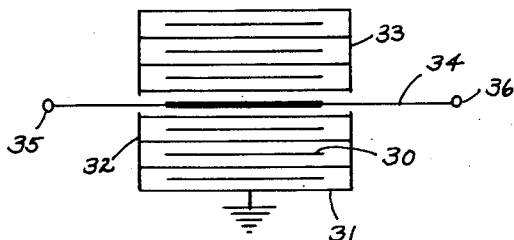


FIG. 2

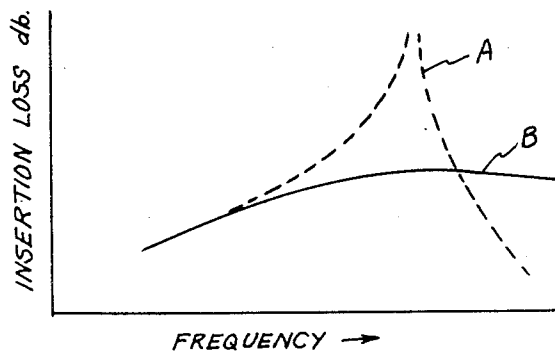


FIG. 3

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ARTIFICIAL TRANSMISSION LINE

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5 Claims. (Cl. 178-44)

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This invention relates to new and improved electrical circuits and more particularly refers to artificial transmission lines having characteristics which are highly desirable, but heretofore have been practically unattainable. This application is a continuation-in-part of my copending U. S. patent application, Serial Number 673,726, filed June 1, 1946, and entitled "Artificial Transmission Line," patented October 17, 1950, Number 2,526,321.

The classical picture of a transmission line is a network of an infinite number of sections, each consisting primarily of a series inductance (corresponding to the inductance per unit length of the wire constituting the transmission line), a series resistance (corresponding to the resistance per unit length of the wire) and a parallel capacitance (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 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 the lower radio frequencies.

A further difficulty with the known artificial transmission lines 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 shunt capacitance at its 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. A still further object is to produce an artificial transmission line which combines the

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advantages of prior art transmission lines without at the same time being subject to their disadvantages. A still further object is to produce artificial transmission lines and networks of simple physical structure which have characteristics greatly desired but heretofore unattainable. Additional objects will become apparent from a consideration of the following description and claims.

10 These objects are attained in accordance with the present invention which is concerned with an artificial transmission line comprising two layers of electrically conducting materials separated by layers of dielectric material and convolutedly wound, one of the layers of electrically conducting material being connected on both sides throughout substantially its entire length to a terminal and the other layer of electrically conducting material being connected at its inner extremity only to an axial terminal which extends from both sides of the winding. In a more restricted sense the invention is concerned with an artificial transmission line comprising a wide electrode foil and a narrow electrode foil separated by layers of dielectric material of intermediate length and convolutedly wound, the wide electrode foil being connected on both sides throughout substantially its entire length to a terminal and the narrow electrode foil being connected at its inner extremity to an axial terminal which extends from both sides of the winding. In one of its preferred embodiments the invention is concerned with an artificial transmission line comprising a wide electrode foil and a narrow electrode foil separated by layers of dielectric material and convolutedly wound upon an electrically conducting core which extends beyond both sides of the winding, the narrow electrode foil being connected at its inner extremity to said core and the wide electrode foil being connected on both sides throughout substantially its entire length to a metallic housing for said winding. In one of its limited embodiments the invention is concerned with an artificial transmission line comprising a wide electrode foil and a narrow electrode foil separated by layers of dielectric material of intermediate width, the longitudinal center lines of each of said foils registering with each other and the resulting assembly being convolutedly wound on a rigid metal core which extends beyond the edges of said winding, the inner turn of said narrow foil electrically engaging said core and the projecting edges of the wide foil being embedded in solder and connected to a cylindrical metal housing which encloses said convolutedly wound assembly. The invention is also concerned with an electrical

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circuit useful as a transmission line and in bypassing undesired high frequencies which circuit comprises the artificial lines described above in which the housing and one end of the core are connected as input terminals and the metal housing and the other end of the core are connected as output terminals.

In the accompanying drawing:

Figure 1 shows a cross-section of an artificial transmission line of the invention;

Figure 2 shows a schematic diagram of the line of Figure 1; and

Figure 3 shows the insertion loss vs. frequency curve of an electrical condenser (A) and of the transmission line of the invention (B).

Referring more specifically to Fig. 1, 10 represents an axial electrically conducting core, which extends beyond both sides of the assembly. This core may be fabricated as a wire, rod, bar, plate or other metal configuration. Further, it may be employed as the mandrel for the winding of the assembly. Silver-plated copper, tin-plated copper and aluminum are representative core materials. The extensions of 10 may be provided with studs, clips or other devices to permit connection into a circuit and also, in some cases, to facilitate physical mounting.

The convolute winding consists of narrow electrode foil 11, wide electrode foil 12 and intermediate width dielectric layers 13. The extended edges of foil 12 are embedded in solder or similar conducting material 14 and 15. The narrow foil 11 contacts core 10 at its inner extremity 16. This contact may be soldered or welded, if desired.

Insulating bushings 17 and 18 are provided on core 10, to insulate core 10 from foil 12. These may be of rubber, plastic, ceramic or other insulating material. Metal housing 19 encloses the winding and is crimped onto bushings 17 and 18 as shown at 20. Thus electrical contact is made to foil 12, through low resistance paths 14 and 15. At the same time, the assembly is physically sealed and protected from vibration etc.

It is generally advisable to provide a metal clamp on housing 19, to simplify mounting and electrical connection. A wide clamp is preferable for lowest coupling impedance. Another useful mounting arrangement can be produced by welding or soldering a flange about the housing 19, preferably in the middle. This flange may be bolted, welded, soldered, threaded or otherwise connected into a metal wall and the device of the invention used for feed-through filtering purposes. For example, the device could be used to remove unwanted high frequencies from a direct current power supply for an automobile radio.

Fig. 2 shows a schematic diagram in which narrow foil 30 is connected to core 34. The extremities of the latter serve as input and output terminals. Wide foil 31 is provided with low resistance paths 32 and 33 throughout the winding and is connected to a housing and/or clamp, which serves as an input and output terminal.

Fig. 3 shows the insertion loss frequency curves for a condenser and for my artificial transmission line. In this instance, the condenser is of the so-called non-inductive type, with one foil extending beyond one side of the winding. The artificial transmission line is of the type shown in Fig. 1 and possesses the same electrical capacity (in microfarads) as the condenser, when measured at 60 cycles. The condenser or the transmission line is placed as a filter in shunt with a load,

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so as to reduce or eliminate unwanted higher frequencies in the incoming signal. In the case of the transmission line, one side of the line is connected and fed through the core of the artificial transmission line; one end of the core is connected to the signal source and the other end of the core to the load. The metal housing is connected to the other side of the line, which is usually grounded. One terminal of the condenser is connected to one side of the line and the other terminal to the other side of the line, which, as aforesaid, is usually grounded. The effectiveness is measured by noting the ratio of voltage across the load at a particular frequency without and with the transmission line or condenser as a shunt, the source current being maintained constant. The ratio is known as the insertion loss and is expressed in decibels. Thus, if a high value of insertion loss occurs at a certain frequency, the signals of that frequency passing through the load are considerably reduced by the bypassing action when the transmission line or condenser is in shunt with the load circuit. High insertion losses indicate that the impedance across the bypassing device is low. A high insertion loss is therefore desirable when the artificial line or the condenser is to be employed as a filter circuit, for example, to remove high frequency signals from a primarily direct current power source.

Referring now to Fig. 3 of the drawing, curve A represents the insertion loss for the condenser previously mentioned. As the frequency increases, the insertion loss increases until resonance occurs. At this point, the insertion loss is very high and the filtering effectiveness is appreciable. As the frequency is further increased, however, the insertion loss rapidly decreases and approaches a relatively low value as a result of the appreciable inductance of the device. Curve B shows the insertion loss of the artificial transmission line. At lower frequencies, it is substantially similar to the condenser. As the resonant frequency is approached, however, the insertion loss approaches a maximum and thereafter, at higher frequencies, the insertion loss is maintained at or near this relatively high level. Thus its effectiveness as a filter circuit element for bypassing high frequencies is pronounced and far greater than that of the electrical condenser.

It is apparent that numerous modifications may be made of this invention without departing from the spirit and scope thereof. Representative modifications will be discussed in the following paragraphs.

The winding may be made with a number of different conducting layers. For example, paper may be metallized with zinc, aluminum, etc. to provide a very thin but conducting layer on the dielectric spacer. Alternately carbon paper may be employed. Suitable electrode foils include aluminum, copper, silver, lead, tin, etc. When the length of the narrow foil is appreciable, it is generally advisable to employ a fairly conductive material as the electrode material. For this purpose, copper, aluminum and silver are preferable.

The dielectric spacing material may be paper, a resin film, a resin coating on the electrode foil, a flexible ceramic coating on the foil, an oxide film on the foil, or other material which will withstand the operating voltages without breakdown. It is generally preferred to impregnate the convolutely wound assembly with a dielectric oil, wax or resin. To this end, the impregnation may be carried out either before or after placing the wound assembly in the housing.

The extended edges of the wide foil may be pressed together, soldered, welded, or otherwise interconnected to form a low resistance path to the terminal arrangement from each point in the winding. The housing is generally metal so as to produce a low impedance terminating path to the chassis or other electrical circuit point to which it is to be connected. A metal tube may be spun over the ends of the assembly against the bushing or other insulation on the axial terminal elements to the narrow foil. Alternately the winding may be wrapped in a flexible foil or provided with a sprayed metal coating. For some applications it is desirable to provide an insulating casing about the transmission line. In such cases a resin may be cast or heat-and-pressure molded about the winding, totally enclosing the latter with exception of the axial terminals to the narrow foil.

The axial terminal element which extends from both sides of the winding may be insulated from the extended wide foil edges with a bushing of a plastic material, as aforementioned, such as a polyamide, polyethylene, rubber, polysiloxane, etc. In some instances, particularly for low voltage applications, the insulation may be simply cotton, silk or a wire enamel. Where extremely high operation temperatures are to be met, ceramic or polytetrafluoroethylene bushings may be employed.

The width and length of the electrode foils as well as the materials of which they are made can be varied extensively to produce designs particularly adapted to certain applications. Where relatively low distributed inductance is desired in the transmission line, the narrow foil is shorter and wider than where a high distributed inductance is desired.

My invention has been particularly described in connection with electrostatic transmission lines. It is, however, quite possible to produce electrolytic transmission lines. In such instances the narrow electrode foil would be of a film forming metal such as titanium, aluminum, or tantalum and its surface would be provided with an insulating oxide film of the metal. Instead if a dielectric spacer an electrolyte-saturated spacer would be employed. The wide electrode foil would generally be of unformed aluminum or other film forming material suitably interconnected if necessary, and terminated as previously described. The axial terminal rod or core to the narrow electrode foil would be a film forming metal provided with the insulating oxide film layer thereon, to increase shunt resistance.

The use of cylindrical metal containers for the transmission lines of the invention is by no means critical, as the uncased wound assemblies themselves, with a low impedance terminal or strip to the wide electrode foil, may be employed. Further, the convolutely wound section may be pressed flat or square without any appreciable effect upon the high frequency characteristics. The metal casing adds to the durability of the line, to the simplicity of mounting, and in some cases to the simplicity of electric connection into the circuit.

The artificial transmission lines are usually incorporated in circuits by connecting one end of the core as an input terminal and the other end of the core as an output terminal for one side of the line. The terminal strap or metal housing for the wide foil serves as both input and output connection for the other side of the line, which, in

most instances, is grounded to the chassis or container of the complete circuit assembly.

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

I claim:

1. An artificial transmission line comprising two elongated layers of electrically conducting materials separated by and convolutely wound with dielectric spacing material, one of said layers of electrically conducting material being directly connected on both sides throughout substantially its entire length to a first electrically conductive terminal and the other of said layers of electrically conducting material being directly connected at its inner extremity only to a second electrically conductive terminal which extends from both sides of the winding.

2. An artificial transmission line comprising a wide electrode foil and a narrow electrode foil separated by and convolutely wound with layers of dielectric material of intermediate length, the wide electrode foil being directly connected on both sides throughout substantially its entire length to a first electrically conductive terminal and the narrow electrode foil being directly connected at its inner extremity only to a second electrically conductive terminal which extends axially from both sides of the winding.

3. An artificial transmission line comprising a wide electrode foil and a narrow electrode foil separated by layers of dielectric material and convolutely wound upon an electrically conducting core which extends beyond both sides of the winding, the narrow electrode foil being directly connected at its inner extremity to said core and the wide electrode foil being connected on both sides throughout substantially its entire length to a metallic housing for said winding.

4. An artificial transmission line comprising a wide elongated electrode foil and a narrow elongated electrode foil separated by layers of dielectric material of intermediate width, the longitudinal centers of each of said foils being in register and said foils being convolutely wound on an elongated metal core which extends beyond both edges of said winding, the inner turn of said narrow foil electrically engaging said core and the projecting edges of the wide foil being embedded in solder connected to a cylindrical metal housing which encloses said convolutely wound assembly.

5. An electrical circuit useful as a transmission line and in bypassing undesired electric signals of high frequencies, said circuit comprising the artificial line of claim 4 wherein said housing and one end of said core are connected as input terminals and the metal housing and the other end of said core are connected as output terminals.

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The following references are of record in the file of this patent:

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