BUILDING-OUT UNIT

Filed Oct. 22, 1938

FIG. 1

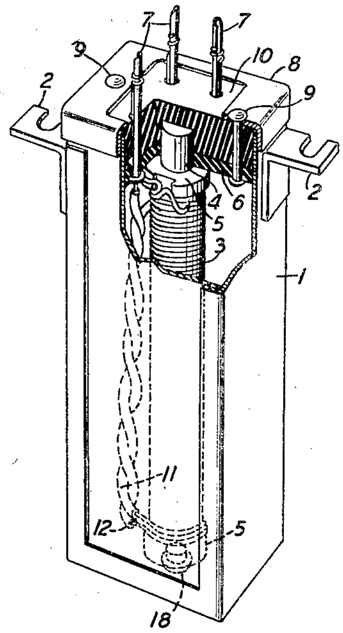


FIG. 2

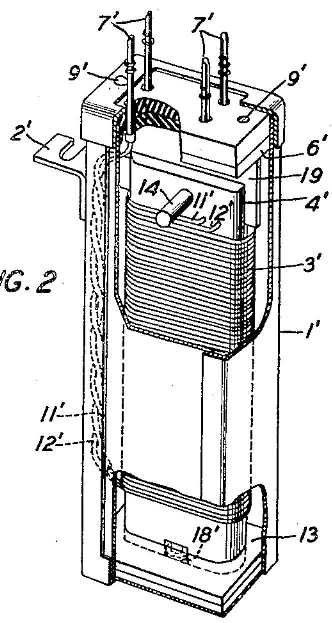


FIG. 3

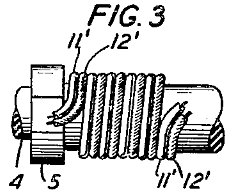


FIG. 3A

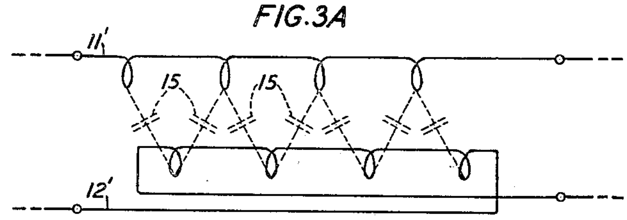


FIG. 4

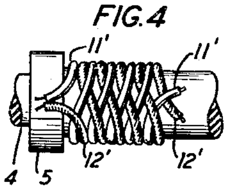


FIG. 4A

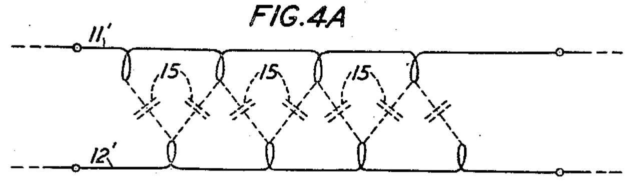


FIG. 5

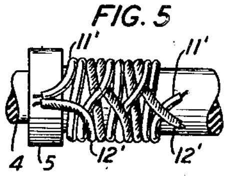


FIG. 5A

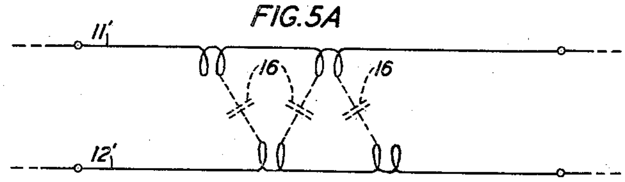
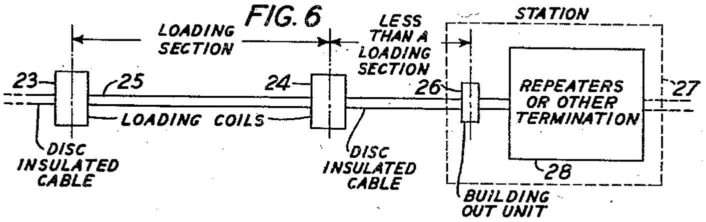


FIG. 6



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UNITED STATES PATENT OFFICE

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BUILDING-OUT UNIT

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9 Claims. (Cl. 178—46)

This invention relates to artificial lines and more particularly to devices which simulate the electrical characteristics of portions of transmission lines.

As is well known in the art, cable transmission lines are usually loaded at definite points with inductors to neutralize the distributed capacitance of the line. The length of the line between loading points is called a loading section and the inductors or loading coils are manufactured to have sufficient inductance to satisfy the requirements of a full loading section or a definite partial section. When repeaters or other transmission apparatus are inserted in the lines practical considerations are such that generally such apparatus is inserted at points other than those which define a full loading section or a definite partial section. It then becomes necessary to insert in the line apparatus which will simulate the characteristics of a length of the line sufficient to make the impedance of the line from the last loading point to the point of insertion of the transmission apparatus the equivalent of a loading section or a definite partial section. Apparatus for thus simulating the impedance of a part of a section is called a building-out unit. With ordinary cables it is, in general, merely necessary to insert capacitors of the proper value to build out the line to the corresponding value of the full or partial loading section.

Under certain conditions it is found economically desirable to apply carrier currents to open wire lines. However, when it becomes necessary to run carrier transmission lines below ground as in cities or under water, open wire lines cannot be used and it has been found advantageous to use disc insulated cable of the general type disclosed in Fig. 3 of U. S. Patent 2,086,629 to S. P. Mead, July 13, 1937, but having an additional lead sheath.

Disc insulated cable has a large distributed inductive reactance as well as distributed capacitive reactance. Building-out units for disc insulated cable must, therefore, have both inductive and capacitive reactances to simulate the characteristics of the disc insulated cable.

An object of this invention, therefore, is a building-out unit having both inductive and capacitive reactances in the same ratio as those of the line which is to be built out.

A further object of the invention is a building-out unit which may be altered in the field to give the required specific values of inductance and capacitance and maintain the ratio constant.

These objects are attained in one embodiment of the invention by using a solenoidal type of winding on a long thin core, the winding being such that when turns thereof are removed the ratio of inductance to capacitance remains substantially constant from full length down to about one-third of its original length.

This invention will be better understood and further objects and features will be apparent from the following description and attached drawing forming a part thereof and in which

Fig. 1 is a perspective view of a building-out unit with part of the enclosing case removed to show the coil;

Fig. 2 shows a modified unit also with a part of the enclosing case removed;

Fig. 3 shows a specific method of winding;

Fig. 3A is a schematic of the winding of Fig. 3;

Figs. 4 and 5 show modifications of the method of winding;

Figs. 4A and 5A show the respective schematics; and

Fig. 6 is a schematic diagram of a transmission circuit illustrating the use of a building-out unit.

Referring now particularly to Fig. 1 a metallic case 1 having mounting lugs 2 soldered or welded thereto encloses a long thin single-layer coil 3 comprising two windings wound as a parallel pair 11, 12, one for each side of a transmission line, on an insulating material core 4, and having insulating material spool heads 5. The coil is held in position, that is, spaced from the sides of the case by a piece of insulating material 6 which forms a terminal plate. A pin 13 or projection formed in the bottom of the case enters a recess in the bottom spool head to fix the coil in the lower end of the case. The ends of the windings are brought out to terminals 7 which are staked or otherwise fastened to terminal plate 6.

Terminal plate 6 is held in position by the cover 8 by means of long rivets 9. The space between plate 6 and the cover 8 is filled with an insulating compound or insulating block 10. The winding is given a wax coating and the cover 8 is preferably soldered to the casing 1.

Fig. 2 illustrates a modified type of unit in which the absolute values of inductance and capacitance as well as the ratio of capacitance to inductance are different from those of the coil of Fig. 1. In this unit the core 4' is substantially rectangular in cross-section and the winding 3' comprises a parallel pair 11', 12'. The enclosing case 1' is of the same shape and size as that of Fig. 1 so that a single type of case will be satisfactory for either type of coil.

To facilitate removal of turns, no spool heads per se are used. To hold the coil in position in the case a thin rectangular piece of insulating material 19 is fitted into a slot in the upper end of the core. Piece 19 is of such dimensions that it touches opposite sides of the case and is just flush with the terminal plate 6'. A cylindrical rod 14 which is tightly fitted into holes through the core 4' and piece 19 spaces the coil from the other sides of the case.

On the bottom there is a spacing piece 13 and a hole in the end of the core into which pin 18' fits to fix the lower end of the coil in the case.

The case is provided with mounting lugs 2' and the structure of the top of the case is the same as that of Fig. 1.

In terminating a length of disc insulated cable at points intermediate to the loading points, the cable can be built out to a certain extent by means of building-out units of fixed values. It so happens, however, that certain adjustments must be made in the field. The structures of Fig. 1 and Fig. 2 lend themselves readily to field adjustments since the cover and coil of either unit may be easily removed from the case. When the coil is removed turns of the windings may be removed to provide the correct values of inductance and capacitance.

With a long, thin coil such as that shown in Figs. 1 and 2 the inductance varies substantially linearly from full length down to about one-third the original length. Since the capacitance of the coil is the sum of the individual capacitances existing between the individual turns of the windings, it varies linearly also. Hence by removing turns from the core the inductance and capacitance are reduced while the ratio of capacitance to inductance remains constant.

Fig. 3 illustrates more clearly the windings when composed of a parallel pair. One winding comprises conductor 11' corresponding to 11 of Fig. 1 and 11' of Fig. 2, while the second winding comprises conductor 12' corresponding to 12 of Fig. 1 and 12' of Fig. 2. To have these windings connected in series aiding around the loop, some such expedient must be used as that shown in Fig. 3A. In this case conductor 12' is shown as doubled back on itself. The capacitances that exist in this coil to give the proper building-out capacitance are shown dotted at 15.

Fig. 4 shows a method of winding in which there need be no doubling back of one conductor to provide a series-aiding connection to the pair comprising a transmission line. In this case, for example, conductor 11' is given one turn in one direction around the core and then conductor 12' is given one turn in the opposite direction around the core. Conductor 11' is then given a second turn and then conductor 12' is given its second turn. This is carried on until the desired number of turns have been made. This method of winding, of course, requires that the conductors cross once per turn. This cross-over, however, will have no detrimental effect. The capacitances between the turns as shown in Fig. 4A are substantially the same as in Fig. 3A.

Fig. 5 shows an arrangement where less capacitance is needed to give the desired ratio. In this case conductor 11' is given two turns around the core in one direction and then conductor 12' is given two turns around the core in the opposite direction. Conductor 11' is then given two more turns, followed by two turns of conductor 12' until the desired number of turns has been applied. In this case there is a cross-over of two turns, as shown.

Fig. 5A shows the distribution of the capacitances, and it is to be noted that these capacitances 16 exist only between adjacent turns of the individual conductors and since there are two turns of one conductor followed by two turns of the second conductor the total capacitance is reduced. It is, of course, understood that there exist other extremely minute capacitances between various parts of the winding but these are so small as to have no appreciable effect. As shown, there exist three effective capacitances 16 with four turns of each conductor wound as in Fig. 5, while with four turns of each conductor wound as in Figs. 3 and 4 there exist seven capacitances.

To give a further decrease of capacitance one conductor may be given three turns and then the second conductor may be given three turns, or to further decrease the capacitance the number of turns of each conductor may be four, five, etc., depending upon the capacitance desired or the ratio of capacitance to inductance required.

Figs. 1 and 2 may be considered from a design standpoint as limiting cases as to the shape of the building-out unit. The capacitance of the units under discussion is broadly proportional to the length of the adjacent wires or to the perimeter of the cross-section perpendicular to the axis of the unit. In the same way the inductance of the unit is broadly proportional to the area of the cross-section of the unit. Hence with a cylindrical unit in which the perimeter of the cross-section is a minimum for a given area, the capacitance is a minimum for the inductance.

Now at the other extreme consider a very thin rectangle. In this case the perimeter is large as compared to the area and it is also found that the capacitance is large as compared to the inductance when the unit is connected to be series aiding in the loop.

Therefore, in arriving at the proper shape for the unit, disregarding methods of windings, as, for example, those of Figs. 4 and 5, the desired ratio of capacitance to inductance will be found with some shape varying in cross-section from the circle of Fig. 1 to the rectangle of Fig. 2. Because of practical winding conditions the corners of the rectangular form must be somewhat rounded.

As specific examples of coils according to this invention, a cylindrical coil having a ratio of length to diameter of about 5 or 6 with the length approximately 2⅓ inches and eighty turns had a normal inductance of 11.7 microhenries and a capacitance of 200 micromicrofarads. A coil of oval or substantially rectangular cross-section had a length of approximately 3½ inches and a thickness of approximately $\frac{4}{10}$ inch, giving a length-to-thickness ratio of approximately 8¾ or 9. With one hundred turns, this coil had a maximum inductance of 23.4 microhenries and a capacitance of 400 micromicrofarads, the ratio of capacitance in micromicrofarads to inductance in microhenries being about 17 in each coil. Coils having a normal ratio of 17 are considered satisfactory if they have a ratio from 16 to 18.

These coils are designed for use with a four-wire disc insulated cable in which the loop inductance for one mile of a diagonally opposite pair is 1,445 microhenries and the corresponding capacitance is 24,670 micromicrofarads at a frequency of 90 kilocycles, the ratio of capacitance to inductance being approximately 17.

It is to be understood in the foregoing discussion involving the number of turns of the coil that a coil wound with a parallel pair and spoken of as one of one hundred turns has fifty turns of the parallel pair. As to the removal of turns, the removal of one turn means the removal of one turn of the pair. For example, a coil having one hundred single turns and having one turn of the pair removed would have a capacitance and an inductance one-fiftieth less than the original coil. This is also true of coils having the cross-over type of winding illustrated in Figs. 4 and 5. A coil having one hundred single turns of the cross-over type has fifty turns in each direction and the removal of one turn means the removal of one turn of each winding. There may be cases in practice where only one turn of one winding is removed. In such cases the resultant unbalance is of less importance than the specific value of capacitance and inductance desired.

Fig. 6 is a schematic circuit diagram showing loading coils **23** and **24** inserted in a transmission line comprising a disc insulated cable **25**. A building-out unit **26** is shown as included in station **27** which houses repeaters or other terminating apparatus **28**. The distance between loading coils **23** and **24** is indicated and defined as a "full loading section" while the distance between loading coil **24** and station **27** or the building-out unit **26** in station **27** is indicated as less than a full loading section thereby making the building-out unit necessary. This figure illustrates that when a transmission line is to be terminated at a point other than a loading point, the length of the line which is physically shorter than a loading section may be built out by means of apparatus which will make such a section equivalent electrically to a full section. Such an electrically built-out section can then be properly terminated.

Certain specific forms of the invention have been described and illustrated as examples. The invention, however, is to be limited only by the scope of the appended claims.

What is claimed is:

1. A building-out unit for a transmission line having capacitive and inductive reactance which comprises a coil in which the ratio of total inductance to total capacitance is substantially equal to that of said line.

2. A building-out unit for a transmission line having capacitive and inductive reactance which comprises a coil having a single-layer winding the loop inductance and the capacitance between the wires of the windings of which are substantially equal to the loop inductance and the capacitance between the wires of a predetermined portion of said transmission line.

3. A building-out unit for simulating the impedance of a section of a loaded transmission line which comprises a coil having a non-magnetic core and a single-layer winding on said core the inductance and capacitance of which have the same ratio as that of the section of the line to be built out.

4. A building-out unit for a loaded transmission line which comprises a coil having a single-layer winding the ratio of the inductance to capacitance of which remains substantially constant for more than half of the number of turns of said winding.

5. Means for building out a section of a transmission line to make said section have an inductance and a capacitance equal to the inductance and capacitance of another section of said line which comprises a core of a length several times its diameter, a single-layer winding on said core, said winding comprising a plurality of conductors wound on said core a sufficient number of turns to give said winding an inductance and a capacitance equal to the difference between the inductance and capacitance of the section to be built out and the inductance and capacitance of said other section.

6. A building-out unit for a loaded transmission line which comprises a coil having a ratio of length to thickness which may vary from 5 to 9 and having a ratio of capacitance as measured in micromicrofarads to inductance as measured in microhenries of approximately 17 and in which the ratio of capacitance to inductance remains substantially constant for approximately two-thirds the length of the coil.

7. In a transmission line loaded at specified points, the distance between such points defining a loading section, a termination of said line at a point other than one of said specified points and means to simulate the electrical characteristics of said line inserted at said termination to make the section of line from the preceding loading point to the termination electrically equivalent to a full loading section, which means comprises a coil having a ratio of length to thickness of approximately 9 and a ratio of capacitance to inductance substantially the same as the ratio of capacitance to inductance of said line.

8. In a transmission line loaded at specified points, the distance between such points defining a loading section and having both inductive and capacitive reactance characteristics, a termination of said line at a point other than one of said loading points and means inserted in said line to build out said incomplete section to the electrical equivalent of a full section which comprises a coil having a cross-section other than circular and having capacitive and inductive reactances which vary substantially linearly for two-thirds of the length of said coil.

9. A building-out unit for a transmission line comprising a cylindrical core having a length of the order of five to nine times the diameter, a single layer winding on said core, said winding comprising a plurality of wires, the ratio of the capacitance in micromicrofarads between the wires to the loop inductance in microhenries of the winding being substantially the same as that of the transmission line which the unit is to build out, said ratio remaining substantially constant for more than half the length of said winding.

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