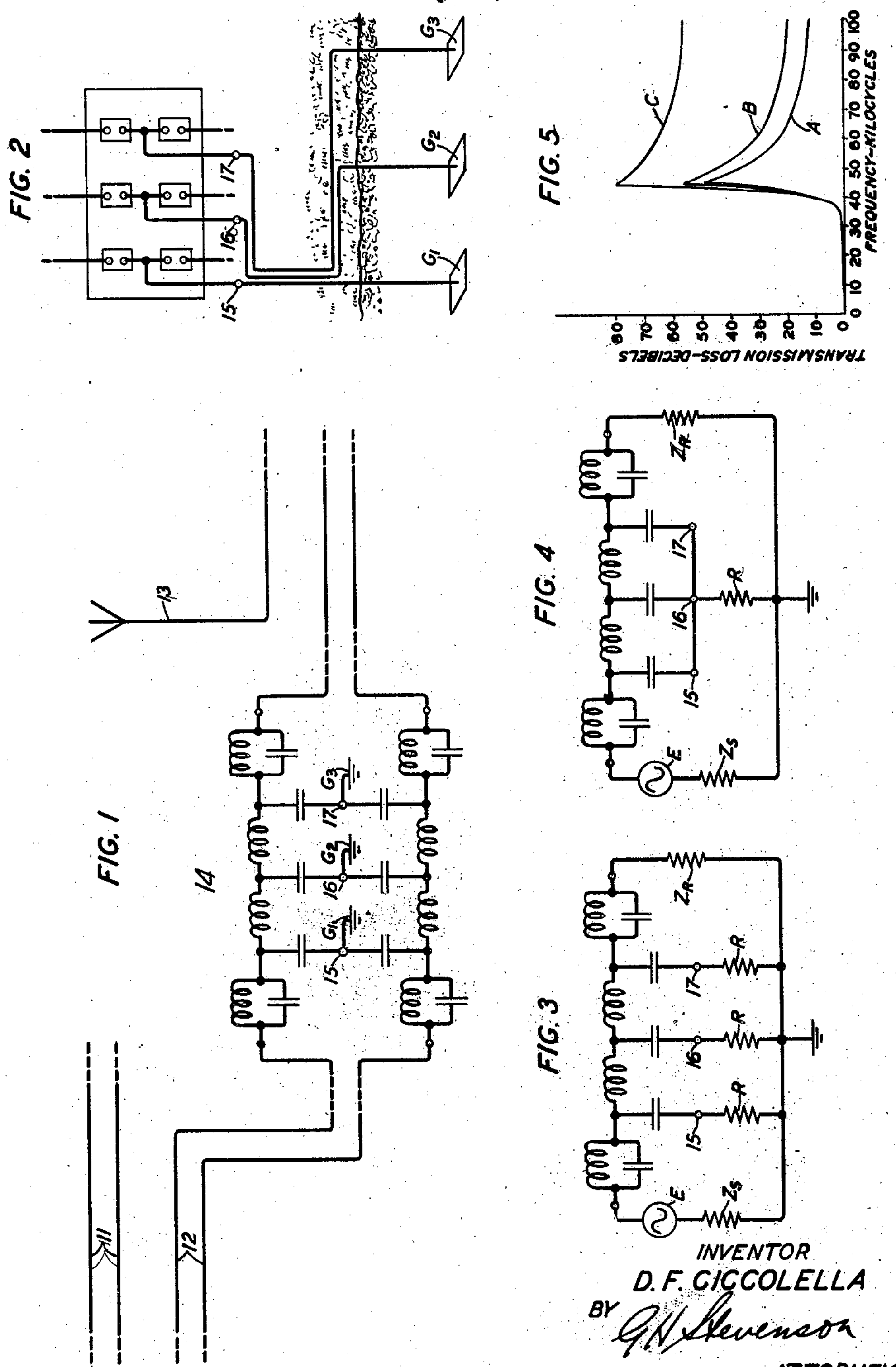
March 24, 1936. D. F. CICCOLELLA 2,035,261

ELECTRICAL WAVE FILTER

Filed Aug. 26, 1932



INVENTOR
D. F. CICCOLELLA
BY G. H. Stevenson
ATTORNEY

Patented Mar. 24, 1936

2,035,261

UNITED STATES PATENT OFFICE

2,035,261

ELECTRICAL WAVE FILTER

David F. Ciccolella, Albany, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 26, 1932, Serial No. 630,528

11 Claims. (Cl. 179—78)

This invention relates to wave transmission and more particularly to electric wave filters adapted for use in a loop circuit which also carries longitudinal currents.

The principal object is to pass without appreciable distortion a range of frequencies in the loop circuit and at the same time to suppress the longitudinal currents over a range of frequencies.

A feature of the invention is a multi-section filter in which each shunt branch is provided with a separate ground connection.

An aerial telephone line which parallels an aerial power line is exposed to electrostatic and electromagnetic induction which tends to set up longitudinal currents in the telephone line. In this way disturbances in the power line produced by switching, changes of load, accidental grounds, lightning or the like cause corresponding disturbances in the telephone line. These surges on the telephone line may, in turn, be reradiated to other communication systems, such as a nearby radio antenna, causing noise or other objectionable interference. Under these circumstances there is presented the problem of suppressing the undesirable longitudinal currents without appreciably interfering with the transmission of the signal currents in the loop circuit.

In one instance in which this problem arose suppression of the longitudinal currents in the telephone line was attempted by inserting a single-section, low pass filter having a single shunt branch in the telephone line at a point some distance from the affected antenna. The filter was of the balanced-to-ground type, with the electrical mid-point of the shunt impedance connected to a metal rod driven into the ground. The cut-off point of the filter was so chosen that carrier telephone currents below 30 kilocycles were transmitted but the longitudinal currents above 40 kilocycles were attenuated and their interference in the antenna circuit was thus reduced. But tests showed that the longitudinal currents were not sufficiently suppressed by the single section filter and, accordingly, a three-section filter was substituted. The mid-points of the three shunt arms were strapped together and connected to the ground. Field measurements showed that, at some frequencies in the attenuation band, the longitudinal currents were attenuated to only a slightly greater extent by the three-section filter than they were by the single-section filter. Further field measurements made in an attempt to find the reason for this showed that the best ground connections obtainable in the vicinity of the filter offered an appreciably high impedance. The straps connecting the mid-points of the shunt arms of the three-section filter were then removed and a separate ground connection to an individual metal rod driven into the ground was provided for each shunt branch. When this had been done the multi-section filter gave a satisfactory performance and the longitudinal currents were sufficiently suppressed.

The nature of the invention will be more fully understood by reference to the following detailed description, taken in connection with the accompanying drawing in which:

Fig. 1 shows an embodiment of the invention in a wave transmission system;

Fig. 2 is a detail of the shunt condensers of the filter of Fig 1, illustrating the separate grounding arrangement;

Figs. 3 and 4 are circuit diagrams to which reference is made in explaining the invention; and

Fig. 5 shows typical attenuation characteristics obtainable with the structures of Figs. 1, 3 and 4.

In Fig. 1 a power line 11 or other source of disturbance is shown located in such proximity to a portion of a two-wire telephone line 12 that electrical disturbances in the power line will induce longitudinal currents of corresponding frequency in the telephone circuit. By carefully balancing the two sides and by transposing the two wires in a well known manner the effect of these disturbances on the loop circuit of the line 12 may be largely overcome. There remains, however, the longitudinal current which traverses both wires of the line 12 in the same direction, with ground as the return path. A radio receiving antenna 13 is shown adjacent to a portion of the line 12. Disturbances on the telephone line of the frequency used in the radio channel tend to be radiated to the antenna and to cause interference with the received radio signals, either directly or by modulation. To suppress the undesired longitudinal currents in that portion of the telephone circuit 12 which is near the antenna 13, an electric wave filter 14 is inserted in the telephone line. The filter 14 is of the low-pass type, with a balanced-to-ground construction, and comprises two full sections of the type illustrated and described in the patent to Campbell, 1,227,113 of May 22, 1917, to either end of which is added a half section of the type disclosed in Patent 1,493,600, also to Campbell, issued May 13, 1924. The electrical mid-points of the shunt branches are brought to separate ground terminals 15, 16 and 17, which are connected, respectively, to the individual grounds G_1, G_2 and G_3. These grounds may be metal stakes driven into the earth, buried metal plates, or other suitably constructed grounds.

The grounding arrangement is shown in more detail in Fig. 2 which illustrates a portion of the filter 14 comprising the three pairs of condensers in the shunt arms and the ground connections. The ground terminals 15, 16 and 17 are connected to separate metal plates G_1, G_2, and G_3 buried in the earth at some distance from each other.

The reason for having separate grounds G_1, G_2 and G_3 for the different shunt branches of the filter will now be explained, with the aid of the diagrams shown in Figs. 3 and 4. When a ground of the type described is used in a dry or rocky terrain it will be found that there is always associated therewith an impedance of appreciable magnitude. In the instance referred to above, the value of this impedance was found by measurement to be as high as 100 ohms in certain places. This ground resistance is shown schematically in Figs. 3 and 4, as R.

In accordance with former practice the three ground terminals 15, 16 and 17 would be strapped together and connected to a single ground. The filter 14 would then present to the longitudinal circuit the configuration shown schematically in Fig. 4 in which R represents the ground resistance, Z_s is the impedance facing the input end of the filter, Z_r is the impedance into which the filter works at the output end and E represents the electromotive force acting between the two wires of line 12 and ground. Curve A of Fig. 5 shows a typical transmission characteristic obtainable with the network of Fig. 4. The transmission loss in decibels is given by the ordinates and the frequency in kilocycles per second is represented by the abscissas. It will be noted that the maximum loss is below 50 decibels and at 100 kilocycles the curve falls to the vicinity of 10 decibels. The reason that the loss falls to such a low value in the attenuating region of the filter is due largely to the fact that there is a common impedance R in the ground connection and the shunt branch of every section of the filter is coupled to the load impedance through a low impedance path comprising only capacitances.

Some increase in the attenuation of the filter may be obtained by the use of a multiplicity of grounds, thus, in effect, reducing the value of the ground impedance R. If, for example, three different ground connections are used in parallel, while terminals 15, 16 and 17 remain strapped together, the value of R in Fig. 4 is reduced to one-third of its former magnitude, and the transmission characteristic of the filter will be as shown by curve B of Fig. 5. Curve B it will be noted indicates an increase of approximately ten decibels over the corresponding points on curve A.

In the arrangement of the invention each shunt arm of the filter is grounded separately, as shown schematicaly in Fig. 3, and in this way the path through the ground wire in the filter to the load is effectively open circuited. Curve C of Fig. 5 shows a typical transmission characteristic given by the filter of Fig. 3, which is identical to the filter of Fig. 4 except for the separate grounding arrangement noted. It is seen that curve C reaches a maximum loss of approximately 75 decibels and at no point in the attenuating range falls below 50 decibels. The lowest point in the attenuated band of curve C exceeds the lowest point in the same region of curve A by approximately 40 decibels, and this very desirable increase in attenuation is brought about by the use of a separate ground for each shunt impedance arm. In order that the conduction between the various ground terminals 15, 16 and 17 will not be too large and thereby defeat the purpose of the separate grounding, it is necessary that the individual ground rods or plates G_1, G_2 and G_3 be spaced apart a distance which is dependent upon the character of the earth at the place where the filter is located. In practice it has been found that a spacing of the order of five to ten feet is satisfactory, but under certain conditions a greater or a less distance may be required.

What is claimed is:

1. In a communication system, a transmission circuit comprising a balanced telephone line as one path with ground as the return path, and a wave filter of balanced construction comprising series arms and shunt arms, said filter being located in said telephone line and the electrical mid-point of each shunt arm of said filter being connected to a separate ground, whereby the impedance of the electrical path formed by the ground connections between any two of said electrical mid-points is made of sufficient magnitude to prevent the tendency to short-circuit the series arms of said filter.

2. In a signal transmission system, a signal circuit comprising a pair of line wires balanced with respect to ground, a longitudinal circuit comprising said pair of line wires as one path and ground as a return path, and a balanced wave filter having series branches in each of said line wires and a plurality of branches in shunt with respect to said line wires, the mid-point of each of said shunt branches being connected to a separate ground, whereby the impedance of the electrical path formed by the ground connections between said mid-points is made so high that the effective short-circuiting of the series branches of said filter is prevented.

3. In an electrical communication system, a transmission circuit consisting of a telephone line as one path and ground as the return path, and frequency selective means in said circuit comprising a wave filter of the ladder type having a plurality of shunt impedances in which the electrical mid-point of each shunt impedance is connected to a separate ground, whereby the short-circuiting effect caused by the ground connections between said mid-points is substantially eliminated.

4. A two-wire signal transmission circuit in which longitudinal currents are flowing in the same direction in each wire of said circuit with ground as the return and suppression means in said circuit consisting of a wave filter of the series shunt type comprising a plurality of shunt branches, the electrical mid-point of each of said shunt branches being connected to an individual ground, whereby the conductance of the electrical path between two of said mid-points comprising the ground connections is greatly decreased.

5. A signal circuit comprising a pair of line wires, a longitudinal circuit including said pair of wires as one path with ground as the return path, and frequency selective means located in said signal circuit consisting of a wave filter comprising series impedances and shunt impedances, the mid-point of each of said shunt impedances being connected to a separate ground, whereby the impedance of the electrical path formed by the ground connections between two of said electrical mid-points is made sufficiently large in magnitude to avoid the effective short-circuiting

of a series impedance of said filter in the attenuating region.

6. A two-wire signal circuit in which undesired longitudinal currents are flowing and a balanced wave filter comprising series impedances and shunt impedances in alternation therewith located in said signal circuit, the electrical mid-point of each shunt impedance being connected to an individual ground, whereby the impedance of the path formed by the ground connections between said electrical mid-points is made of sufficient magnitude to prevent the tendency to short-circuit the series arms of said filter at frequencies falling in its region of suppression.

7. In a wave transmission system, a two-wire signal circuit in which undesired longitudinal currents are induced, and means located in said signal circuit for suppressing said longitudinal currents consisting of a balanced wave filter comprising series impedances and shunt impedances, the mid-point of each of said shunt impedances being connected to a separate ground, in order to increase the impedance of the electrical path between two of said mid-points comprising the ground connections.

8. In a wave transmission system, a two-wire circuit in which undesired longitudinal currents are induced, a balanced wave filter comprising series impedances and shunt impedances located in said two-wire circuit, the electrical mid-point of each of said shunt impedances being connected to a separate ground, whereby the short-circuiting effect upon a series impedance of said filter caused by the conductance between two of said mid-points through the ground connections is substantially eliminated.

9. In a wave transmission system comprising a loop circuit in which undesired longitudinal currents are also flowing, with ground as the return path, a wave filter of the series-shunt type comprising series impedances and a plurality of shunt impedances located in said loop circuit, said filter being adapted to attenuate said longitudinal currents and said filter having the electrical mid-point of each shunt impedance connected to a separate ground, whereby the impedance of the electrical path formed by the ground connections between any two of said electrical mid-points is made of sufficient magnitude to prevent the tendency to short-circuit the series impedances of said filter.

10. In a signal transmission system, an open-wire telephone line in which longitudinal currents are flowing with ground as the return path, and frequency selective means located in said telephone line consisting of a balanced wave filter comprising impedances in series with the line and a plurality of impedance branches in shunt with the line, the electrical mid-point of each of said shunt branches being connected directly to a separate metal plate, and each of said plates being buried in the ground at a minimum distance of the order of five feet from said other plates.

11. In an open-wire signal transmission system, a signal circuit comprising a pair of line wires balanced with respect to ground, a longitudinal circuit comprising said pair of line wires as one path and ground as the return path, a source of disturbing voltage tending to cause undesired currents to flow in said longitudinal circuit, and a balanced wave filter having series branches in each of said line wires and a plurality of branches in shunt with respect to said line wires, said filter being adapted to attenuate said undesired currents, the electrical mid-point of each of said shunt branches being connected directly to a separate ground plate, and each of said plates being buried in the earth at spaced intervals from each other.

DAVID F. CICCOLELLA.