Jan. 12, 1932. F. A. COWAN 1,840,434

CONDUCTOR SYSTEM FOR SIGNALING CURRENTS

Filed Feb. 14, 1931

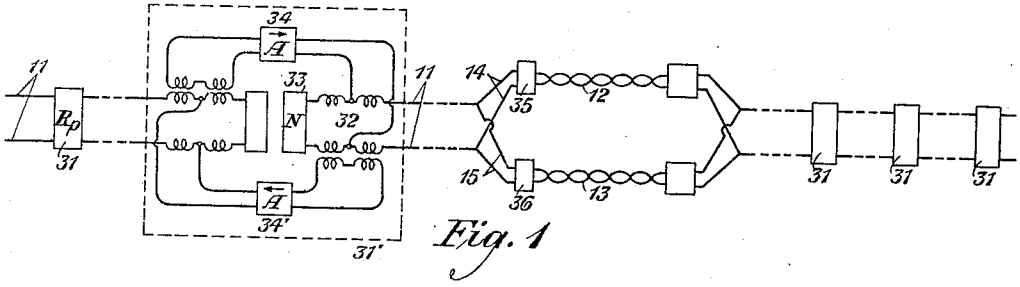


Fig. 1

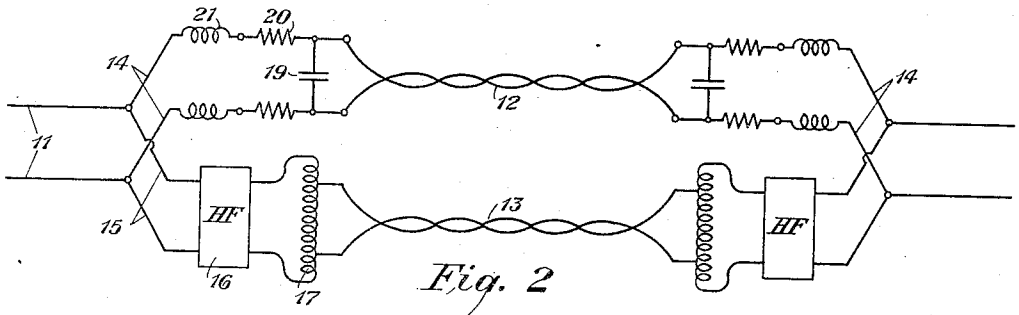
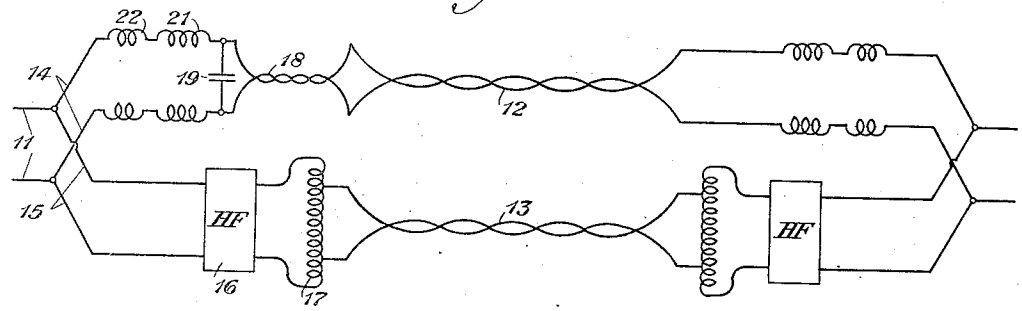


Fig. 2



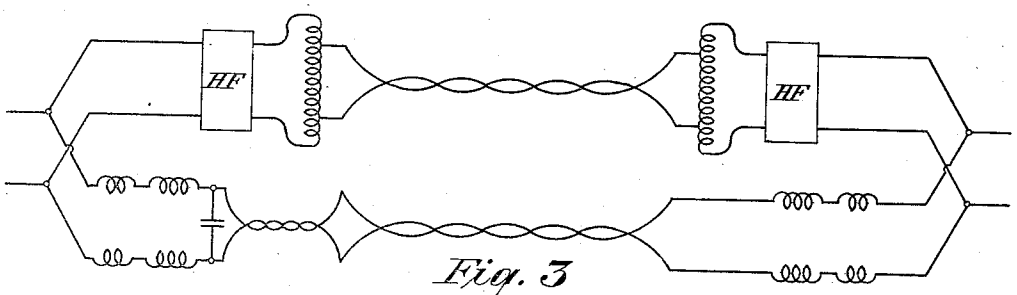


Fig. 3

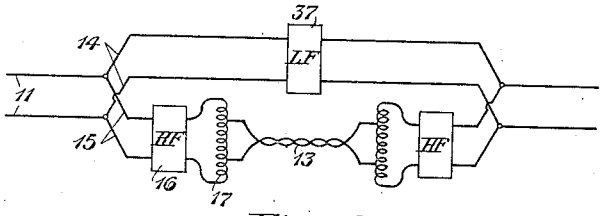


Fig. 4

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Patented Jan. 12, 1932 1,840,434

UNITED STATES PATENT OFFICE

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CONDUCTOR SYSTEM FOR SIGNALING CURRENTS

Application filed February 14, 1931. Serial No. 515,860.

An object of my invention is to provide a new and improved system for conducting signaling currents over a line having diverse characteristics in different parts. Another object is to effect transmission over a signaling circuit having two consecutive parts of widely different character, so that there shall be substantially no loss nor irregularity due to the connection of these parts. Another object is to connect an open wire transmission line through a link of submarine cable in such a way that there shall be no loss nor irregularity due to this connection. Still another object is to connect an open wire transmission pair through two parallel submarine cable pairs, one for high frequency and the other for low frequency, with corresponding filters, making the low frequency cable pair a constitutent element of a low-pass filter. These objects and other objects of my invention will become apparent on consideration of a limited number of specific examples of practice according to the invention, which will be disclosed in this specification. It will be understood that this disclosure will relate principally to these particular examples of the invention and that the scope of the invention will be indicated in the appended claims.

Referring to the drawings, Figure 1 is a diagram showing an open wire transmission line with several repeaters therein and a connecting link therein through two conductor pairs of a submarine cable; Fig. 2 is a diagram more in detail showing the two cable pairs and associated filters; Fig. 3 is a corresponding diagram for two side circuits and a phantom circuit; and Fig. 4 is a diagram corresponding to Fig. 2 but with the low-pass filter shown symbolically to facilitate explanation.

The open wire line 11 shown in Fig. 1 carries ordinary superposed Morse telegraph currents, and currents of low or voice frequency range, say from about 200 cycles to 2800 cycles, and currents of high frequency, say from 3300 cycles up to 30,000 cycles per second. 22-type repeaters 31 are interposed at intervals, say of about 200 miles. In Fig. 1 these repeaters are shown symbolically by boxes, except that one of them is elaborated enough to show the three-winding transformers 32, the balancing networks 33 and the two one-way amplifying elements 34.

Assuming that this line 11 must be connected across a body of water too wide for an aerial span, the connection is made through two conductor pairs 12 and 13 of a submarine cable, each pair twisted to minimize cross-talk. Apparatus represented symbolically at 35 and 36 in Fig. 1 is associated with the ends of the cable pairs 12 and 13 to make the transmission without substantial loss or irregularity. In other words the construction at and in connection with the span is such as to make the "return loss" high, thus preserving repeater balance, reducing reflection cross-talk and reducing transmission loss. These cable pairs 12 and 13 and the associated apparatus are shown more in detail in Fig. 2. The arrangement is such that the low frequency currents go through a pair 12 and the high frequency currents through a pair 13.

As shown in Fig. 2, line 11 leads by one pair of branch conductors 15 to the high-pass filter 16 which cuts off, say, at 3,000 cycles per second. The other pair of branch conductors 14 leads to the low-pass branch of the system, which transmits freely up to 3,000 cycles, for the example chosen. On its output side the filter 16 is connected to the high voltage side of transformer 17, which is shown in the drawings as an autotransformer, and the ends of the cable pair 13 are connected to the low voltage side of this autotransformer 17. The end elements of the low-pass and high-pass branches are so designed that the impedances of these branches are complementary to each other in the sense that their combined impedance in parallel is substantially equal to the impedance of the line 11 over the greater part of the frequency ranges transmitted by the two branches. Further information on this detail of construction may be gained from the United States patent to O. J. Zobel, No. 1,615,252 granted January 25, 1927. On the other end of the high-pass structure, when connection is made to the autotransformer 17, a mid-series or mid-shunt termination is used so that the impedance of the structure is very

nearly equal to that of the cable pair 13, as viewed through the autotransformer.

Whereas there are two high-pass filters at the respective ends of the cable pair 13, there is properly speaking, only one low-pass filter associated with the cable pair 12. The conductor pair 12 has considerable capacity between its two sides, and it also has resistance, inductance and leakage. All of these properties are recognized as factors in the design of the low-pass filter. The capacity is utilized in the building of the low-pass filter connecting the branch conductors 14 on one side with the branch conductors 14 on the other side. This is indicated symbolically in Fig. 4, where the low-pass filter is represented at 37. The chief source of loss in the transmission band of a filter is the resistance element. Where low loss is important it is necessary to make the resistance small. In the present case, however, the principal consideration is the matching of two impedances which can be accomplished only by adding resistance to the filter structure, at the same time, of course, adding some loss.

Whatever the capacity between the two conductors of the pair 12, two condensers 19, equal to each other, are connected across the sides of the pair at its ends so as to build out the total capacity to 0.171 microfarad. Then, equal resistances 20 are added in series so as to build out the total resistance of the pair 12 to such a value that the ratio of resistance to inductance in one complete section of the low-pass structure shall equal the corresponding ratio for any length of the open-wire line 11. The reason for adding the resistance 20 as specified above is to make the filter structure simulate at low frequencies the impedance of the open wire line 11, to which the cable pair 12 is connected.

Beyond the resistances 20, series inductances 21 are interposed of the proper values so that with the capacity mentioned, namely, 0.171 microfarad, the combination will constitute a low-pass filter with the proper fractional termination and cutting off at 3,000 cycles per second, and having an impedance characteristic closely simulating the open wire line to which it will be connected.

In the line 11 the high frequency and low frequency currents will be superposed, but where it branches at 14 and 15, the high frequency currents, those above 3,000 cycles per second, will go through the conductor pair 13 and the low frequency currents, those below 3,000 cycles per second, will go through the conductor pair 12. The arrangement which we have disclosed gives operation with fairly low transmission losses and practically no adverse reaction on superposed direct current telegraph or other signal operation.

Referring to Fig. 1, the network 33 is designed to have the same impedance looking into it from the right that the line 11 has looking toward the right from the three-winding transformer 32. If this balance is perfect, then the energy from the output side of the amplifier 34 will divide equally at the three-winding transformer 32 and none of it will be communicated to the input side of the other amplifying element 34'. The interposition of the cable conductor or conductors would destroy this balance unless provision were made to preserve it. The design of the system, as shown in Fig. 2 and explained in connection therewith, is such that the impedance looking in from the line 11 toward the junction of the branch conductors 14 and 15 is substantially the characteristic impedance of the line 11 at all frequencies, except in that range immediately around the cutoff point. Moreover, this desirable relation is secured without the introduction of any considerable transmission loss in the cable. Of course, the resistances introduced at 20 will occasion some loss, but this amounts only to about 1 decibel, which is not serious.

The design is flexible and easily adapted to various widths to be connected; that is, various lengths for the conductor pairs 12 and 13. Using 10 gauge cable pairs of low capacitance, this distance could probably be made as much as three miles. According to the present specific illustrative example, the limiting distance is about 6,000 feet, and whatever the length of the span to be bridged, within about 6,000 feet, the condenser or condensers 19 are added to build out the capacity to 0.171 microfarad, and the resistances 20 are added to build out the resistance to the proper value corresponding to the resistance of the open wire line, as explained heretofore.

The two sides of a phantom combination are shown in Fig. 3. Each side is substantially the same as Fig. 2, with the addition of a small amount of extra inductance, as indicated at 22, comprising a coil so wound as to be inductive in the phantom circuit but non-inductive in the side circuits. In Fig. 3 the additional resistances are not introduced in the form shown at 20 in Fig. 2, but by building out the cable pair 12 with the extended cable pair 18, so that the total length of the parts 12 and 18 is 6,000 feet or the amount necessary to give the proper resistance value. This gives the necessary resistance, and then a condenser 19 is added to build out the capacity so that the capacity of 12, 18 and 19 amounts to 0.171 microfarad. In Fig. 2 the building out with resistance and capacity has been done symmetrically on both ends of the conductor pair 12, but in Fig. 3 the building out has been done all on one end by the introduction of the elements 18 and 19.

The building out condenser 19 may be in the form of stub cable pair, and in Fig. 3

the two building out condensers 19 may be in the form of stub cable quad. In this case the chief purpose of using cable for building out is to adjust the phantom to a definite length, so that a standard phantom load coil may be used. In lieu of this, a building out condenser equal to that in the side circuits could be obtained by tapping the side circuit condensers at their midpoints and connecting these midpoints. Another condenser could be inserted at this point if a lower capacity value were desired in the phantom.

I claim:

1. In a signaling system, a line having two parallel branches, one for high frequency and the other for low frequency, and a low-pass filter in the low frequency branch having the capacity between the two sides of the branch as at least a part of the shunt capacity of said filter.

2. In a signaling system, a line having two parallel branches each with certain reactance values and respective filters to separate the currents in the line to the two branches according to their frequency, one of these filters comprising a reactance element of the associated branch as a component element of the filter.

3. In a signaling system, an open wire line carrying high and low frequencies, a length of multi-conductor cable having two conductor pairs interposed in parallel in said line, high-pass filters, one at each end of one conductor pair and a low-pass filter in the other pair, said last mentioned filter comprising the capacity of that pair as at least a part of the shunt capacity of the filter, and further impedance component elements at an end of the pair to build it out to constitute the proper low-pass filter.

4. In a signaling system, an open wire line carrying high and low frequencies, a length of multi-conductor cable having two conductor pairs interposed in parallel in said line, high-pass filters at the ends of one conductor pair each matching the impedance of the open wire line, autotransformers between said high-pass filters and the corresponding cable conductor pair to match their impedances, and a low-pass filter in the other pair, said low-pass filter comprising the reactance elements of said last mentioned pair as part of the reactance elements of the filter.

5. In a signaling system, an open wire line carrying high and low frequencies, 22-type repeaters interposed therein each with networks to balance the line, a length of multi-conductor cable having two conductor pairs interposed in parallel in a length of said open wire line between two repeaters, and a high-pass filter and a low-pass filter in the respective interpose conductor pairs each with its impedance looking in from the line the same as the characteristic impedance of the line so that the balance between the open wire line and its balancing network is not disturbed, the said low-pass filter comprising as its essential reactance element the cable conductor pair with which it is associated.

6. In a signaling system, an open wire line carrying high and low frequencies, a length of multi-conductor cable having two conductor pairs interposed in parallel in said line, high-pass filters at the ends of one conductor pair and a low-pass filter in the other pair, said last mentioned filter comprising the capacity of the pair as at least a part of the shunt capacity of the filter, and further impedance component elements at an end of the pair to build it out to constitute the proper low-pass filter, and a building-out resistance also incorporated in the low-pass filter to match its impedance to the line at the lowest frequencies.

7. In a signaling system, an open wire line with interposed 22-type repeaters and carrying high and low frequencies, said line comprising a comparatively short submarine cable length, and means to keep the line in balance with the balancing networks in the repeaters comprising impedance component elements combined with a conductor pair of said cable so that the combination shall constitute a low-pass filter with the capacity between the two sides of the pair serving as at least part of a shunt capacity of the filter.

8. In a signaling system, an open wire line carrying high and low frequencies, a length of multi-conductor cable having two conductor pairs interposed in parallel in said line, high-pass filters at the ends of one conductor pair and a low-pass filter in the other pair, said last mentioned filter comprising the capacity of the pair together with lumped capacity to build it out to a fixed capacity value to constitute the shunt capacity of the low-pass filter, and lumped inductances to constitute the series inductances of such filter.

In testimony whereof, I have signed my name to this specification this 9th day of February, 1931.

FRANK A. COWAN.