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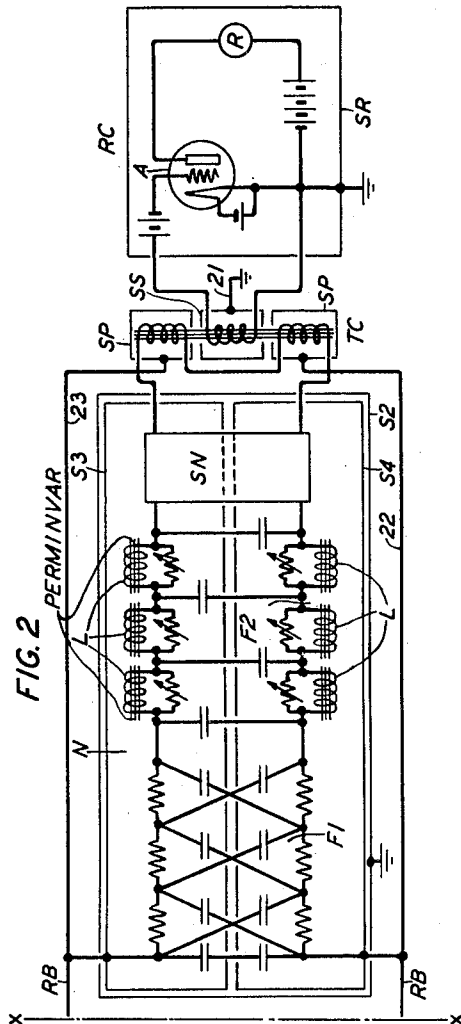
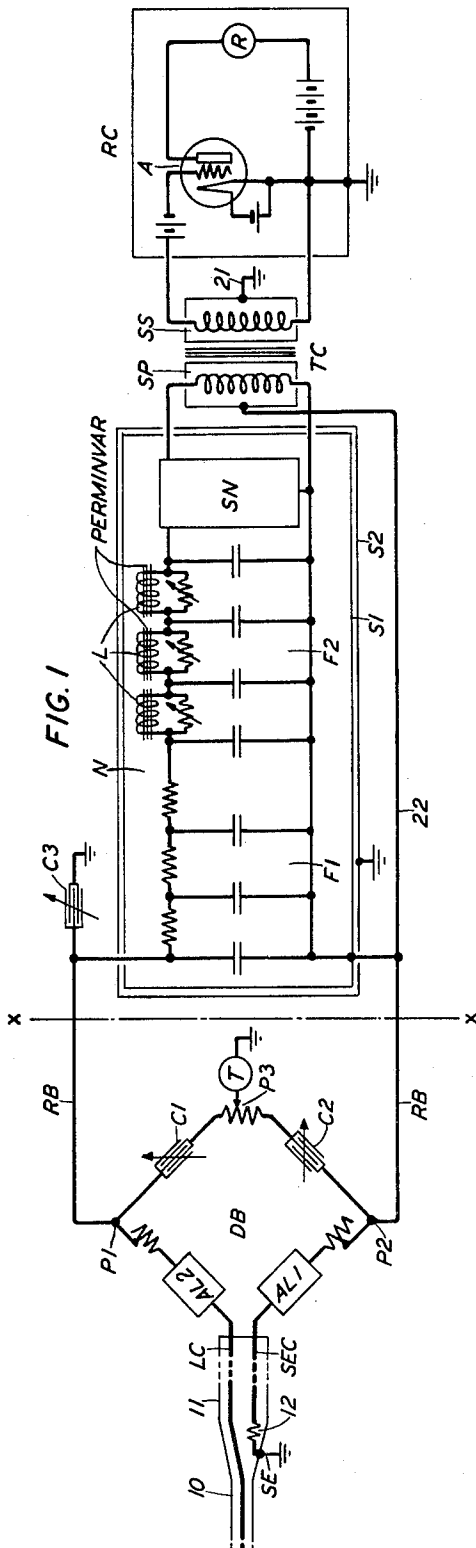
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1,948,981

DUPLEX COMMUNICATION SYSTEM

Filed Sept. 13, 1930

2 Sheets-Sheet 1



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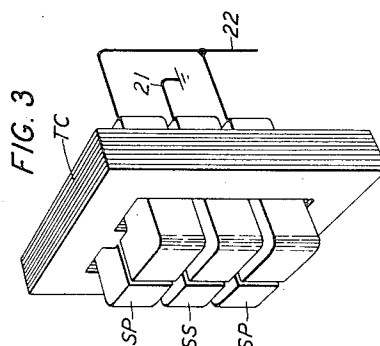
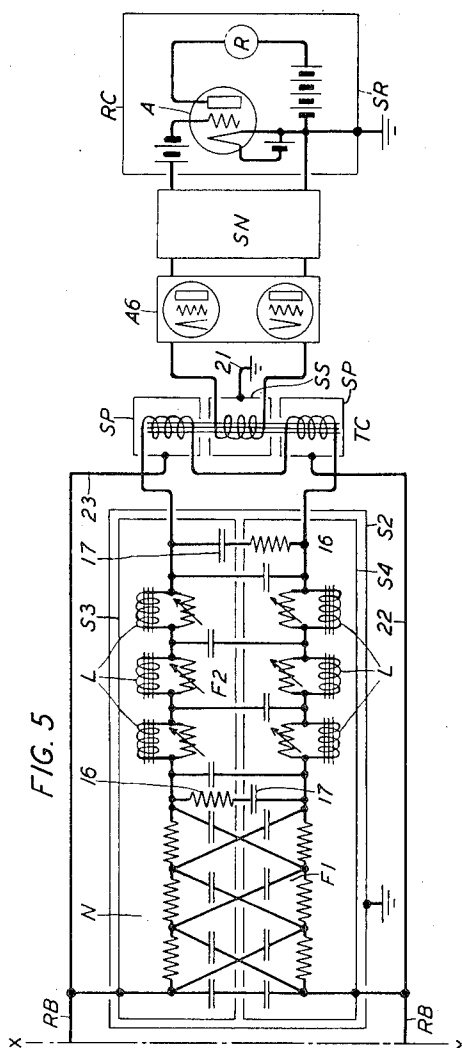
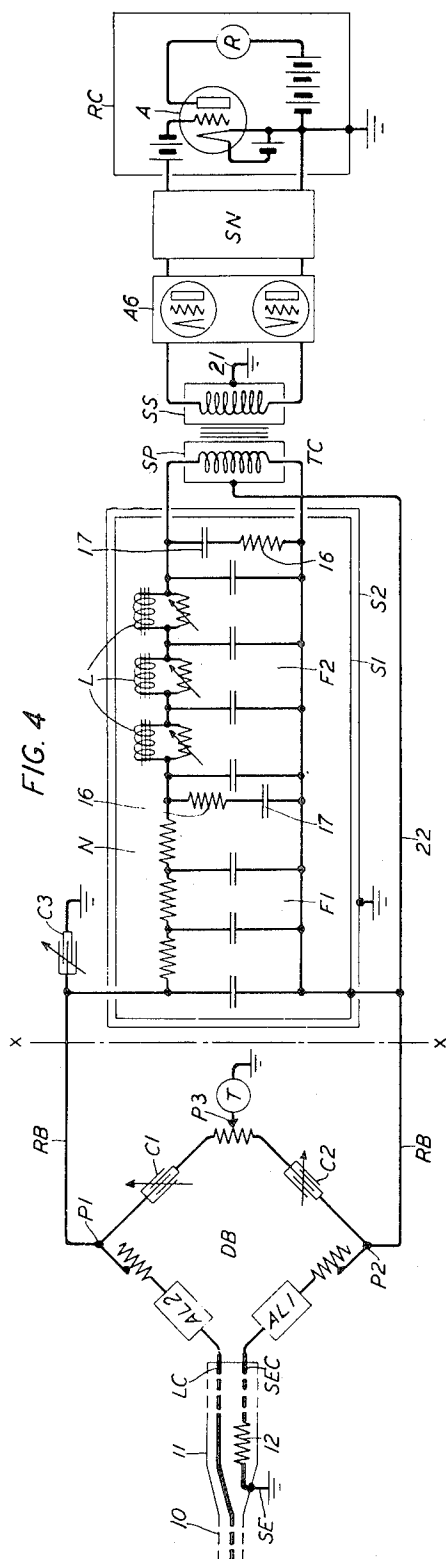
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DUPLEX COMMUNICATION SYSTEM

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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DUPLEX COMMUNICATION SYSTEM

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York, N. Y., a corporation of New York

Application September 13, 1930, Serial No. 481,668
In Portugal October 24, 1929

17 Claims. (Cl. 178—63)

This invention relates to duplex communication systems and more particularly to systems of this kind for operation over long lines or over long submarine cables.

5 The greater part of the subject matter of this application is disclosed by applicant's earlier application Serial No. 320,308 filed November 19, 1928.

10 An object of the invention is to reduce the disturbing influence of the transmitted impulses upon the highly sensitive receiving circuit in such a system.

15 Thermionic amplifying and wave shaping circuits employed in submarine cable telegraph systems generally include coils of which the relation between input voltage and output current may be non-linear. Also, the characteristics of the amplifying devices are non-linear especially at the ends of their operating range. Consequently, a particular object of the invention is to eliminate to as great an extent as possible all interfering voltages due to duplex operation or other causes before allowing them to become impressed upon the amplifying circuit.

20 The enormous relative magnitudes of the intensities of the incoming signals and the outgoing signals in systems for communicating over long lines such as a long submarine cable renders the problem of duplexing such a system a difficult one. The incoming signals are extremely weak and are ordinarily greatly distorted, for which reason it is necessary to provide in the receiving circuit for correction of the distortion and for considerable amplification of the signals in order that they shall be sufficiently strong and distinct to operate an indicating device.

25 When the cable is terminated in a duplex bridge circuit equipped with the usual artificial lines the receiving branch connected to the conjugate points of the bridge will be subject to high voltage variations due to the operation of the local transmitter. These variations may be divided into two groups, one group being due to unequal potentials at the conjugate points caused by improper balance and for convenience termed unbalance potentials; the other group consists of simultaneous potential variations between the conjugate points and earth.

30 The transmitted signal wave may be considered as being made up of currents of a wide range of frequencies. In practice, a good balance between the cable and the artificial line can be secured only for those frequencies which fall within the signal band and near thereto. Consequently, relatively high unbalance voltages of

frequencies outside the signaling band are present between the conjugate points of the duplex bridge and are the cause of corresponding currents in the receiving branch. These unbalance voltages may be comparable to the voltage of the sending battery and would, if not prevented from doing so, produce currents in the receiving branch which would be many times stronger than the currents of the incoming signals.

35 Good engineering practice demands that the amplifier in the receiving circuit, and particularly the output stage of the amplifier, be worked at an energy level at which the incoming signal is amplified with the greatest efficiency and with the least amount of distortion. It may therefore be seen that if the incoming signal were superimposed upon the much stronger unbalance currents set up in the receiving branch by the local transmitter, and this combined wave permitted to enter the amplifier, overloading of one of the later stages of the amplifier would take place. Modulation would produce combination frequencies, some of which would fall within the signal band and could not subsequently be separated therefrom. Similarly, when the combined signal and interference bands are impressed upon transformers or upon inductive elements, for example in the shaping network, which have magnetic cores designed to be operated with high efficiency and negligible modulation by the weak signals, the interference currents, some of which are of much greater intensity than the signal currents, would cause saturation of the cores which again would result in modulation and the production of new frequencies, some of which may coincide with the signal band and cannot possibly be separated therefrom.

40 From this it is apparent that the modulating effects due to the strong unbalance currents must be avoided in a system of this kind if the incoming signals are to be intelligible.

45 Fortunately, it is possible to build a filter for suppressing a wide band of the high frequency currents by connecting distortionless resistances and capacities into a network, the type of network used, whether of the T, H or lattice type, depending upon the requirements. Such a network is capable of suppressing the higher disturbing frequencies and yet pass the lower frequencies, including the signal band, with little attenuation. A similar filter, equally free from modulation, may be employed for the suppression of frequencies below the signaling band in systems where the essential signaling frequencies do not include frequencies down to zero. In the

filter for suppression of frequencies above the signaling band the resistances are connected as series elements and the capacities as shunt elements, whereas a filter useful for suppression of frequencies below the signaling band contains shunt resistances and series capacities. For a sharp discrimination between the signal band and adjacent frequencies, the first filter is followed by another, which, besides being composed of condensers and resistances, must also contain inductance elements with magnetic cores. By building these cores of magnetic material which exhibits a practically linear relation between the energizing current and the flux densities produced thereby, that is, of magnetic material having a substantially constant permeability within the range of magnetizing forces produced by the combined signal and unbalance currents in the windings, it is possible also in this filter to avoid a modulating effect. Magnetic materials which are suited to this use have been described under the name "Perminvar" by Elmen in the Journal of the Franklin Institute, vol. 203, No. III, September, 1928, page 317. Perminvar includes a large range of compositions of iron, nickel and cobalt with or without other substances. At low magnetizing forces this material displays practically no hysteresis loss and the magnetic induction is linearly related to the magnetizing forces over a wide range. Other magnetic materials, if any should be found which have characteristics approaching those of Perminvar, may be used in its place in some or all of the inductance cores. The type of network used in the latter filter will, of course, depend upon the requirements.

By the insertion of filters, such as here described, in the receiving branch of the duplex system it is possible to suppress substantially all the frequencies outside of the signal band without objectionable attenuation of the signal band, or at least to reduce the amplitude of the unbalance currents sufficiently to prevent them from causing modulation either in the shaping network, the transformers, or the amplifier. It is possible to insert filters after the first stage of amplification for further purification of the signal band, since by an arrangement such as here described the signal band and the major disturbing frequencies are within separate and distinct ranges.

As stated, the usual artificial line equipment of the duplex bridge is satisfactory in balancing the bridge for currents of the signal frequency. The balance, however, becomes more and more unsatisfactory as the higher and lower limits of the signaling frequencies are exceeded with the result that the strongest unbalance currents occur at frequencies considerably above and below the signal band. The advantage of inserting the non-inductive filter in the receiving branch before the inductive filter thus becomes apparent since the non-inductive filter is capable of suppressing the strongest currents and will pass only such currents as are of frequencies in the neighborhood of the signaling band and therefore are sufficiently weak not to cause modulation by overloading the cores in the inductive filter. On the other hand, by the insertion of the inductive filter a sharp separation is obtained which can not be effected by the non-inductive filter alone.

It has before been proposed to use amplifying means in duplex telegraph systems of this type with amplifiers of the push-pull type symmetri-

cally arranged in the circuit with respect to the duplex bridge. The object is to neutralize in the output circuit the effects of the transmitting potentials upon the two halves of the push-pull amplifier. In the present system no such neutralization is resorted to. It is evident from what has already been explained that, with the ordinary commercial equipment, neutralization by means of a pair of electron discharge devices connected in push-pull arrangement will be accomplished only for currents of the signal frequencies, since only for these frequencies can a balance be secured by economical means, whereas the potential variations of higher frequencies which can not be balanced out, are impressed upon the second stage of the amplifier with the resultant modulation. The first stage of the amplifier in the present system requires only a single amplifying device such as an electron discharge tube and care is taken to completely isolate the input of this stage from the receiving branch of the duplex circuit except for the provision of a purely magnetic coupling between the amplifier and the circuit associated with the receiving branch. By thus isolating the input circuit it is possible to ground one side thereof and thereby avoid the necessity of insulating the batteries or other sources from earth and to limit the shielding of the amplifier circuit to a minimum.

Now as regards the protection of the input circuit of the first stage of the amplifier from the influence of the potential variations at the conjugate points with respect to earth which, of course, are present whether a balance may have been obtained or not, it has before been proposed to shield the amplifier and the winding of the input transformer for this purpose. Such shielding ordinarily introduces an unbalance in the duplex bridge which has been compensated for by a separate adjustable condenser or possibly by adjustment of the condensers in the bridge arms.

Since the frequency range, as explained above, is very extended, it is necessary that such shielding have the same impedance at all frequencies, in order that the balance shall not be disturbed to a varying extent at the different frequencies and therefore may be effectively maintained by means of a simple condenser. By providing a double metallic casing about the networks inserted in the receiving branch described above consisting of an inner and an outer metallic layer insulated from each other, a condenser is formed with air for the dielectric and which therefore has a constant capacitance at varying frequencies. This capacity may be connected between one of the conjugate points and the earth and a corresponding balancing condenser may be connected between the other conjugate point and earth; or the double shield may be divided into two symmetrical halves, each half being connected between a conjugate point and earth, one half balancing the other. The static potential variations at the conjugate points are, of course, distributed over all those parts of the circuit which are in metallic connection therewith and the shielding condenser is effective in shutting in the static field emanating from the circuit.

The windings of the input transformer for the amplifier are shielded in the present system, the primary and secondary windings being enclosed in separate shields, which are open-circuited to prevent them from forming a short-circuited winding. A special precaution has been taken

by making the connections to the shields at points so chosen that each shield will be divided into two symmetrical halves, so that equal discharge currents in each shield will flow in opposite directions in the two halves thereof and their effects upon the enclosed winding thereby be neutralized. It is possible to make the point of connection adjustable and by trial determine the point at which the neutralization is complete.

In the drawings and the following detailed description, the principles hereinbefore explained are applied to a system of impulse telegraphy over a submarine cable, but the principles of the invention are applicable also to telephony or to "carrier current" telegraphy.

Referring now to the accompanying drawings, Fig. 1 is a schematic circuit diagram of a terminal equipment for a submarine cable arranged in accordance with this invention;

Fig. 2 shows a modification of the circuit arrangement shown to the right of line X—X in Fig. 1; and

Fig. 3 is a simplified showing of one form of a transformer used in these circuits.

Fig. 4 shows a modification of the terminal equipment shown in Fig. 1 specially arranged to eliminate undesired reactions between certain parts of the circuit and to prevent the distortion of the signals therein; and

Fig. 5 shows how a modification similar to that shown in Fig. 4 may be made in the terminal equipment of Fig. 2.

In Fig. 1, a single core submarine cable 10 is terminated in a twin core section of submarine cable 11, which extends from a point where the sea earth SE is located. The line circuit LC comprises the single core of section 10 and one core of section 11 and is connected to the point P1 of the terminal duplex bridge DB. The sea earth return circuit SEC extends from the sea earth SE through impedance 12 and over the other core of section 11 to bridge point P2 of the duplex bridge. This return circuit also includes the usual artificial line AL1 for balancing the bridge circuit against the line circuit LC. The line circuit LC similarly includes an artificial line AL2 suitable for balancing against the sea earth circuit SEC. The usual adjustable bridge condensers C1 and C2 are connected as shown between the points P1 and P2 and point P3, at which latter point the transmitting equipment T is connected in a well known manner.

The terminal receiving equipment is shown to the right of line X—X and is connected in the receiving branch RB between the conjugate points P1 and P2. This receiving equipment includes a receiving circuit RC which comprises a translating device R for the incoming signals which may be of any well known type for rendering the signals observable. The incoming signals before being received by the receiving device R pass through an amplifying stage, which is indicated at A as a single three-element electron discharge device with current sources connected in a known manner and having its cathode connected directly to ground. Other amplifying stages with or without phase and attenuation equalizing devices or such devices without other stages may be inserted between this stage and receiving device R.

An input transformer TC has its secondary winding connected between the control electrode and the cathode of the electron discharge tube A and has its primary winding connected to a shaping network SN of any well known type provided for correction of phase shift or un-

equal attenuation suffered by the incoming signals. The shaping network SN may also, if desired, be designed to compensate for distortion of the signals caused by their passage through the remainder of the circuit.

Filters F1 and F2 complete the circuit between the shaping network SN and the receiving branch RB. The filter F1 is a non-inductive distortionless filter designed to suppress a broad band of frequencies above the signaling band, whereas filter F2 is an inductive filter, which besides containing resistances and condensers also includes inductive elements L having magnetic cores of a material, such as Perminvar. The filter F2 is thereby rendered distortionless for frequencies within the signaling band and such higher frequencies immediately above the signaling band as have been passed by filter F1.

The filters F1 and F2, as well as the shaping network SN, are completely enclosed in a metal box S1 which in turn is enclosed in a metal box S2 of a similar form but separated and insulated from S1 principally by an air space. The inner shield S1 is preferably connected to conjugate point P2 and the outer shield S2 is directly grounded. A compensating condenser C3 is similarly connected between conjugate point P1 and ground to offset the capacity effect of the shields S1, S2.

Transformer coupling TC has its windings enclosed in separate shields, which is shown more particularly in Fig. 3, where SP, SP are the primary shields enclosing two sections of the primary winding and where SS is the secondary shield enclosing the secondary winding. Each shield is built of thin sheet metal as a more or less toroidal casing having a slot clear across the casing at one place to prevent short-circuiting of the enclosed winding. The discharge connections 21 and 22 are taken from points on the shields exactly opposite the respective slots. The connection 22 from the primary shield is preferably made to conjugate point P2, whereas the connection to the secondary shield is grounded. The compensating condenser C3 may be adjusted to also compensate for the capacity effect between the shields SP and SS.

The duplex bridge circuit DB operates in the usual manner to separate the incoming and outgoing signals. However, since the artificial lines AL1 and AL2 are fully effective in balancing the circuit only for frequencies within or near the signal band, the separation of outgoing and incoming signals is incomplete, and superimposed currents of both signals will pass over the receiving branch RB and into the filter F1. The currents of higher frequencies and strong intensities are suppressed in this filter and only the weaker currents of signal frequency and frequencies somewhat above the signal frequency are impressed upon the filter F2, which is designed for sharp discrimination between these frequencies. The currents leaving filter F2 consequently are composed mainly of the received signal and possibly of components of the unbalance currents which, however, have been suppressed to such an extent that they will be unable to cause modulation during their passage through the shaping network SN or through the primary of transformer TC; nor would the voltages induced by the primary currents in the secondary be sufficient to overload the electron discharge tube A and cause modulation in the output circuit thereof.

In the modification shown in Fig. 2 the filters F1 and F2 are symmetrical and the shaping net-

work SN also has its elements arranged symmetrically; the primary winding of transformer TC is divided into two symmetrical halves. The inner shield surrounding the networks is divided into two similar halves S3 and S4 arranged symmetrically with respect to corresponding parts of the networks N and SN. Capacity currents flowing into the inner shield flow symmetrically with respect to the elements of the network. The part S3 is connected to conjugate point P1 and the part S4 to point P2 and these parts together with the outer shield S2 form equal capacities between the conjugate points and ground and thus counter-balance one another.

In Fig. 2, the two halves of the primary winding of transformer TC are enclosed in separate shields SP, similar to those shown in Fig. 3 and one shield is connected by conductor 23 to the conjugate point P1 and the other by conductor 22 to conjugate point P2 and thus will mutually counter-balance their capacities with respect to the secondary shield SS.

As another modification of the shielding of the networks N and SN in the case where these networks, as shown in Fig. 2, consist of elements which are symmetrically connected to the receiving branch, the inner shield or shields may be dispensed with since in that case the capacity between the network and the outer grounded shield S2 would be symmetrically applied to the receiving branch and the duplex balance maintained.

It is also possible to use the filter arrangement of Fig. 2 with the shield of Fig. 1 as well as to evenly distribute the parts of the filters shown in Fig. 1 in physical relation with respect to the two halves of the double shield shown in Fig. 2 to obtain a symmetrical arrangement which in itself would provide for a proper balance of the system. The filter F2 may have its elements grouped in any manner known to the art for discriminating between the signal and the interference current.

A modification of Fig. 1 is disclosed in Fig. 4 wherein any danger of an undesired reaction of the shaping network SN on the filter F2 is avoided by inserting between these two elements an amplifier Ab which may be of the push-pull type and must be able to pass without modulation the entire signal received from filter F2. As shown in Fig. 4, the output terminals of the filter F2 are connected to the primary winding of the transformer TC, the secondary of which is connected to the input of the amplifier Ab. The shaping network SN is suitably associated with the output circuit of the amplifier Ab. Since this amplifier Ab is a uni-directional device, it follows that there can be no reaction of the shaping network on the filters F1 or F2.

Fig. 4 also differs from Fig. 1 in that a shunt circuit comprising a resistance 16 and a condenser 17 is connected on each side of the filter F2. These shunt circuits are designed to enable the filter F2 to work into approximately its own characteristic impedance as viewed in either direction from the filter. Hence the values of the elements 16 and 17 depend upon the characteristic impedance of the filter F2, and as one example the resistance 16 may have a value of approximately 700 ohms and the condenser should have a fairly large capacity (such as 20 to 50 microfarads), since its primary purpose is to increase the impedance of the shunt circuit for those low frequencies very close to zero frequency. For most purposes it will be satisfactory to have the value of resistance 16 equal to the characteristic impedance of the filter F2. This feature of having

the filter terminated at both ends in its own characteristic impedance prevents any undesired distortion of the signals that might otherwise be caused by the filter due to improper impedance termination thereof. With the exceptions noted, the terminal equipment of Fig. 4 is similar to that of Fig. 1 and similar reference characters have been employed.

Fig. 5 shows how the receiving circuit of Fig. 2 may be modified to include the two novel features just described for Fig. 4. Shunt circuits 16, 17 insure that the filter F2 terminates in its own impedance and amplifier Ab prevents the shaping network SN from reacting on filter F2.

The invention is not limited to the specific embodiments described above and may be applied to other signaling systems than those employing submarine cables.

What is claimed is:

1. The combination in a signaling channel of a selective network including a plurality of non-inductive sections followed by a selective network including a plurality of substantially distortionless sections each having an inductance with a magnetic core, each of said networks having shunt capacities included in their sections.

2. A receiving circuit for a duplex system having a resistance-capacity network for transmitting a band of signaling frequencies and suppressing another band of frequencies followed by a network including inductance elements for transmitting the same band of frequencies transmitted by the first network and suppressing a band of frequencies immediately adjacent to said transmitted band.

3. In a duplex signaling system, amplifying means for incoming signals and non-modulating means for suppressing before they reach the input circuit of said amplifying means unbalance currents of frequencies above the signal band, comprising a non-inductive filter for suppression of a wide band of frequencies above the signal band and an inductive filter for suppression of frequencies immediately above the signal band.

4. In a duplex signaling system, a receiving circuit, unsymmetrically arranged amplifying means for said receiving circuit having an input circuit with one side grounded, a network for discriminating between currents within the signal band and currents of other frequencies, a transformer between said amplifying means and said network comprising inductively coupled primary and secondary windings statically isolated from each and surrounded by conducting screens.

5. In a duplex signaling system, a duplex bridge circuit having a receiving branch, a transmitting circuit including a signal source, a receiving circuit including amplifying means, means for balancing said bridge circuit for potential variations from said transmitting circuit of frequencies within the signal band, and a non-modulating network for suppression of equalizing currents in said branch of higher frequencies than those of the signal band to prevent said currents from affecting said amplifying means, said network including an inductive element having a ferromagnetic circuit of substantially constant permeability at the magnetizing forces produced by impulses of the suppressed frequencies.

6. In a duplex signaling system, grounded amplifying means for incoming signals, and means for excluding, from said amplifying means, unbalance and interference currents of frequencies not within the signal band comprising a non-inductive filter for suppression of a wide band of

frequencies above the signal band and an inductive filter for suppression of frequencies closely adjacent to the signal band which includes one or more inductance elements having ferro-magnetic cores with permeability more constant than iron within the operating range.

7. In a system in accordance with claim 6 having a grounded amplifier, a magnetic coupling between the filters and the amplifier, and a conducting double screen about said filters forming in itself a condenser connected between said filters and ground.

8. A signaling system in accordance with claim 6 including a matching impedance connected to each terminal of said inductive filter.

9. A signaling system in accordance with claim 6 including a terminal resistance connected to each terminal of said inductive filter to match the impedance thereof and a large capacitance in series with each of said resistances to prevent shunting out of the very low frequency components of the signal.

10. In a duplex receiving system, a transmitter, a balancing network, a receiver circuit connected to said network at points conjugate with respect to the transmitter characterized in this that a translating element such as a filter in said receiver circuit is enclosed in two independent shields, one of which shields encloses the other and is separated therefrom by good insulating material such as air.

11. An arrangement in accordance with claim 12 in which the inner shield is insulated from the outer to present a fixed capacity, said inner shield being in two symmetrical halves and connected to symmetrical points in said network.

12. In a cable duplex system, a pair of conjugate points, a receiving selective network having input terminals connected to said points, an inner shield about said network being connected to one of said points, an outer grounded shield surrounding said inner shield, and an adjustable capacity connecting the other point to ground.

13. Arrangement in accordance with claim 12 in which the dielectrics between the shields and between the plates of the adjustable capacity are essentially composed of identical materials.

14. In a duplex signaling system a conjugate

circuit including a balancing network for frequencies within and near the signaling band, transmitting and receiving channels connected to conjugate points of said circuit, a selective network in said receiving channel for absorbing unbalanced current outside the signal frequency, amplifying means including an inductive coupling for connection to said selective network and balanced capacity means of constant admittance at varying frequencies at least a part of said capacity means surrounding the elements of said receiving channel which are conductively connected to said circuit to screen them from said amplifying means.

15. A signaling system in accordance with claim 14 in which the elements of said selective network are divided into two groups arranged and connected symmetrically with respect to said points and in which said part of the capacity means surrounding said elements is divided into corresponding symmetrical halves each connected to one of said points.

16. In a signaling system a signal receiving device having one side of its input circuit connected to a ground potential, a signal channel, shielding means of conductive material surrounding at least a part of said channel and connected to a different potential, an inductive coupling between said channel and said device having input and output windings, shielding means for at least a portion of said input windings and separate shielding means for said output windings connected independently to said different potential and said ground potential, respectively.

17. In a signaling system a signal receiving amplifier having an input circuit, one side of said circuit being at ground potential, a signal channel, conductive shielding means surrounding at least a part of said channel and being at another ground potential, a transformer for inductively coupling said channel and said input circuit and having a primary and a secondary winding, screening means for statically separating said channel from said input circuit comprising separate shields for said primary and secondary windings connected independently to said different ground potentials.

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