Aug. 23, 1927. 1,639,929

A. M. CURTIS

SIGNALING SYSTEM

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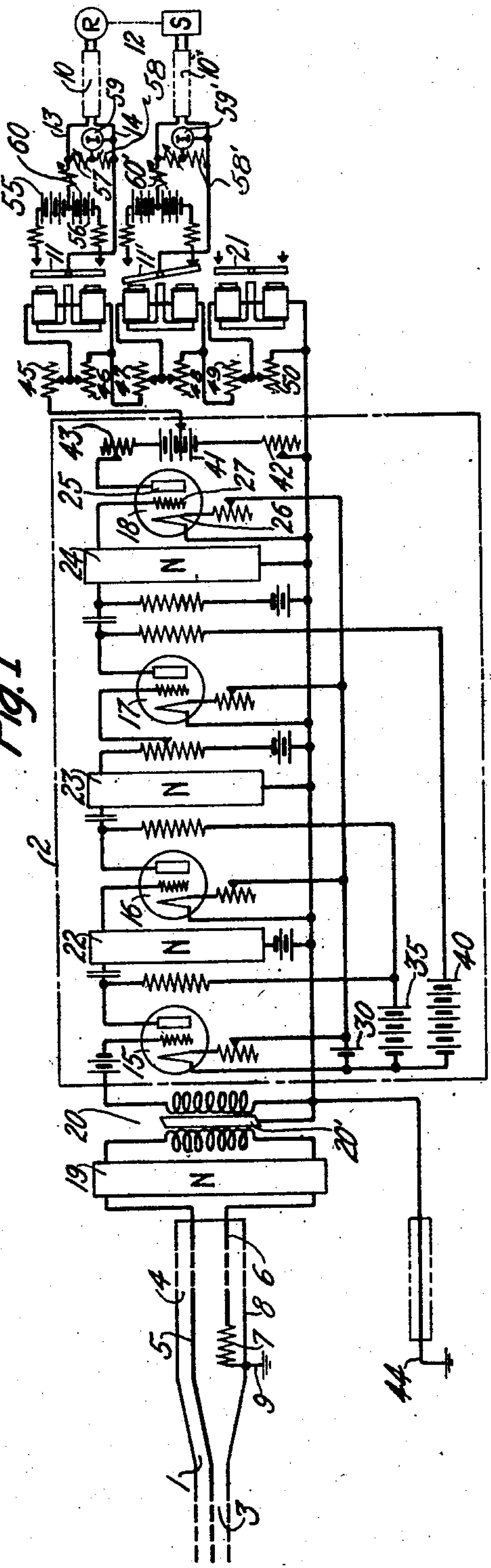

Fig. 1

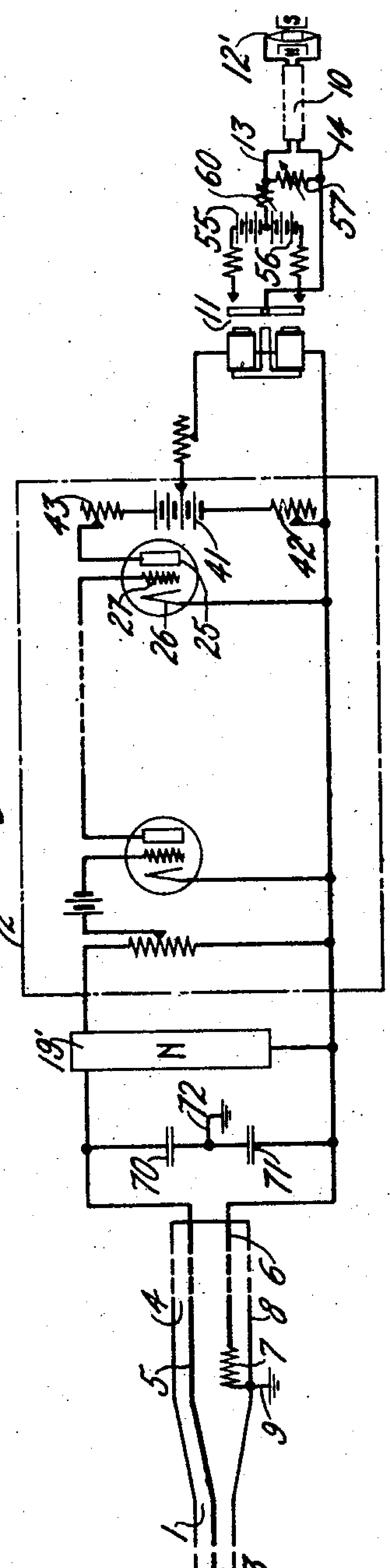

Fig. 2

Inventor:
Austen M. Curtis
by E. W. Adams Att'y.

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UNITED STATES PATENT OFFICE.

AUSTEN M. CURTIS, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SIGNALING SYSTEM.

Application filed December 12, 1925. Serial No. 75,019.

This invention relates to signaling and to amplifiers and circuits for use therein and aims for simplicity and efficiency in transferring signals between an amplifier and a circuit for connection to the amplifier input or output, especially where disturbance due to undesired currents, such for instance as currents resulting from the tendency of the amplifier to oscillate and from voltages induced in the circuit by extraneous sources, should be guarded against.

In accordance with the invention, signals may be transferred between the amplifier and the circuit, for instance over a twin conductor cable balanced as regards the impedances to earth of its conductors, without disturbing such balance or introducing serious transmission loss, and at the same time the amplifier is effectively stabilized and any necessity for employing a connecting transformer is avoided. Such a transformer might be difficult to design and construct where the signal wave contains current components of very low frequencies, as is the case in the transmission of telegraph signals over a long submarine cable.

It is also an object of the invention to reduce disturbances in transferring signals or the like through two circuits between which is interposed an amplifier and which are exposed to interference from extraneous electric fields.

In transmitting signals between a space discharge amplifier and a circuit which is balanced with respect to the impedances of its two sides to earth, the amplifier is stabilized with relation to its surroundings, for frequencies at which otherwise it might oscillate, by earthing the amplifier cathode through a connection having impedance sufficiently low to prevent such oscillation; and at the same time, the balance of the circuit is maintained by interposing an electromechanical relay between the amplifier and the circuit. Signals are transmitted between the circuit and another circuit, such as a submarine cable with its balancing circuit, through the amplifier and the electromechanical relay, and unbalance between the cable and its balancing circuit is avoided by employing a transformer to connect the cable and its balancing circuit to the amplifier or by balancing the impedance which earths the cathode and the cable conductor, or its balancing return circuit conductor, with a like impedance between the other of those two conductors and earth. These impedances between the two latter conductors and earth may be two similar condensers having capacity sufficiently large to prevent the amplifier from oscillating, but not so large as to cause undue shunting of the signals between the cable and its balancing circuit.

Other objects and advantages of the invention will be apparent from the following detailed description in connection with the accompanying drawing, wherein each of the figures illustrates an application of the invention in submarine cable telegraphy, although it is not limited to such application. Fig. 1 is a circuit diagram of a form of the invention employing a transformer for connecting the cable and its balancing circuit to the amplifier, as referred to above, and Fig. 2 shows diagrammatically a form of the invention in which similar condensers are connected from earth to the cable and its balancing circuit, respectively, as referred to above.

The cable systems herein described are adapted for use with submarine cables of such great length that signals arrive from the cable greatly attenuated and distorted. In order to retransmit these signals it is therefore necessary to amplify them and correct the distortion by suitable shaping apparatus and it will frequently be found essential to use efficient means of minimizing the effect of extraneous electrical fields acting on the cable or on the second circuit to which signals are transmitted in order to prevent the signals from being masked by the induced disturbances. Such means may, however, become of use in other types of signaling systems as the severity of operating conditions increases.

In the drawing, 1 is intended to represent a cable, for example, a loaded submarine cable having large distributed capacity, inductance and resistance, and 2 is intended to represent a direct amplifying type of electric space discharge amplifier for receiving telegraph signals from the cable 1 and transmitting them by means of relays 11 and 11′ through circuits 10 and 10′ to receiving apparatus 12. The term "direct amplifying type" is used in the specification and claims to define an amplifier that increases the energy of an electric wave without shifting or converting the frequency of the wave before, after, or during the amplification.

To provide for multiplex transmission, the receiving apparatus 12 may be of a well known type employing a rotary distributor (not shown) having a brush movable over a solid ring and a ring of segments for separating a plurality of messages which have been combined by a similar rotary switching means (not shown) at the sending end of the cable, the segments of the receiving distributor being connected to correspond with receiving devices (not shown), to distribute the messages to the receiving devices, which may be siphon recorders, such as the recorder indicated at 12′ in Fig. 2, or may be any desired type of receiving or relaying devices. The receiving apparatus 12 may also include means (not shown) responsive to signals transmitted from the sending end of cable 1 through the cable 1, the amplifier 2, a relay 11′ and a circuit 10′ to maintain the receiving distributor in synchronism with the rotary switching device at the sending end of the cable 1. This synchronizing apparatus may be, for instance, of the tuning fork and phonic wheel type described in detail in U. S. patent to Spencer 1,333,000, granted March 9, 1920. The windings of relay 11 are shown connected in serial relation to those of relay 11′ and to those of a third relay 21 which may be employed to operate a siphon recorder or the like (not shown) or means (not shown) which may be local to the amplifier 2 for influencing the potential of a grid of the amplifier in such a manner as to reduce zero wander in the system as disclosed in my application Serial No. 106,355, filed May 3, 1926. Means are described hereinafter whereby the current in the windings of each relay may be adjusted independently of the current in the windings of the other relays.

The cable 1 comprises a single core section 3 terminated in a twin core section 4. One core 5 of a twin core section 4 is connected at one end to the single core section 3 and at the other end to one terminal of signal receiving apparatus which comprises amplifier 2 and which will be presently described. The other terminal of the receiving apparatus is connected to one end of the second core 6 of the twin core section 4, the other end of core 6 being connected through a resistance 7 to a conductor in contact with the sea water, to furnish an earth connection. As shown, the resistance is connected to the cable armor wires 8 at point 9, a conventional grounding symbol being employed in the drawing to indicate that the armor wires are earthed. The core 6 together with the network 7 grounded at the point 9 constitutes a cable balancing return circuit of the type disclosed in Osborne Patent 1,390,580, Sept. 13, 1921. Each of the cores 5 and 6 and also the core of the single-core cable section 3 may be of the nickel-iron alloy loaded type described and claimed in patent to G. W. Elmen 1,586,887, issued June 1, 1926, the cores being surrounded by insulation (not shown) and armor wires as usual. The cable balancing return circuit greatly reduces the voltages which would otherwise be induced in the cable by electrical fields acting upon the portion of the cable which lies in shallow water. The twin core section of the cable is terminated in the connection through the resistance 7 to the sea water at a depth beyond which the effect of extraneous electrical waves of signaling frequencies employed in the cable is negligible, and the effect of disturbing electric waves of such frequencies at lesser depths is made negligible by a balanced relation of the main cable and its balancing return circuit, with respect to the receiver, as pointed out in the Osborne patent just mentioned. The length of the core 6 required to carry the balanced section of the cable out to an adequate depth of water may be considerable as indicated by the dotted portion of the twin core cable section 4. In the case of a cable between New York and the Azores, it has been found advisable to use a sea earth core about 100 miles in length at the western end of the cable.

The circuit 10, comprising conductors 13 and 14, may be, for example, a twin conductor or full metallic land cable having a length of the order of 15, or 20 miles that is exposed to inductive interference from electric railroads and power lines (not shown) which it parallels. The dotted portion of circuit 10 is intended to indicate the considerable extent of the circuit. The circuit 10′ may be similar to the circuit 10. Although in the drawing these circuits are shown as separate cables, the conductors 13 and 14 and the conductors of circuit 10′ may all be in the same cable. The amplifier 2 is indicated as a four-stage amplifier comprising vacuum tubes 15, 16, 17 and 18 in tandem. An input transformer for the amplifier is indicated at 20. Block 19 between the cable and transformer 20 and blocks 22 to 24 between the various stages of the amplifier indicates any desired signal shaping networks or elements, for instance networks of the general character of those illustrated in my U. S. Patents 1,586,970 and 1,586,972, both issued June 1, 1926, and British Patent 153,357 to Western Electric Company, Limited, in connection with a circuit similar to that in which the networks are here shown.

The tube 18 comprises an anode 25, a cathode 26 and a control electrode 27, and each of the other tubes of the amplifier 2 has similar electrodes. A battery 30 supplies cathode heating current for the tubes, and space current is supplied to tubes 15 and 16 from a battery 35, to tube 17 from a battery 40 and to tube 18 from a battery 41. The circuit of tube 18 includes an adjustable resistance 42 preferably of a magnitude of several thousand ohms and a resistance 43. The resistance 43 is for straightening the grid potential plate current characteristic of the tube 18, to reduce distortion, and is preferably of a magnitude of several hundred ohms, but may be omitted, if desired. One end of a current path including the windings of relays 11, 11′ and 21 is connected to a point on battery 41, which when no signals are being received is at the same potential as the junction of the other end of the path with resistance 42. This prevents battery 41 from sending current through the circuit of the windings of relays 11, 11′ and 21, except when received signals cause increases and decreases of the space current of tube 18, in which case a considerable portion of the current changes is permitted to flow through the windings of the relays. Amplifier 2 may have a possible voltage amplification at some frequencies of the order of 25,000 times, and therefore should be earthed locally through a connection of sufficiently low impedance to keep the amplifier at practically the same potential as its surroundings for all frequencies high enough to permit an appreciable electrostatic feed-back between various parts of the amplifier. Failure to so stabilize the amplifier is likely to cause it to oscillate continuously. However, if this stabilization should be effected by earthing the cathodes of the amplifier directly, as is customary with vacuum tube amplifiers, and the circuit 10 were conductively connected to the amplifier, the circuit 10 would be unbalanced as regards the impedances between earth and its conductors, as conductor 14 would be connected to earth while conductor 13 would be connected to a point on battery 41 and to earth through resistances 42, 43 and the plate to cathode circuit of amplifier 18, this point having an impedance of about 1,000 ohms to earth. Consequently, voltages induced in conductors 13 and 14, from electric railroads and power lines which it parallels, would send currents through circuits of unequal impedances to earth, with the result that there would appear across the receiving instruments, in the receiving apparatus 12, disturbing voltages which might have a material effect in masking the signals.

To prevent undue disturbance caused by the tendency of the amplifier 2 to oscillate and at the same time avoid interference or masking effects resulting from unbalancing the circuit 10, the amplifier cathodes are earthed locally, or through a short sea earth cable of low impedance as at 44, and a relay 11 is interposed between the output of the amplifier and the circuit 10. To provide for varying currents in the windings of any of the relays 11, 11′ and 21 without necessitating variations in the windings of the others of these relays, a variable resistance 45 is connected in series with the windings of relay 11 and the variable resistance 46 is connected in shunt to those windings. These resistances are so arranged that their variation produces no variation in the impedance with which the circuit constituted by those two resistances and the windings of relay 11 faces its supply circuit; and a similar set of resistances 47 and 48 is similarly associated with the windings of relay 11′; and a set of resistances 49 and 50 is similarly associated with the windings of relay 21. The relay 11 repeats signal elements represented by periods of positive, negative and zero current flow. The armature is normally held in a central position corresponding to zero signaling current, but when actuated by a positive signal in its winding it applies a positive voltage to line 10 from battery 55, and when actuated by a negative signal it applies a negative voltage to line 10 from battery 56. A resistance 57, indicated as variable in magnitude is connected in shunt relation to line 10 in order that when the armature of relay 11 returns to its neutral position after having applied either battery to the line 10, the charge remaining in the line will quickly discharge through the line shunt, thus avoiding the distortion of the signal which would result if the entire charge on line 10 were compelled to flow through the receiving apparatus 12. The resistance 57 depends on the capacity and resistance of line 10, and also on how much of the voltage of batteries 55 and 56 it is permissible to sacrifice. In a certain case a value of 400 ohms was found satisfactory. If desired, a resistance 58 of the order of 10 ohms may be connected in series with resistance 57 for supplying voltage to a monitoring device 59 local to the amplifier 2.

It will be noted that when the tongue of the relay 11 makes contact with either of the battery connectors the voltage of the battery is applied abruptly to the line and resistance 57 through the resistance 60 and one of the battery protective resistances, but when the relay tongue opens the connection the line discharges through its shunt resistance 57. This results in the voltage applied to the line by the relay rising to its full value more rapidly than it falls when the contact opens and the line discharges through resistance 57, but if resistance 60 is given a sufficiently large value, the distortion of the signal thus caused is reduced to a negligible amount. In a certain case the resistance 60 plus the battery protective resistance amounted to about one thousand ohms. Line 10′ is associated with relay 11′ in substantially the manner in which line 10 is associated with relay 11, preferably with the employment of batteries, resistances and oscillograph 59′ corresponding to the batteries, resistances and oscillograph just described in connection with line 10 and relay 11. However, the resistances connected in series across the line 10′ may be of any value convenient for supplying current to the monitoring device 59′ since the relay 11′ need repeat only positive and negative impulses. As this permits the use of a relay whose armature has only two positions of rest, that is, with the armature tongue resting against either of its contacts, it is not necessary to provide means for discharging the line 10′ while its armature is midway between contacts, as the line discharges through the battery and the travel time of the armature is too short to permit appreciable signal distortion.

The relay 21 when employed as a zero wander correcting relay, as referred to above, may be a three-element relay, the armature of which vibrates through its mid-position in response to current passing through its windings, but does not close either of its contacts except when the signal current has added to it a low frequency component (commonly called "zero wander") of a magnitude at least as great as is to be permitted. This relay is therefore marginal in its operation and the provision of the resistances 49 and 50 makes it possible to properly adjust the operating margin without changing the current flow through the windings of relays 11 and 11′, or the impedance of the output circuit of tube 18.

In Fig. 1 the amplifier input is connected to the submarine cable and its balancing return circuit by the transformer 20, the secondary winding of which is surrounded by an electrostatic shield 20′ of copper which is electrically connected to the terminal of the secondary winding that is connected to the amplifier cathodes and the earth connection 44. The transformer 20 prevents disturbance of the balance between the sea cable and its balancing return circuit by the earthing connection 44 and therefore prevents that earthing connection from adversely affecting the functioning of the balancing return circuit which is for the purpose of diminishing interference due to action of extraneous electric fields upon the receiving end of cable 1.

Fig. 2 shows a form of the invention in which the cable 1 is connected to the input of an amplifier 2′ which may be similar to the amplifier 2 of Fig. 1, but without a transformer such as the transformer 20 of amplifier 2. Identical elements in the two figures are indicated by the same reference characters, and elements of Fig. 2 which are similar to elements of Fig. 1 are indicated in Fig. 2 by the reference characters employed in Fig. 1, but with the addition of a prime mark.

To prevent undue disturbance resulting from the tendency of the amplifier 2′ to oscillate and at the same time avoid unbalancing the circuit 1, the input of the amplifier, when connected to the cable 1, is shunted by two condensers 70 and 71 of equal capacity connected in series and the junction of the two condensers is earthed locally through a low impedance sea earth cable, as at 72. Network 19′ having the same general character and function as network 19 of Fig. 1 may be inserted between the grounded capacitative shunt circuits 70, 71 and the amplifier 2′. The capacity of the condensers 70, 71′ should be sufficiently large so that the amplifier 2′ with its cathodes earthed through condenser 71 is sufficiently stabilized for the frequencies which would otherwise cause oscillation. With the grounded condenser shunt, the cable circuit 1 of Fig. 2 is still balanced. The connections from the shunt 70, 71 to the grid and the filament of the first tube of amplifier 2′ may be conductive, no transformer such as transformer 20 of Fig. 1 being required in Fig. 2. In Fig. 2 the natural capacities to ground of the amplifier batteries (not all shown) corresponding to the batteries such as 30, 35, 40 and 41 of Fig. 1, are not usually large enough to require that they be taken into account, although it is quite evident that this capacity is connected in parallel with condenser 71.

If in the system of Fig. 2 the circuit 10 were connected to the amplifier 2′ conductively instead of through relay 11 the balance between conductor 5 of the sea cable and its return conductor 6 would be destroyed, as conductor 6 would be connected directly to conductor 14 of the land cable 10, which has a capacity to earth of several microfarads, while conductor 5 would not have a similar direct connection to conductor 13. The balance between conductors 13 and 14 of the land cable 10 would similarly be destroyed, conductor 14 being connected directly to conductor 6, while conductor 13 is connected to conductor 6 only through an impedance of several thousand ohms.

This mutual unbalancing of the two cables would cause each to be seriously affected by extraneous electrical fields and the resulting induced voltages would interfere seriously with signaling.

The use of relay 11 prevents this direct connection and consequent unbalance.

In a system such as that of Fig. 2, the impedance to earth of the amplifier ends of cores 5 and 6 may be so large that it would, if the amplifier end of the sea cable and its balancing return circuit were connected conductively to the conductors 13 and 14 as symmetrically with respect to those conductors as referred to above, exert upon the balance of the circuit 10 a disturbing effect material in comparison to that which the cathode capacitive earthing connection at 72 would exert. The relay 11 between the circuit 10 and the amplifier prevents each of these disturbing effects, either of which might be serious.

In Fig. 2 only one relay has been shown in the output circuit of tube 18 instead of three relays as in Fig. 1. However, it will be clear that the system of Fig. 2 may be arranged for multiplex operation and zero wander correction as is the system of Fig. 1 by the addition of synchronizing means and zero wander correcting apparatus as indicated in connection with Fig. 1, or from another point of view, it will be clear that the system of Fig. 1 may be modified by earthing the cathodes and connecting the sea cable to the input of the amplifier in the manner shown in Fig. 2 instead of in the manner shown in Fig. 1. It will also be clear that, if desired, the zero correcting means may be omittted from the system of Fig. 1, and that so may also the synchronizing apparatus where only the usual visual signaling by means of the Morse code is desired.

What is claimed is:

1. In combination, a circuit of substantial length, balanced as regards the impedances of its two sides to earth and exposed to interference from extraneous electric fields, an electric space discharge amplifier of direct amplifying, non-duplex type at one end of said circuit, said amplifier having a cathode with an earth connection of impedance sufficiently low to prevent said amplifier from oscillating, and a relay adjacent said amplifier interposed between said circuit and said amplifier and insulating said circuit from said amplifier so that said balance of said circuit is maintained, in order to minimize deleterious effects of said interference.

2. A cable system, unbalanced with respect to ground and having a grounded sea earth return conductor, feeding into a non-duplex direct amplifying amplifier having a grounded cathode, input means whereby differences of potential of signaling frequency (due to disturbances) between the sea earth ground, and the cathode ground are amplified less by the amplifier than signaling waves of equal voltage applied to the amplifier at the cable and sea earth conductor terminals, in combination with an output line for said amplifier having its sides balanced with respect to ground, and a relay connecting said amplifier and output line.

3. A signaling system comprising an electric space discharge amplifier of direct amplifying, non-duplex type having a cathode earthed through impedance sufficiently low to prevent said amplifier from oscillating and means transmitting low frequency telegraph signals to said amplifier, said means including a submarine cable, a balancing circuit therefor arranged to reduce disturbances, and means preventing said cathode earthing connection from unbalancing said cable and its balancing circuit; said system comprising also a transmission circuit of substantial length, balanced as regards the impedances to earth of its conductors, and a relay adjacent said amplifier, having an input circuit and an output circuit insulated from each other, to relay the amplified low frequency telegraph signals to said transmission circuit and prevent said cathode earthing connection from disturbing said balanced condition of said transmission circuit and thereby increasing effects of interference to which the latter circuit may be exposed.

4. A signaling system comprising an electric space discharge amplifier of direct amplifying, non-duplex type, means transmitting low frequency telegraph signals to said amplifier, said means including a long submarine cable and a balancing circuit therefor arranged to diminish disturbances, a transmission circuit of substantial length, balanced as regards the impedances to earth of its conductors and also as regards their exposure to extraneous magnetic fields, and a relay adjacent said amplifier having an input circuit and an output circuit insulated from each other, for relaying the amplified low frequency telegraph signals to said transmission circuit and also insulating the transmission circuit from the submarine cable and its balancing conductor so that the transmission circuit will not adversely affect the functioning of the cable balancing circuit in diminishing interference effects, and so that the cable and its balancing circuit will not disturb the balance of the impedance to earth of the conductors of the transmission circuit and thereby increase effects of interference to which the latter circuit may be exposed.

5. A signaling system comprising an electric space discharge amplifier of direct amplifying, non-duplex type, having a cathode element, means transmitting low frequency telegraph signals to said amplifier, said means including a long submarine cable and a balancing return circuit therefor arranged to diminish disturbances from sources extraneous to the system, a transmission circuit of substantial length, balanced as regards the impedances to earth of its conductors, a relay adjacent the amplifier, having an input circuit and an output circuit insulated

from each other, for relaying the amplified low frequency telegraph signals to said transmission circuit and insulating the transmission circuit from the submarine cable and its return circuit to prevent the transmission circuit from adversely affecting the functioning of the cable and its balancing return circuit in diminishing interference effects and to prevent the cable and its balancing return circuit from disturbing the balance of the impedances to earth of the conductors of the transmission circuit and thereby increasing effects of interference to which the latter circuit may be subjected, and similar impedances connected in serial relation across the amplifier end of said submarine cable and its balancing return circuit, said cathode element being connected to earth through at least one of said similar impedances and only in such manner that the impedances of said cable and its balancing return circuit remain balanced so that the cable and its balancing return circuit maintain their efficiency in diminishing interference effects.

6. A system according to claim 5, said similar impedances having such values as to shunt from said amplifier a small part only of the currents of signaling frequencies.

7. A system according to claim 5, said similar impedances consisting principally of capacitative reactance.

8. A system according to claim 5, said similar impedances consisting principally of capacitative reactance and having such values as to shunt from said amplifier a small part only of currents of frequencies from zero to several hundred cycles per second.

9. In a submarine cable signaling system, a submarine cable, an electric space discharge receiving amplifier therefor having an output circuit, a line for retransmitting signals received over said cable, a line for transmitting synchronizing impulses generated by the signals received over said cable, a plurality of relays, each of said relays having windings included in said circuit, one of said relays repeating signals to said signal transmitting line, and another of said relays repeating synchronizing impulses to said other line, a resistance in series with said windings of each of said relays, a resistance in shunt to said windings, and means for varying said resistances in such manner as to maintain constant the value of the impedance presented by the circuit consisting of said latter windings and said resistances.

10. A relay and batteries for repeating telegraph signals constituted by elements of positive, negative or zero voltage, a line for transmitting said signals, a resistance shunting said line for permitting the charge received thereby to be discharged at the termination of a positive or negative impulse, and a resistance in series between said batteries and said line shunt, proportioned so as to make the time of building up of the voltage on the line approximately equal to the time in which said voltage is discharged, whereby signal distortion is reduced.

11. In a submarine cable signaling system, an electric space discharge receiving amplifier having an output circuit, a plurality of relays having windings in said output circuit, one of said relays repeating signals to a line circuit, another of said relays repeating synchronizing impulses to another line circuit, and another of said relays repeating zero wander impulses.

12. A submarine cable signaling system comprising an electric space discharge receiving amplifier having an output circuit, two relays having their operating windings connected in said output circuit, receiving apparatus and synchronizing apparatus, and separate circuits each extending from one of said relays to the receiving apparatus and synchronizing apparatus respectively.

In witness whereof, I hereunto subscribe my name this 1st day of December, A. D., 1925.

AUSTEN M. CURTIS.