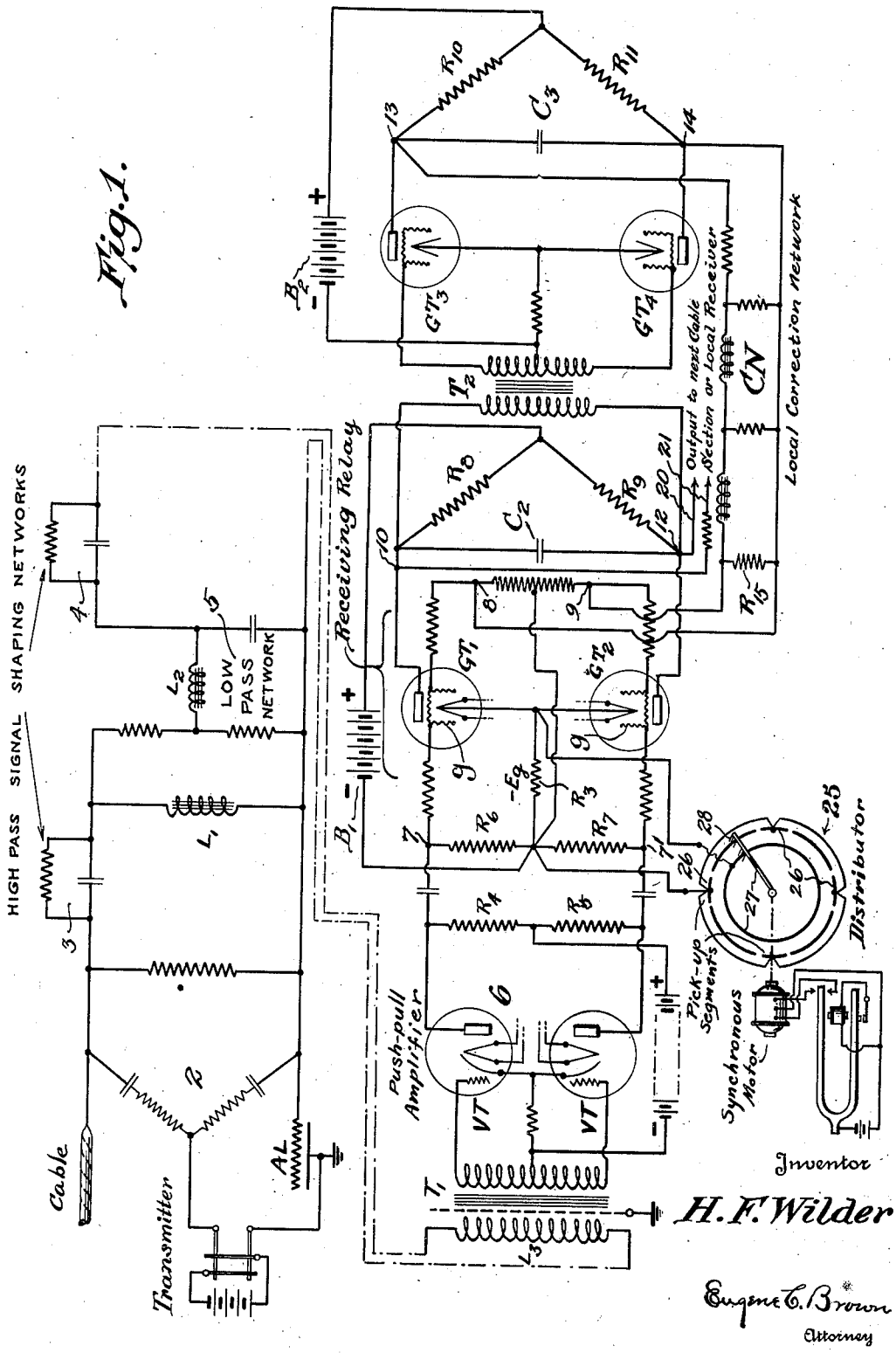
Sept. 19, 1939. H. F. WILDER 2,173,740

LOCAL CORRECTION OF CABLE SIGNALS

Filed July 15, 1936 2 Sheets-Sheet 1

Fig. 1.



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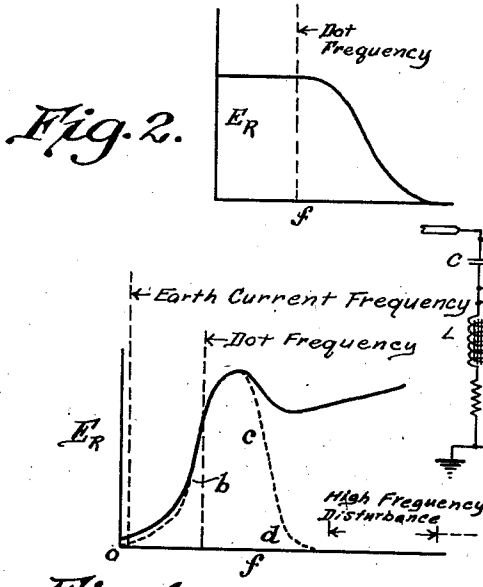


Fig. 2.

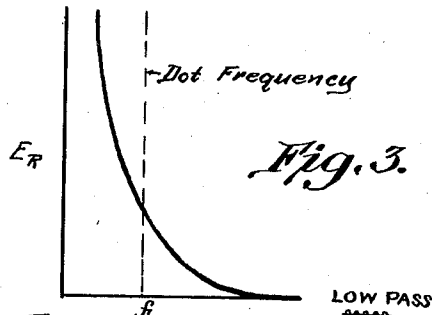


Fig. 3.

Fig. 4.

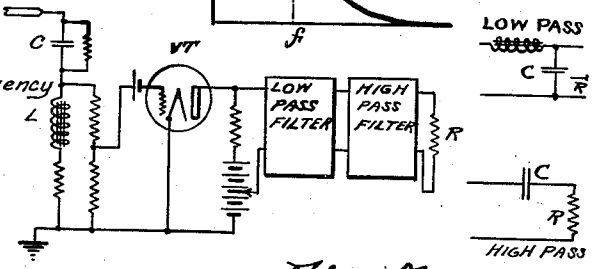


Fig. 7.

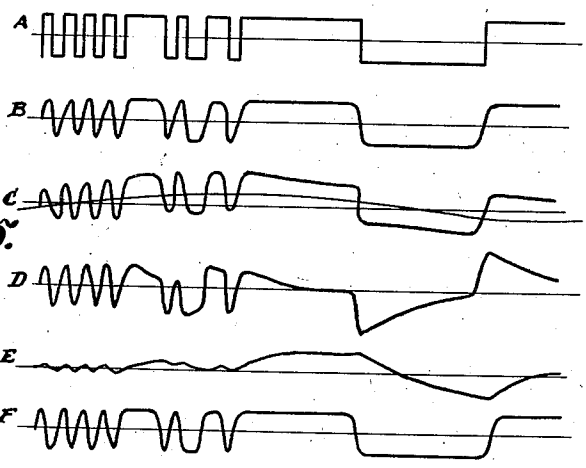


Fig. 5.

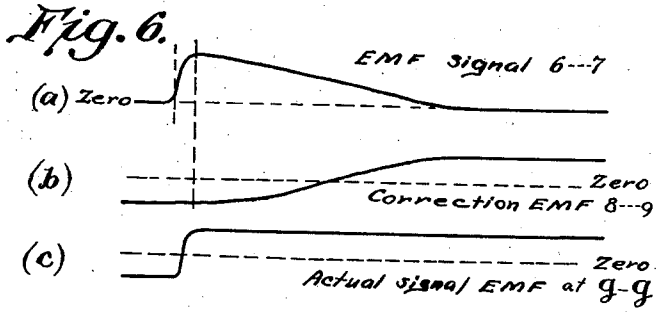


Fig. 6.

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UNITED STATES PATENT OFFICE

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LOCAL CORRECTION OF CABLE SIGNALS

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Application July 15, 1936, Serial No. 90,804

8 Claims. (Cl. 178—63)

This invention relates to ocean cable telegraph systems and pertains particularly to circuit arrangements for restoring the signal waves to their proper shape by supplying through a local correction circuit the low frequency components of the telegraph signals which are suppressed in filters and amplifiers of the primary receiving equipment.

It is well known that telegraph signals are attenuated and distorted in their passage through a cable, due to the resistance, capacity and inductance of the cable. In recent years the effect of the capacity of the cable conductor to the sheath and the earth in attenuating the higher frequency components to a greater extent than the lower frequencies has been greatly reduced by continuously "loading" the conductor with a material which increases the inductive reactance of the line. The higher frequencies from approximately twice the frequency of the signal reversals to infinity are entirely dissipated in transmission, but the signal is nevertheless quite suitable for the control of retransmitting or printing equipment. It is necessary, however, to pass the signals through the shaping networks and amplifiers before they enter the receiving apparatus. Owing to natural potential differences between the terminals of the cable and to unbalance between the cable and the artificial line impedances under duplex conditions, high frequency interference is developed. These same sources may produce interference at frequencies well below the signal frequency, although the natural potentials are usually predominant. Low frequency disturbance will also be caused by variations in the zero of the amplifier.

Due to the loss of low frequency components in the shaping networks and the amplifier, the signal waves are distorted or are not sustained in amplitude and if the signal frequency becomes sufficiently low, the current through the receiving impedance may approach zero and the entire generated E. M. F. will become stored in the capacity.

The object of my invention is to restore the signal waves to their normal undistorted condition without the presence of low frequency disturbance by returning to the signal waves an E. M. F. of the proper shape having frequency components equal in magnitude to those components suppressed by the local capacitance.

In the following description of my invention I shall refer to the accompanying drawings, in which—

Figure 1 is a schematic drawing illustrating circuit arrangements at the receiving end of a cable embodying my invention;

Figure 2 is a diagram illustrating the overall frequency characteristic of the transmitting network, the cable and the receiving network with its associated amplifier;

Figure 3 is a diagram illustrating the attenuation characteristic of the representative cable;

Figure 4 is a diagram illustrating the frequency response characteristic of the receiving network;

Figure 5 illustrates a group of signal combinations in the multiplex code as originally transmitted and the effects of distortion;

Figure 6 illustrates the graph of a single signal wave at the crossover from minus to plus polarity; also the correction E. M. F. and its summation to reproduce a perfect signal; and

Figure 7 is a diagram illustrating conventionally the receiving circuits at a cable terminal.

In order to determine the characteristics of a cable and the proportions of the shaping and amplifying elements at the terminal, as illustrated conventionally in Fig. 7, we may proceed as follows: By transmitting sinusoidal currents at different frequencies from 0 to $3f$ at a constant voltage, we may determine the overall frequency characteristic of the transmitting network, the cable and the receiving network with the associated amplifier, and plot the response E_R against frequency as I have illustrated at Fig. 2.

The attenuation characteristic of the representative cable is shown at Fig. 3, and indicates that as the frequency of signaling increases, the received voltage decreases in amplitude proportionally to the Naperian base (ϵ) with the attenuation constant of the cable as an exponent (E_R is inversely proportional to ϵ^{α}). Now from a knowledge of the desired overall frequency response characteristic of the system (Fig. 2) and the attenuation characteristic of the cable (Fig. 3) the frequency response characteristic of the receiving network can be determined by dividing the ordinates of curve Fig. 2 by the ordinates of curve Fig. 3. The solid line curve of Fig. 4 will be obtained for the shaping network (high pass filter section) and vacuum tube amplifier in a system such as shown in Fig. 7. As indicated in Fig. 4, the response or gain increases to a semi-resonant point at a frequency 20 to 30% greater than the signal reversal or dot frequency and after a slight decline immediately following the resonant point, the gain again increases as the reactance of the magnetic shunt increases with frequency. It is in this higher frequency band of the spectrum that interference from un-

balance is present while practically no signal energy is received in this region as was shown at Fig. 2. A low pass filter section if introduced in the amplifier will greatly reduce the high frequency gain of the amplifier as shown along the line *cd*. The efficiency of cut-off may be further increased by additional sections in cascade. The optimum values of L and C are determined by taking a series of frequency response curves with the aid of an oscillator and selecting that combination of L and C which has the sharpest cut-off with a minimum effect on the response near the signal frequency.

Referring to the schematic diagram of receiving circuits at the terminal of a cable illustrated in Fig. 1, the cable bridge circuit **2** and artificial line AL are well known. Likewise the high pass signal shaping networks **3**, **4** are in common use. To suppress high frequency induction, originating from sources previously mentioned, a low pass network **5**, is introduced between the shaping networks. To suppress low frequency interference or induction, and for the purpose of electrically separating the cable from the amplifier **6**, and its associated circuits, the amplifier is coupled to the shaping networks by a transformer T_1.

The introduction of a transformer distorts the signals by suppressing their lower frequency signal components, referred to by engineers as "zero wander." I have shown in Fig. 5 at A, a graph of the transmitted signal E. M. F. and at B, the received signal after shaping and amplification. During a magnetic storm or a period in which the earth's magnetic field shifts or changes in magnitude perpendicular to the axis of the cable, an E. M. F. of a relatively low frequency will appear at the receiving terminal, upon which the signals are superposed, causing the latter to deviate from their so-called zero position, as indicated at Fig. 5C. These adverse frequencies of a low order may be effectively suppressed or prevented from entering the receiving apparatus, by the interposition of a condenser or a properly adjusted high pass filter. The latter also suppresses low frequency components in the signal waves so that the longer signal pulses are not sustained in amplitude and fall to zero, as indicated at 5D, with great consequent distortion and susceptibility to interferences as the E. M. F. declines to zero.

It becomes necessary, therefore, to locally restore the missing low frequency components, the summation of which is represented as at 5E, to reform the signal to its original condition, as shown at 5B and 5F. My invention herein disclosed provides means for thus locally restoring the lower frequency components corresponding to the suppressed components of the signal impulses.

Referring again to Fig. 1, the distorted signal waves, illustrated at 5D, are amplified by the distortionless amplifier **6** in which the vacuum electronic tubes VT are connected in the well-known "push-pull" arrangement.

The receiving relay or relaying unit comprises the electrostatically controlled arc discharge rectifier tubes GT_1 and GT_2, together with their respective anode resistances. In this relay device I utilize the characteristics of gaseous arc discharge tubes of a well known type in which the grid completely surrounds the cathode and merely functions to initiate a discharge between the plate and cathode, with no further control over the arc after starting. The discharge across the gaseous path is instantaneous upon the application of the critical voltage to the grid and the current rises abruptly to the full value. A pair of these tubes are connected in an inverter circuit arrangement as described in the proceedings of the National Academy of Sciences, March 1929, vol. 15, No. 3, page 218. In this arrangement the tubes are mutually quenching. In other words, one of the tubes being in operation, it is instantly extinguished or quenched by the actions set up upon the starting of the other tube. The second pair of gaseous tubes GT_3 and GT_4 are also connected in inverter arrangement by means of the condenser C_3 and the resistances R_{10} and R_{11} in the plate circuits. The second pair of tubes is operated in phase with the first pair by means of the transformer connection T_2. The regenerated alternating current E. M. F. set up between the points **13** and **14**, is impressed on the low pass filter or local correction network CN. Only frequency components of a very low frequency nature are passed in to the resistance R_{15} by this network. The exact character of the E. M. F. may be made to simulate the missing frequency components corresponding to the predetermined suppressed components of the signal impulses, as shown at 5E.

The corrected properly shaped and regenerated signal impulses will be repeated into the next section of cable or to the local recording apparatus over the conductors **20** and **21**, connected at the points **10** and **12**.

One embodiment of my invention is disclosed in the circuit arrangement by which the correction E. M. F. developed across the resistance R_{15} is introduced in an aiding direction to the signal E. M. F. between the points **7** and **7'**, by the location of each of the grids of the arc-discharge tubes GT_1 and GT_2 in the mid-point of two high resistance potentiometers between points **7** and **7'**, and the resistance R_{15}. The resistance between the points **8** and **9** is several times the magnitude of resistance R_{15} and has no appreciable effect upon the local shaping constants.

The E. M. F. of a signal impulse between points **7** and **7'** at the instant of a single crossover from minus to plus is shown at Fig. 6 (*a*). The corresponding correction E. M. F. occurring between points **8** and **9** is shown at Fig. 6 (*b*); and the summation of the two to produce a perfect signal is indicated at Fig. 6 (*c*). Both pairs of arc-discharge tubes reverse at the proper time, that is, at the instant of signal pick-up, which is accomplished by means of the synchronous distributor **25**, held in phase with the signal impulses by means of a fork-controlled motor or other well-known device.

Periodically, at the instant the brush **28** connects one of the pick-up segments **26** with the solid ring **27**, the high negative bias $-Eg$, due to the drop across resistance R_3, is reduced to a level at which the signal E. M. F. is able to positively start the tube GT_1 or GT_2 of the proper polarity. The oppositely phased tube will be extinguished by the depression of its anode potential by the condenser C_2. As soon as the distributor **25** is held in synchronism, the commuator ring may be oriented until the pickup segment is adjusted to scan the signal wave when its surface integral is a maximum.

The output E. M. F. of the local correction network CN which has been designed to supply the correction components, as shown at Fig. 5E, appears across the resistance R_{15}, the latter being connected at **8** and **9** in parallel with a portion of the receiving impedance in order that the effective impedance of R_6 and R_7, will re-

main appreciably the same, regardless of the constants of the local network. The resultant E. M. F. between the tube grids 9—9 will therefore appear as at Fig. 5F.

If it is desired to use the same battery in place of the two batteries B_1 and B_2, to energize both arc-discharge tube inverter circuits, a transformer may be introduced in the output conductors of the correction network, thereby preventing the positive battery potential from passing a steady bias to the grid potentiometers.

In operating with two element signals (either plus or minus), it is never necessary to open the battery circuits as the extinguishing of the tubes is effected automatically by the condensers C_2 and C_3. Three element signals, which are composed of plus, minus and zero elements, require the opening of the battery circuits just before the brush 28 engages a pick-up segment since both tubes of each pair must remain extinguished during the zero elements of the signals.

It will be evident to engineers that various modifications may be made in the circuit arrangements to suit varying conditions without departing from the invention defined in the appended claims.

I claim:

1. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, the method of restoring the amplitude of the distorted portions of the signal impulses which consists in regenerating voltages in phase with the signal impulses, filtering from said locally produced voltages the lower components thereof corresponding to the predetermined suppressed components of the signal impulses and combining said lower components of the locally produced voltages with the received signal impulses to thereby restore the proper shape of said distorted impulses.

2. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, the method of restoring to normal amplitude the distorted portions of the signal impulses, which consists in regenerating voltages in synchronism with the signal impulses, electrostatically controlling the phase relation of said voltages with the received signals, selecting from said regenerated voltages only those components which correspond to said suppressed lower components and combining said selected components with the received distorted signal impulses for retransmission.

3. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, a repeating or relaying device embodying a circuit having a pair of electrostatically controlled arc-discharge thermionic tubes in inverter arrangement, each tube having anode, cathode and grid elements, means for normally applying a predetermined bias on said grids, means for periodically reducing the value of said bias to permit a discharge through one or the other of said tubes in accordance with the signal polarity, and auxiliary means for supplying to said circuit correcting impulses corresponding to said suppressed components of the signals and in phase therewith.

4. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, a repeating or relaying device embodying a circuit having a pair of electrostatically controlled arc-discharge thermionic tubes in inverter arrangement, each tube having anode, cathode and grid elements, means for normally applying a predetermined bias on said grid, means for periodically reducing the value of said bias to permit a discharge through one or the other of said tubes in accordance with the signal polarity, a second pair of arc-discharge thermionic tubes in inverter arrangement having their input circuits inductively connected to the output of said first mentioned tubes, a correcting network connected to the output of said second pair of tubes and connected to said first named circuit to supply correcting impulses corresponding to said suppressed lower frequency components of the signal waves.

5. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, a resistance connected across the output of said amplifying means, a repeating or relaying circuit connected in shunt to said resistance and having a pair of high resistance potentiometers, a pair of arc-discharge thermionic tubes connected at midpoints respectively of said potentiometers in inverter arrangement, means for locally regenerating voltages in synchronism and phase with the received signals, means for combining the received distorted signal impulses with the components of said locally regenerated voltages corresponding to said suppressed lower frequency components in the input circuit of said tubes, and means for transmitting the resulting restored signals from the output of said tubes.

6. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, a repeating or relaying arrangement connected to the output of said amplifying means embodying a pair of electrostatically controlled arc-discharge electronic tubes in inverter arrangement, a second pair of electrostatically controlled tubes in inverter arrangement having their input circuits inductively connected to the output of said first named tubes, a filtering network connected to the output of said second pair of tubes and arranged to supply to the input circuits of said first named tubes voltages corresponding to said suppressed lower frequency components of the received distorted signals.

7. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, correction means for reshaping the signals, comprising electrostatically controlled arc-discharge tubes connected to the shaping and amplifying means, auxiliary electrostatically controlled arc-discharge tubes operated synchronously with said first-named tubes, a filtering network connected to the output of said auxiliary tubes and constructed to transmit voltages corresponding to the suppressed lower frequency components of the distorted signal impulses, and means for superposing the distorted signal impulses and the output voltages of

said network upon the input of said first named tubes, whereby the output of said tubes corresponds to the normal undistorted shape of the signal impulses.

8. In a communication system having a receiving terminal provided with signal shaping and amplifying means which distort the received signals by suppressing the lower frequency components of the received signal impulses, correction means for reshaping the signals, comprising electrostatically controlled arc-discharge tubes connected to the shaping and amplifying means, auxiliary means operating to locally regenerate voltages corresponding to the suppressed lower frequency components of the received distorted signal impulses, and means to superpose said locally regenerated voltages upon said distorted signal impulses in the input circuits of said tubes.

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