

**April 4, 1944.**

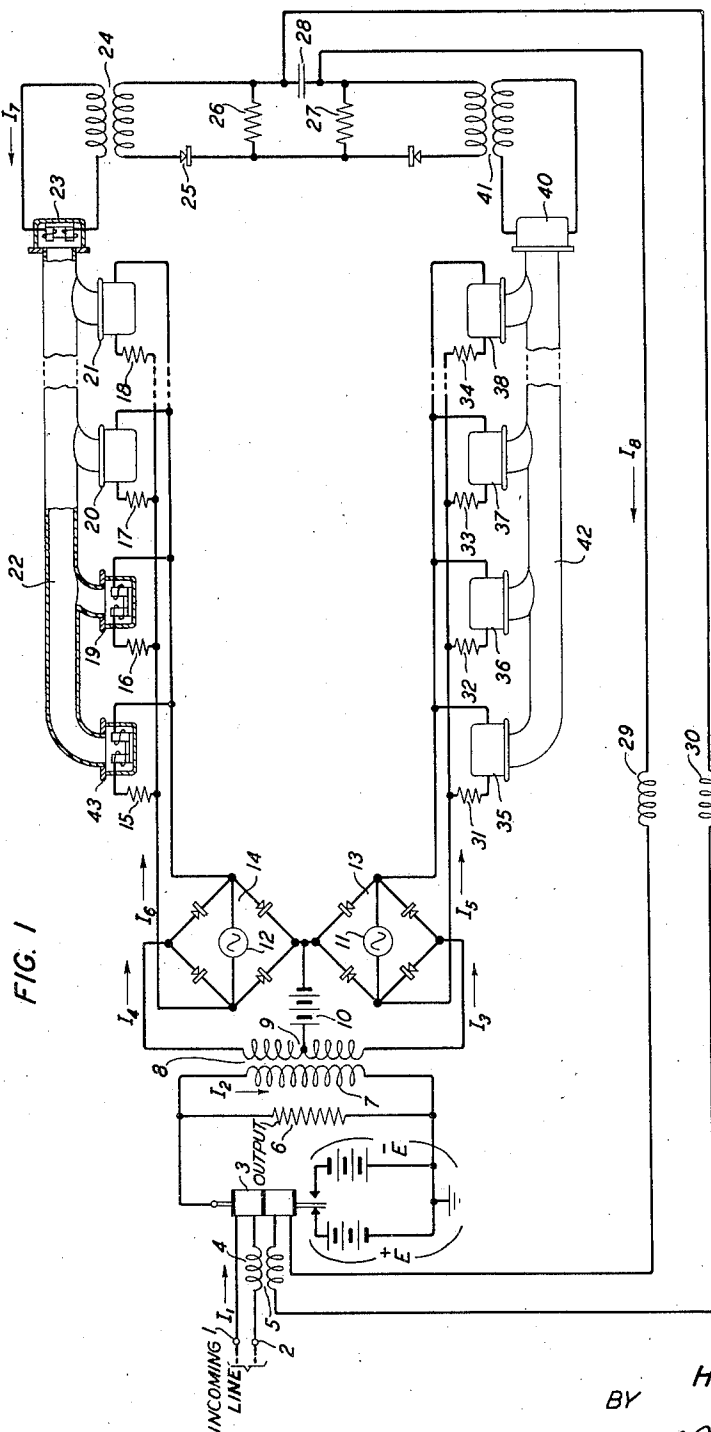
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**2,345,881**

CORRECTION OF DISTORTED TELEGRAPH SIGNALS

Filed May 12, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 2

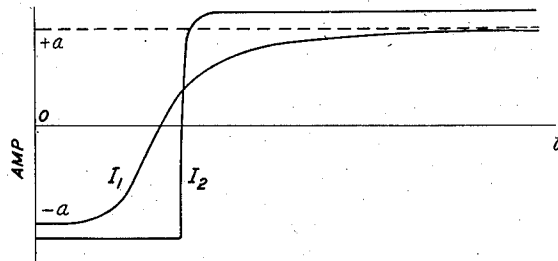


FIG. 3

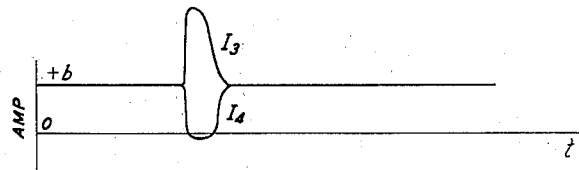


FIG. 4

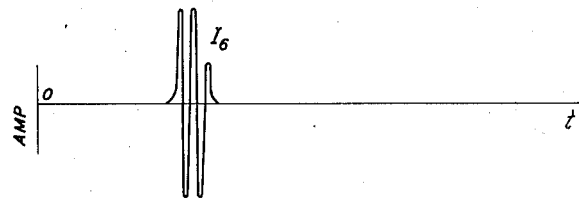


FIG. 5

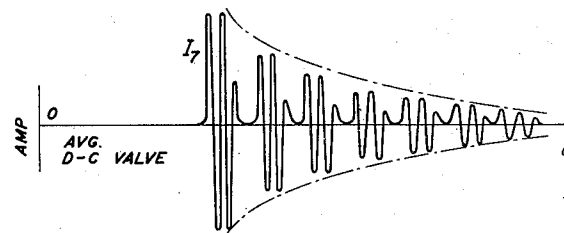


FIG. 6

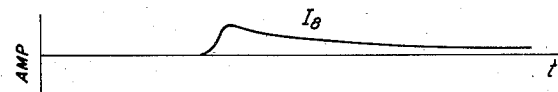
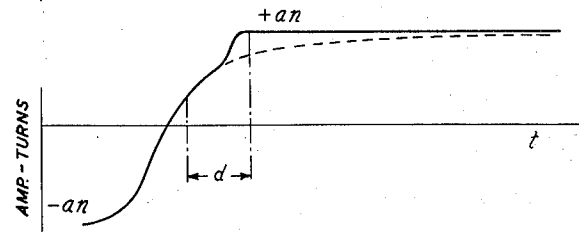


FIG. 7



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## UNITED STATES PATENT OFFICE

2,345,881

## CORRECTION OF DISTORTED TELEGRAPH SIGNALS

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Application May 12, 1942, Serial No. 442,650

10 Claims. (Cl. 178—70)

This invention relates to telegraph systems and particularly to the correction of received telegraph impulses.

As is well known, in the transmission of direct current telegraph impulses, such as positive and negative direct current telegraph impulses, the signals as generated and impressed on the line change at the beginning and end of pulses almost instantaneously through their full amplitude for each transition. At the beginning of a positive pulse the current rises from its full negative value to its full positive value in practically zero time. At the end of the positive pulse it falls from its full positive to its full negative value in practically zero time.

In passing over the transmission line interconnecting the transmitter and receiver the signal impulses, particularly the beginnings and ends of the signal impulses, are modified to a greater or less extent depending upon the length and character of the line. Where the shape of the received signals has been excessively changed, it is frequently necessary at the receiving end to compensate for the distortion in some manner. One manner of doing this is by generating a transient at the receiving station conforming to the portion of the signal which has been lost in transmission and, in effect, adding the transient to the received impulse to restore it to its original form.

It is an object of the invention herein to shape current impulses particularly to correct received telegraph signal impulses.

It is a more particular object of the invention herein to correct received telegraph signal impulses by generating a transient at the receiving station which closely conforms to the portion of an impulse lost in transmission of the impulse to the receiving station and, in effect, adding the transient to the received impulse, to restore the signal to its original form.

The invention may be understood from the following description when read with reference to the associated drawings, in which:

Fig. 1 shows a telegraph receiving relay 3 and the electromechanical mechanism of this invention adapted to generate a transient at the receiving station to complement a distorted telegraph signal impulse received over a telegraph line by relay 3. Arrows  $I_1$  to  $I_5$  in this figure indicate currents in the portions of the circuit of Fig. 1 with which the arrows are associated;

Fig. 2 shows a current-time graph of the current  $I_1$ , received in the line winding of the receiving relay 3 and the current  $I_2$  which flows in

the primary 7 of transformer 8 after the armature of relay 3 has operated to engage its positive contact;

Fig. 3 shows a current-time graph of the currents  $I_3$  and  $I_4$  after they have been unbalanced due to the effect of  $I_2$ ;

Fig. 4 shows a current-time graph of the output current  $I_5$  of the oscillator 12 in Fig. 1, when the resistance of its short-circuiting rectifiers has been increased, due to the reversal of the direction of the flow of  $I_4$ ;

Fig. 5 represents a current-time graph of the output current  $I_7$  of the electromechanical current shaping and delay device of the invention resulting from impressing  $I_5$  through a number of parallel impedances of different magnitudes and interposing delays in different amounts;

Fig. 6 shows a current-time graph of the current  $I_3$  resulting from the rectification of the current  $I_7$ ; and

Fig. 7 shows the total ampere-turns time graph for the two windings of relay 3 resulting from the flow of current  $I_1$  through one winding and  $I_3$  through the other winding.

Refer now to Fig. 1. In the upper left-hand portion of Fig. 1 terminals 1 and 2 denote the receiving end of a four-wire direct current metallic telegraph line. The receiving polar relay 3 is assumed to have  $n$  turns in its line winding which is connected in series with the secondary winding 4 of transformer 5 whose mutual inductance is the same as that between the two windings of the relay 3. The polarity is such that the current  $I_3$ , developed in a manner to be described below, in the bottom winding of the relay has no effect on  $I_1$  in the line winding. It is assumed that the current  $I_1$  has been constant at the value  $-a$  and then changes to  $+a$ , as shown in Fig. 2. As a result of this, the armature of relay 3 moves, soon after the current value of the wave passes through zero, to the position shown in Fig. 1, and connects with the positive terminal of a battery of potential  $E$ . Accordingly, the flow of current through the armature to load 6 reverses from negative to positive. In parallel with the load 6 is the primary 7 of transformer 8. The load device 6 typifies a winding of a repeating relay, an outgoing line circuit, the input of a thermionic tube of the grid or magnetron type, the input of an oscillograph tube or other suitable device. The current  $I_2$  in the transformer also changes from negative to positive, as shown in Fig. 2. This curve may or may not show the travel time of the relay. The travel time is assumed to be negligibly small. Spark

killers, well known in the art, may be used to eliminate the effect of armature travel time on curve  $I_2$ .

As shown in Fig. 1, a battery 10 furnishes currents  $I_3$  and  $I_4$  which are equal and flow in the forward or low-resistance direction through bridge-type copper oxide rectifiers 13 and 14 maintaining all eight of their resistances at substantially zero when  $I_2$  has a steady value. Therefore, alternating current delivered by oscillators 11 and 12 cannot flow past the rectifiers in this condition since their outputs are effectively short-circuited. The reason for this is that the resistance of the path through battery and one-half of the secondary of transformer 8 plus the resistance through the rectifiers in the forward direction for either  $I_3$  or  $I_4$  modulated with the oscillator current is negligible as compared with the resistance of the parallel path through the input of the sound delay device. As long as the relative magnitudes of the direct current component and the amplitude of the modulating alternating current is such that the polarity of the resulting combined current remains the same as the polarity of  $I_3$  and  $I_4$  which passes freely through the rectifiers in the forward direction no current will flow in the input of the delay circuit.

When a transition in  $I_2$  occurs there results a momentary inductive kick in transformer 8. Let it be assumed, for example, that the voltage induced in the secondary winding 9 of transformer 8 causes current  $I_3$  to be temporarily increased and current  $I_4$  to be decreased so as to become negative momentarily as shown in Fig. 3. Accordingly, oscillator 11 remains short-circuited because the current through the bridge-type rectifier 13 is still in the forward direction. The rectifier bridge 14, however, becomes in effect suddenly composed of high resistance members due to the reversal of  $I_4$ . Reference to Fig. 3 indicates that the current  $I_4$ , which normally has a magnitude indicated by the ordinate  $0+b$  is decreased in value to a point just below zero. It is assumed, as shown in Fig. 3, that  $I_4$  becomes slightly negative. But whether  $I_4$  does in fact become negative or if no negative current passes through the rectifiers so that the value of  $I_4$  becomes zero instead of some negative value, in effect the low resistance path shunting the input to the delay network has been changed to a high resistance path. Oscillator 12 therefore momentarily delivers current  $I_5$  to the input of resistors 15, 16, 17, 18, etc., energizing telephone receivers 43, 19, 20, 21, etc. In the drawings only a few such receivers are shown but the dashed lines indicate that additional receivers may be inserted if necessary to produce a transient of any desired shape.

The receivers produce sound waves in the pipe 22, which sound waves are similar to  $I_6$  of Fig. 4. The sound waves reach the microphone 23 after some delay which depends upon the distance along pipe 22 from each receiver to the microphone. The transient current resulting in microphone 23 is prolonged as shown by  $I_7$  in Fig. 5.

The first spurt of alternating current in this transient is due to sound from receiver 21. The second spurt is due to sound from receiver 20, etc. Resistors 15, 16, 17, 18, etc., are adjusted to make the sound waves have suitable amplitude so that the envelope of the alternating components in  $I_7$ , as indicated by the dashed lines

in Fig. 5, is approximately in proportion to the departure of curve  $I_1$  from its final value  $+a$ .

The alternating components of  $I_7$  pass through transformer 24 and are rectified by copper oxide unit 25. The rectified wave flows over resistors 26 and 27 and past condenser 28 and inductances 29 and 30 which act as a low-pass filter. The current  $I_8$  therefore has a form substantially as shown in Fig. 6 as it enters the bottom winding of polar relay 3. The constants of the various apparatus units are chosen so that after  $I_8$  has reached its peak value it is substantially equal to the difference between  $+a$  and  $I_1$ .  $I_8$  can be given any desired shape by suitable choice of constants for the various elements.

The instantaneous total ampere-turns in relay 3 are proportional to  $I_1$  multiplied by the number of turns  $n$  in the top or line winding plus  $I_8$  multiplied by the number of turns in the bottom or local winding. It is assumed in this embodiment that both windings on the polar relay 3 are formed by a twisted pair, so that each has the same number of turns. The instantaneous total ampere-turns are shown by the heavy curve in Fig. 7. At a short time,  $d$  seconds later than the armature transition, the total ampere-turns reach their final value,  $+an$ , so that the effect on the relay due to the slow build up of  $I_1$  is thereafter eliminated. If thereafter another transition occurs, the net force which operates the relay will be similar in wave form to that which was exerted during the first transition, except for a change in sign. It is assumed that the relay is symmetrical, so that its space-to-mark and mark-to-space operations have equal delay with respect to zero points of the total ampere-turns versus time characteristic when the same shape in wave front exists on going from space to mark as on going from mark to space, except for a change in sign. If there is no bias in the sending voltage, the time between relay operations should equal that between the two transitions at the sending end. Consequently, there will be no distortion in the duration of the first pulse which is transmitted to load 6.

The bridge-type rectifier 13, oscillator 11, resistances 31, 32, 33, 34, etc., receivers 35, 36, 37, 38, etc., together with their associated apparatus 40, 41, 42, etc., operate to eliminate the effect of the tail of the second transient, which is of opposite sign, in a manner similar to that just described concerning the first transient. Thus all transients are compensated for and all signal combinations are transmitted substantially without characteristic distortion so long as the shortest dot is no less than the time interval  $d$ . The fastest speed which can be attained without distortion depends, of course, upon the degree of refinement which is exercised in this transient correction.

In long four-wire metallic circuits the transient  $I_1$  usually approaches its final value gradually. On some short lines where there is a low dissipation, the transient may oscillate about the final value, so that the current  $I_8$  is required to pass through zero several times. This may be accomplished by interchanging certain receivers from one pipe to the other so that they give rise to pulses in  $I_8$  which are of opposite sign. The requirements for  $I_8$  may be observed and the synthesis may be verified by means of oscillograms of  $I_1$  and  $I_8$ .

Transformer 5 may be omitted because there

is no harm in letting  $I_s$  effect the line current  $I_l$ . However, its use simplifies the calculations involved. Without transformer 5 it would be necessary to take into account the change in  $I_l$  when shaping the wave  $I_s$ . With transformer 5 this can be neglected. There is no need for making the line and local windings of relay 3 equal so long as their relative effects on the relay operating force are known and the magnitude of  $I_s$  is designed accordingly.

Feedback equalization in accordance with the disclosure herein is especially beneficial on long four-wire direct current metallic telegraph circuits where characteristic distortion is severe.

What is claimed is:

1. In a telegraph system, the method of correcting a received telegraph signal, to restore said signal to its shape as originally transmitted which comprises: impressing the output of an oscillator on a delay network in response to said received signal thereby developing a complementary signal wave and adding said complementary wave to the received signal to correct distortion in said signal.

2. In a telegraph system, the method of correcting distortion in a received telegraph signal which comprises: 1, impressing the output of an oscillator on a delay network in response to said received signal during the interval while said received signal varies; 2, interposing a plurality of parallel impedance branches of different magnitudes on delay paths of different lengths in said delay network; 3, combining the output of said delay network with said received signal.

3. In a telegraph system, a telegraph signal receiving device, means for controlling the output of an oscillator connected to said device in response to the reception of electrical telegraph signals by said device, a plurality of parallel impedances connected to the output of said oscillator, a plurality of delay means connected to said impedances and means connecting the output of said delay means to said telegraph receiver.

4. In a telegraph system, a telegraph receiver, an oscillator, a plurality of parallel impedance branches, a plurality of delay means for interposing delay intervals of different lengths, means responsive to the reception of a telegraph signal by said receiver for impressing the output of said oscillator on said delay means through said impedances and means for impressing the output of said delay means on said receiver.

5. In a telegraph system, a telegraph signal reshaping device comprising an oscillator, means for impressing the output of said oscillator on the inputs of a plurality of impedance branches in response to the reception of a telegraph signal and means for reorienting the outputs of said branches to complement the received signal as desired.

6. In a telegraph system, a telegraph relay, a line winding on said relay, a local winding on said relay, means connected to said relay, responsive to the reception of a current pulse in said line winding for supplying a current pulse to said local winding and means connected to said relay for varying the shape of said pulse in said local winding dependent on the shape of said pulse in said line winding to compensate for distortion in the shape of said pulse in said line winding.

7. In a telegraph system, a device for receiving telegraph signals, means connected to said device responsive to signals received by said device for compensating for distortion in said signals, said means comprising two oscillators connected to said device, two independent groups of impedances connected to said oscillators and two delay devices connected to said impedances.

8. In a telegraph system, a telegraph relay, an oscillator, a plurality of copper oxide rectifier units short-circuiting said oscillator delay circuit connected to said oscillator and means responsive to the operation of said relay for removing said short circuit from said oscillator and impressing a voltage wave on said delay circuit.

9. In a telegraph system, a telegraph receiver, a pair of oscillators, a network of copper oxide rectifier units short-circuiting each of said oscillators, an independent delay device connected to each of said oscillators and means responsive to the operation of said receiver for removing said short circuit from one or the other of said oscillators to impress a voltage wave on one or the other of said delay devices.

10. A telegraph system comprising an electric telegraph signal transmission path connected to an electric telegraph signal receiver, an acoustic delay path connected to said receiver and means responsive to the reception of electrical telegraph signals by said receiver over said path for impressing sonic signals on said path.

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