Sept. 1, 1936. O. E. PIERSON 2,053,044

REGENERATIVE REPEATER FOR TELEGRAPH SYSTEMS

Filed June 20, 1934 2 Sheets-Sheet 1

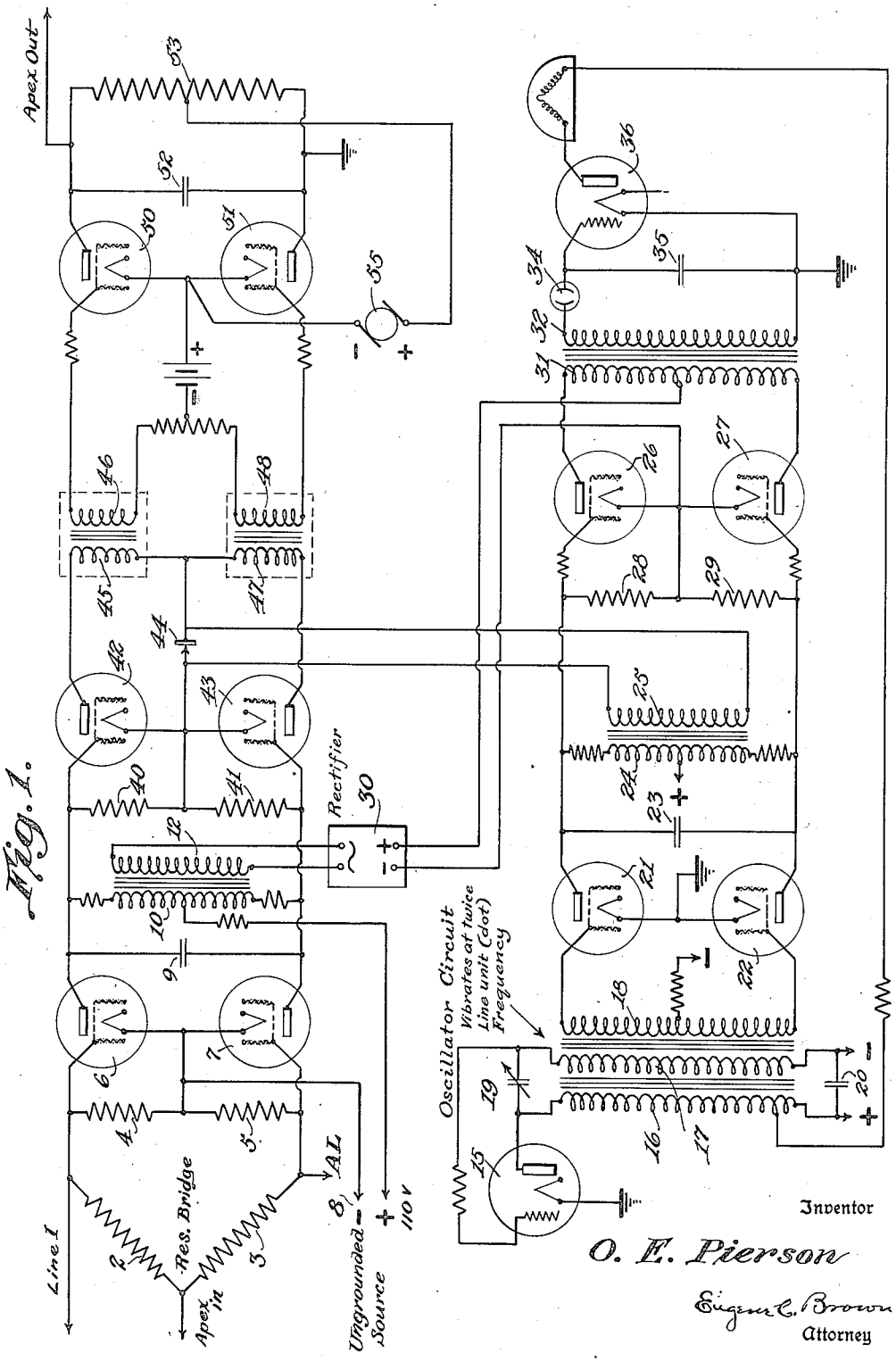


Fig. 1.

Inventor

O. E. Pierson

Eugene C. Brown

Attorney

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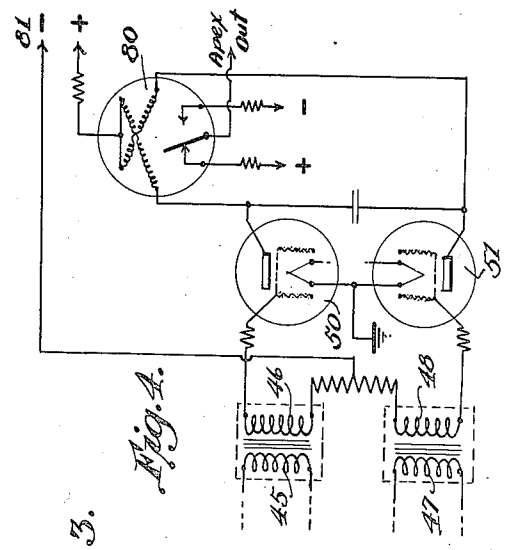


Fig. 4.

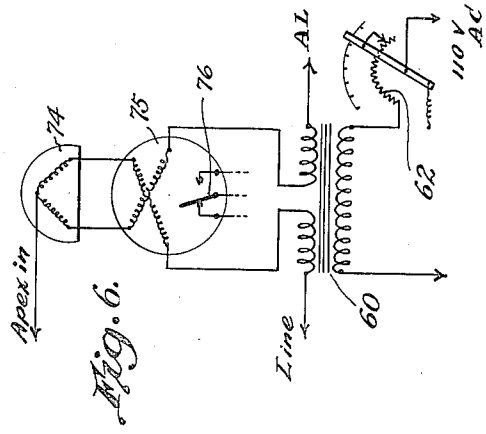


Fig. 6.

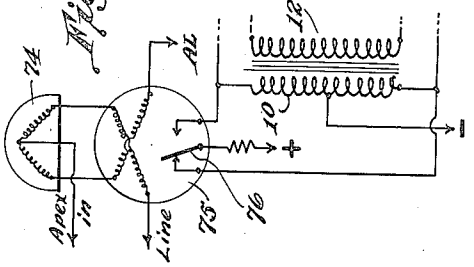


Fig. 3.

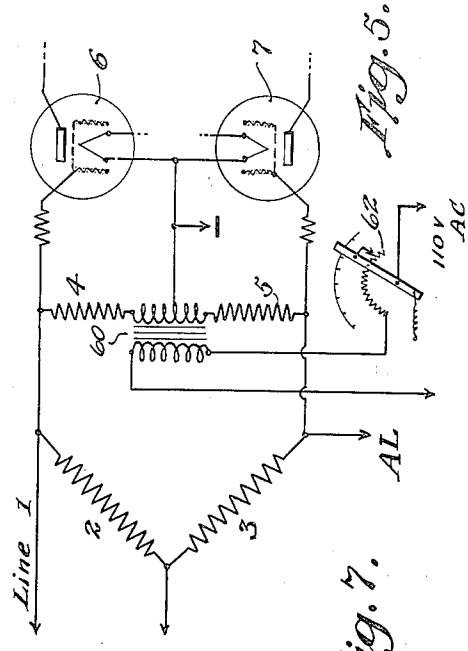


Fig. 5.

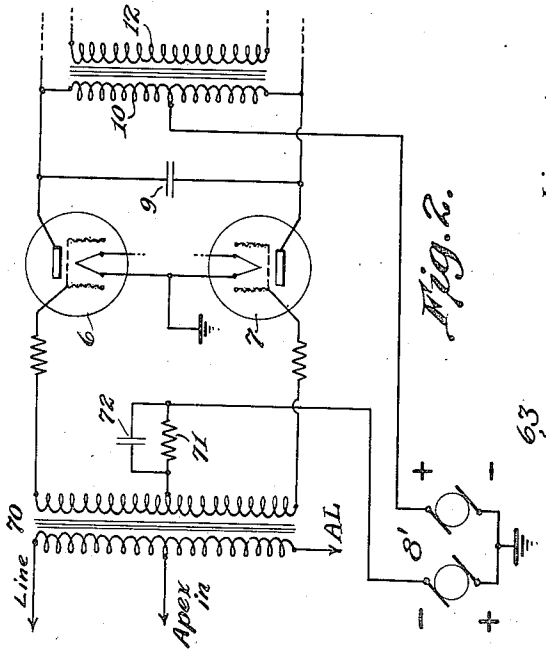


Fig. 2.

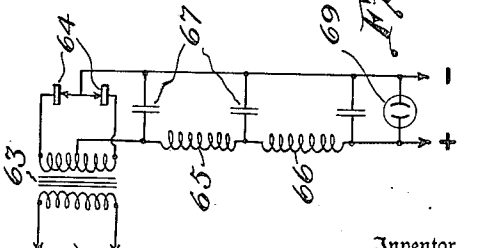


Fig. 7.

Inventor

O. E. Pierson

Eugene C. Brown

Attorney

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REGENERATIVE REPEATER FOR TELEGRAPH SYSTEMS

Oscar E. Pierson, Brooklyn, N. Y., assignor to The Western Union Telegraph Company, New York, N. Y., a corporation of New York

Application June 20, 1934, Serial No. 731,508

7 Claims. (Cl. 178—70)

This invention relates to synchronous communication systems and particularly to high speed printing telegraph systems.

The general object of the invention is to provide a telegraph repeater of the regenerative type which receives distorted signals from one section of a line and retransmits them into the next section free from distortion at accurately spaced time intervals and without employing a mechanically operating device such as a vibrating reed or fork or a rotating commutator.

In all former types of regenerative repeaters designed to repeat the usual five-element code signals, two contacting devices, each operating at twice the line frequency, are necessary. The first is for the purpose of selecting the middle or reliable portion of each unit impulse and recording this signal in some manner such as by causing it to operate a relay. The second is for the purpose of maintaining synchronism between the received signals and the contacting devices of the regenerative repeater. These functions are identical with those of the receiving and correcting rings of the face-plate on a multiplex terminal distributor. In the case of the terminal set, the double frequency is obtained from a brush passing over segments of half the length of the sending segments.

In the repeater herein described, I employ a vacuum tube oscillator adjusted to vibrate at twice the line frequency. The output of the oscillator is in turn made to operate upon the grids of a pair of gas-filled grid-controlled hot-cathode rectifier tubes of the gaseous arc discharge type such as disclosed in reissue patent to Von Lieben et al., No. 13,779, more fully described in Elektrotechnische Zeitschrift of November 27, 1913, at page 1359; and the Langmuir Patent No. 1,289,823, described in the Journal of the American Institute of Electrical Engineers of November 1928 at page 802, together with other forms in which the characteristics of the Von Lieben tube when employed as a trigger device, are more fully set forth. Said rectifier tubes are caused to alternately open and close their anode circuits, thus producing the electrical effect of a brush passing over segments and constitute the means for selecting the incoming signals and for re-transmitting them at accurately spaced time intervals.

I have found that when rectifier tubes of the type specified are connected in a manner to be operated by the vacuum tube oscillator, the anode circuits of the rectifier tubes open and close with an abruptness hardly equalled by a brush and segment commutator. In spite of the sinusoidal character of the voltage impressed upon the grids of these tubes, the anodes, at a critical point on the grid voltage curve, change in a few microseconds from an infinite impedance to one of a few hundred ohms.

In the accompanying drawings referred to in the following description:—

Figure 1 is a diagram of a regenerative repeater embodying my invention, only one side of the repeater being shown as this is sufficient to amply disclose the theory and operation.

Figures 2 to 6 inclusive illustrate modified arrangements which may be employed as hereinafter pointed out.

Figure 7 illustrates a conventional method of obtaining an ungrounded potential supply adapted for use in connection with this repeater.

The telegraph signals received over line 1, produce differences of potential across the terminals of the arms 2, 3 of the differential resistance bridge and thereby across the connected resistances 4 and 5. Gaseous grid-controlled rectifier tubes are connected across resistances 4 and 5 so that their grids alternately become positive and negative with respect to their cathodes and thereby cause their anode or plate currents to follow the incoming line signals. An ungrounded source of potential 8 supplies positive potential to the center of the primary of transformer 10, 12, the negative returning through the cathodes of tubes 6 and 7. Condenser 9 operates in the well-known manner to cause the anode current of one tube to cease the instant the other tube starts to operate. Current changes in the primary coil of transformer 10, 12, produce very abrupt reversals of magnetic flux in accordance with the received signals. In this repeater the transformer 10, 12, may be regarded as the equivalent of the line relay tongue of an ordinary multiplex set, in that it furnishes impulses to a synchronizing circuit and also to a selecting circuit.

Let us first consider the synchronizing circuit. The oscillator, comprising the thermionic oscillator vacuum tube 15, associated with inductances 16, 17 and 18 and with capacitances 19 and 20, produces a sinusoidal frequency of twice the dot frequency of the line signals. The frequency of oscillations may be adjusted by means of the adjustable condenser 19. The potentials set up in the secondary coil 18, operate the gaseous grid-controlled rectifier tubes 21, 22, in the same manner as the line signals operate the rectifier tubes 6 and 7. Accordingly the sinusoidal potentials generated in the oscillator circuit thus produce

nearly square topped currents in the transformer 24, 25. The condenser 23 operates in the manner previously referred to in stopping one tube at the instant the other tube starts. Transformer 24, 25 in association with tubes 21 and 22 may be said to function like the multiplex receiving distributor of an ordinary multiplex set, in that they control two circuits each operating at twice the dot frequency of the line signals, one circuit being the equivalent of the receiving ring of the distributor and the other that of the corrector ring.

Let us first consider the circuit which functions like that of the corrector ring. This corrector circuit is formed by bridging the grid circuits of two grid-controlled rectifier tubes 26, 27, of the type described, across the terminals of the primary coil 24 and across resistances 28, 29, so that the grids of tubes 26, 27 will alternately become positive and negative with respect to their cathodes and in phase with the flux alternations in transformer 24, 25. It will be observed that the anode circuits of tubes 26, 27 are not connected to any steady source of potential and consequently the opening and closing of the anode circuit of a tube by means of its grid does not necessarily cause any current to flow in the anode circuit. It merely closes or conditions the anode circuit in anticipation of an impulse which may be received from the secondary 12 of transformer 10, 12. This impulse, which occurs at the instant of each line reversal, is first passed through a rectifier 30, so that it reaches transformer 31, 32 as a unidirectional impulse with the positive potential applied to the center of primary coil 31. It will be apparent that three possible conditions may be encountered, viz:—

(1) The grid of tube 26 being positive and that of tube 27 being negative with respect to the cathodes. In this case the impulse from rectifier 30 will find a closed path through the anode circuit of tube 26, thereby producing a momentary flux in transformer 31, 32. This transformer is so designed that only the rising current is capable of generating sufficient potential in the secondary 32 to break down neon lamp 34 and thereby influence the grid of thermionic corrector vacuum tube 36.

(2) The grid of tube 26 being negative and that of tube 27 being positive with respect to their cathodes. This is the opposite of condition (1) and the impulse will now find a path through the anode of tube 27 and cause a potential to be generated in secondary coil 32 opposite to that generated under condition (1).

(3) The grids of tubes 26 and 27 not being sufficiently negative or positive to control the anode circuits. In this case current due to an impulse from rectifier 30 will either flow through both tubes 26, 27 or through neither one, in either event producing no potential in coil 32.

Let us now consider the manner in which these three conditions control the phase relation between the received signals and the oscillator frequency. Assume that when the phase relation is correct, the line reversal will arrive at just the instant when the grid of tube 26 is passing through zero and in the act of changing from positive to negative and the grid of the tube 27 is likewise passing through zero in the act of changing from negative to positive, or as it is sometimes expressed, the tube 26 is being "turned off" and the tube 27 is being "turned on." As pointed out above, this condition will not produce any effect in the transformer 31, 32.

Let us now suppose that the line reversal arrives ahead of time. This condition will find tube 26 "on" and tube 27 "off" and will produce a momentary flux in transformer 31, 32. Secondary coil 32 is connected so that this flux generates a positive potential sufficient to break down neon lamp 34 and causes condenser 35 to become more positive on the side connected to the grid of thermionic vacuum tube 36. This causes the grid of tube 36 to become more positive, thereby increasing the anode current. This in turn affects the impedance of inductance 16, causing it to drop, thereby increasing the oscillator frequency.

Should the line reversal arrive late, the impulse from the rectifier will find the tube 26 "off" and the tube 27 "on" and hence the current flowing through primary coil 31 generates a negative potential in the secondary 32 which is applied to the grid of corrector tube 36. This reduces the current flowing in the anode circuit, thereby reducing the oscillator frequency. It will be seen from the above analysis that the action of tubes 26 and 27 is exactly analogous to that of the corrector segments of a multiplex distributor, tube 26 being the equivalent of the "fast" segments and tube 27 to that of the "slow" segments. For the sake of simplicity, I have shown only one corrector tube 36, but in actual practice the use of two or three tubes arranged in the manner disclosed in the application of Paul A. Noxon, Serial No. 748,142, may produce the most desirable characteristics.

Since all line reversals which arrive when the tube 26 is "on" and the tube 27 is "off", tend to increase the oscillator frequency, while those that arrive when tube 26 is "off" and tube 27 is "on" tend to decrease it, it is evident that the oscillator will be held so that the average line reversal will occur just at the instant the circuit is being switched from tube 26 to tube 27. It will also be evident that the circuit will be switched back from tube 27 to tube 26 at a point midway between two line reversals, i. e., in the middle of the reliable portion of the signal. This reversal also simultaneously produces an impulse in the secondary coil 25, which selects the center of the received signal and marks the moment of retransmission. I have previously stated that transformer 10, 12 was analogous to the tongue of a line relay in that it supplies impulses to the synchronizing circuit and to the selecting circuit. Let us now follow the impulses supplied to the selecting circuit.

Across the outer terminals of the primary winding 10 of transformer 10, 12, is connected resistance bridge 40, 41 and across this bridge are connected the grids and cathodes of rectifier tubes 42 and 43. Hence voltages will be impressed on the grids of these tubes in accordance with line signals. The anode currents of these tubes consist of the very short impulses that originate in the secondary coil 25 of transformer 24, 25. It has been seen that for every unit line signal, two impulses are generated in the secondary coil 25, one at the moment of line reversal and the other at exactly the mid-point between the two reversals of a unit signal. The latter impulse is used for the selecting impulse as it occurs at the most favorable time. The secondary coil 25 is connected so that the selecting impulse is correctly poled, i. e., so that positive potential is applied to the mid-point between primaries 45 and 47 of transformers 45, 46, and 47, 48. This of course is necessary since the anode circuit of a tube is only closed for this condition. We shall speak of this impulse as the positive impulse

and the one which coincides with the line reversals as the negative impulse.

The positive impulse from the secondary coil 25, then finds a closed circuit either through the primary 45 and the anode circuit of tube 42 or through the primary 47 and the anode circuit of tube 43, depending upon which tube has previously been selected by the line signals. Suppose the line signal to be such that tube 42 has been selected. The positive impulse from coil 25 will then find a path through primary 45 and the anode of tube 42 back to coil 25. This will cause a momentary rise and fall of the flux in transformer 45, 46 and on the rise of the flux, a positive potential will be applied to the grid of tube 50, causing it to operate, if not already operated. The operation of tube 50 causes tube 51 to shut off, due to the action of condenser 52. Should tube 50 already be operated, the application of positive potential to its grid has no further effect.

Upon the drop of the flux in transformer 45, 46 a negative potential is momentarily applied to the grid of tube 50, but due to the characteristic of a gaseous grid-controlled rectifier tube of the type described, it produces no effect. I have indicated in Figure 1 that transformers 45, 46, and 47, 48, have no common resistance and are magnetically shielded from each other. The reason for this is that if they are not shielded or have any common resistance there will be a reaction between them so that when one of them applies a positive impulse to the grid of the tube associated with it, the other one would apply a negative impulse to its grid. Trouble would result from this on the fall of potential, as this would cause the undesired tube to be selected.

The negative impulse from secondary coil 25, (which occurs at the moment of line reversal) is by-passed or shunted through the rectifying valve 44, so that no harmful potential strains are produced or applied to the anodes of tubes 42 and 43.

It is evident that the moment of operation of the tubes 50 and 51 will be controlled by the impulses from secondary coil 25. Since these impulses arrive at very accurately spaced intervals of time, tubes 50 and 51 will operate with corresponding accuracy. The anode circuits of these tubes are so arranged that polar signals are transmitted into the apex of the other half of the repeater (not shown). It is therefore evident that these signals will have the same degree of uniformity as that which characterizes the operation of 50 and 51 and hence will be completely regenerated.

In the usual type of rotary regenerative repeater it is customary to orientate the receiving ring for the two-fold purpose of measuring the amount of margin available and in order to find the most favorable location for the receiving segments in relation to the received signals. The second necessity exists only where the corrector is of a type which does not maintain a fixed relation between the corrector segments and the signals. The corrector described herein does maintain a very definite relation between the signals and the oscillator reversals, hence no need exists for altering this relation. It automatically falls in the most advantageous position. There remains then only the necessity for measuring the margin and, since it is not expedient to do this by shifting the phase, an alternate method is here proposed. The "margin" of a circuit is merely a measure of the amount of additional distortion which the signals can bear before they deteriorate to a degree where they are no longer intelligible. We may therefore measure "margin" by simply adding artificial distortion to the signals. This can be done by superimposing an alternating current disturbance upon the signals by means of a transformer and a rheostat which may be introduced in the resistance bridge 4, 5 of Fig. 1, in the manner shown in Fig. 5. In the modified arrangement shown in Fig. 3, the alternating current disturbance may be introduced in the manner shown in Fig. 6. In each of these methods of "ranging" a transformer 60 with a low impedance two-section secondary has its primary coil connected through a variable resistance 62 to an A. C. source. The rheostat may be calibrated in any desired units. The rheostat arm may be automatically returned to open position by means of a spring to guard against the inadvertent failure to remove the resistance 62 while the circuit is in operation. The turn-ratio of the transformer and the value of resistance 62 are such that sufficient disturbance can be introduced to reduce the margin to zero.

In the arrangement illustrated in Fig. 1, I have employed an ungrounded potential source or generator 8 and also an ungrounded generator or source 55 to supply the anode circuits of tubes 50 and 51. This ungrounded source may be conveniently derived from any A. C. source in the well-known manner illustrated conventionally in Fig. 7. The current from a power transformer 63 passes through a rectifier 64 and a filter unit consisting of impedances 65, 66 and filter capacities 67, the unit being provided with a voltage stabilizer, such as a neon lamp 69. The characteristics of the several elements must be such as to give the desired voltage regulation.

It will be evident to engineers that various modifications can be made in the repeater circuits shown in Fig. 1. Instead of employing an ungrounded current source at 8 and 55, a commercial grounded potential source 8' may be used for the grid and anode circuits of tubes 6 and 7 in the manner shown in Fig. 2. The resistance bridge 2, 3 is replaced by a transformer 70 having its primary differentially wound so that the circuit may be balanced for duplex operation in the usual way. The negative bias for the tubes 6 and 7 is supplied through a network consisting of a resistance 71 shunted by a condenser 72, connected to the center tap of the transformer secondary coil. The values of the network and negative potential are such that the tubes will not respond to the induction disturbances of the line but will operate when the regular signal reversals occur.

My repeater will operate if the resistance bridge 2, 3 of Fig. 1, is replaced by a polar relay 75 connected as shown in Fig. 3. In this case the relay also performs the function of tubes 6 and 7 and its tongue 76 produces the same potential changes in transformer 10, 12 as would be done by tubes 6, 7. The remainder of the circuit arrangement beyond transformer 10, 12 is identical with Fig. 1. Signals coming in over line 1, operate differential relay 75, and the milliammeter 74 in the usual manner. The tongue 76 is connected to positive potential, while the center tap of transformer primary 10 is connected to negative potential so that the result of the signal reversals is to produce corresponding potential changes across the outer terminals of the primary coil 10 in exactly the same manner as would be effected by the tubes 6 and 7.

The resistance bridge 53 at the outlet end of

the repeater circuit may likewise be replaced by a polar relay 80 in the manner indicated in Fig. 4, thereby avoiding the use of an ungrounded potential supply indicated at 55 in Fig. 1. The polar relay is operated by the anode currents of the tubes 50 and 51 so that it follows the incoming line signals. Potentials from a regular source 81 may be used to operate the tubes and also for sending the regenerated signals to line or the apex of the other repeater section.

I claim:

1. In a telegraph system, a thermionic repeater for correcting distorted received line signal impulses and retransmitting regenerated accurately spaced impulses, comprising oppositely poled gaseous arc-discharge tubes adapted to receive the line impulses, an oscillatory circuit provided with a thermionic generator operating at twice unit line frequency, means associated with said tubes for supplying unidirectional impulses in response to the received line signals, a correcting circuit associated with said oscillatory circuit provided with thermionic means operatively connected to vary the characteristics of said oscillatory circuit, and means whereby said unidirectional impulses control said thermionic means in a manner to produce an effect upon the frequency of said thermionic generator which is nil, acceleratory or deceleratory in a manner proportional to and dependent upon the phase relation of said received line signals with respect to the impulses generated in said oscillatory circuit.

2. In a telegraph system, apparatus having no moving elements for correcting distorted line signal impulses and retransmitting regenerated accurately spaced impulses, comprising a pair of gaseous arc-discharge tubes in oppositely poled mutually quenching arrangement for receiving the line impulses, a thermionic oscillation generator operating at twice line unit frequency, a correcting circuit associated with said generator and provided with thermionic means operating under the control of the output of said arc-discharge tubes to produce an effect upon said generator which is nil, acceleratory or deceleratory in a manner dependent upon the phase relation of said received line signal impulses with respect to the impulses of said oscillation generator, a retransmitting circuit provided with a current generator and a pair of gaseous arc-discharge tubes in oppositely poled mutually quenching arrangement and means for supplying starting impulses to said last mentioned tubes from said correcting circuit at mid-point intervals between successive current reversals.

3. A system for maintaining current impulses generated in a local circuit in phase with received signal impulses, comprising a receiving circuit having means for producing in response to incoming current impulses of varying values, voltage impulses of one polarity, an oscillation generator embodying a thermionic tube and a tuned circuit for determining the frequency of oscillation thereof, a circuit inductively connected to said tuned circuit and provided with a thermionic device adapted to vary the impedance of said tuned circuit, and means whereby each of said voltage impulses produces an effect upon said generator which is nil, acceleratory or deceleratory in a manner proportional to and dependent upon the phase relation of said received line signal impulses with respect to the impulses produced by said oscillation generator.

4. A system for correcting distortion or phase displacement in received line signal impulses and retransmitting regenerated accurately spaced impulses, comprising means for locally generating oscillatory impulses of twice unit line frequency, instrumentalities for producing in response to incoming current impulses of varying values, voltage impulses of one polarity, and means including correcting circuits whereby each of said voltage impulses produces an effect upon said oscillatory generating means which is nil, acceleratory or deceleratory in a manner proportioned to and dependent upon the phase relation of said received line signal impulses with respect to said locally generated impulses.

5. A system for correcting distortion or phase displacement in received line signal impulses and retransmitting regenerated accurately spaced impulses, comprising means for locally generating oscillatory impulses of twice unit line frequency, instrumentalities for producing in response to incoming current impulses of varying values, voltage impulses of one polarity, means including correcting circuits whereby each of said voltage impulses produces an effect upon said oscillatory generating means which is nil, acceleratory or deceleratory in a manner proportional to and dependent upon the phase relation of said received line signal impulses with respect to said locally generated impulses, and means controlled by the corrected oscillatory impulses for retransmitting regenerated impulses spaced at mid-points between received line current reversals.

6. In a telegraph system, apparatus having no moving elements for correcting distorted line signal impulses and retransmitting regenerated accurately spaced impulses, comprising a pair of oppositely poled thermionic tubes for receiving the positive and negative signal impulses, means associated therewith for producing voltage impulses of one polarity, an oscillatory circuit embodying a thermionic tube associated with a capacity element and an inductance element for determining the frequency of oscillation thereof, said inductance element having a core of magnetic material the permeability of which varies with the flux density, a correcting circuit embodying thermionic tubes controlled by said voltage impulses for producing a controlling effect upon the frequency of the oscillatory circuit by varying the flux density of said magnetic core, transmitting means embodying a current source and a pair of gaseous grid-controlled tubes in mutually quenching arrangement and means for applying starting potentials from the correcting circuit to said last mentioned tubes.

7. In apparatus for repeating telegraph signals, as defined in claim 1, means for determining the range or amount of distortion in received signals which can be corrected and accurately retransmitted comprising means for inductively impressing currents, from an alternating source upon the opposite terminals of the receiving apparatus to thereby superimpose an artificial distortion upon the signal impulses, and means for varying the value of the impressed current by introducing resistance in predetermined calibrated units until the margin is reduced to zero.

OSCAR E. PIERSON.