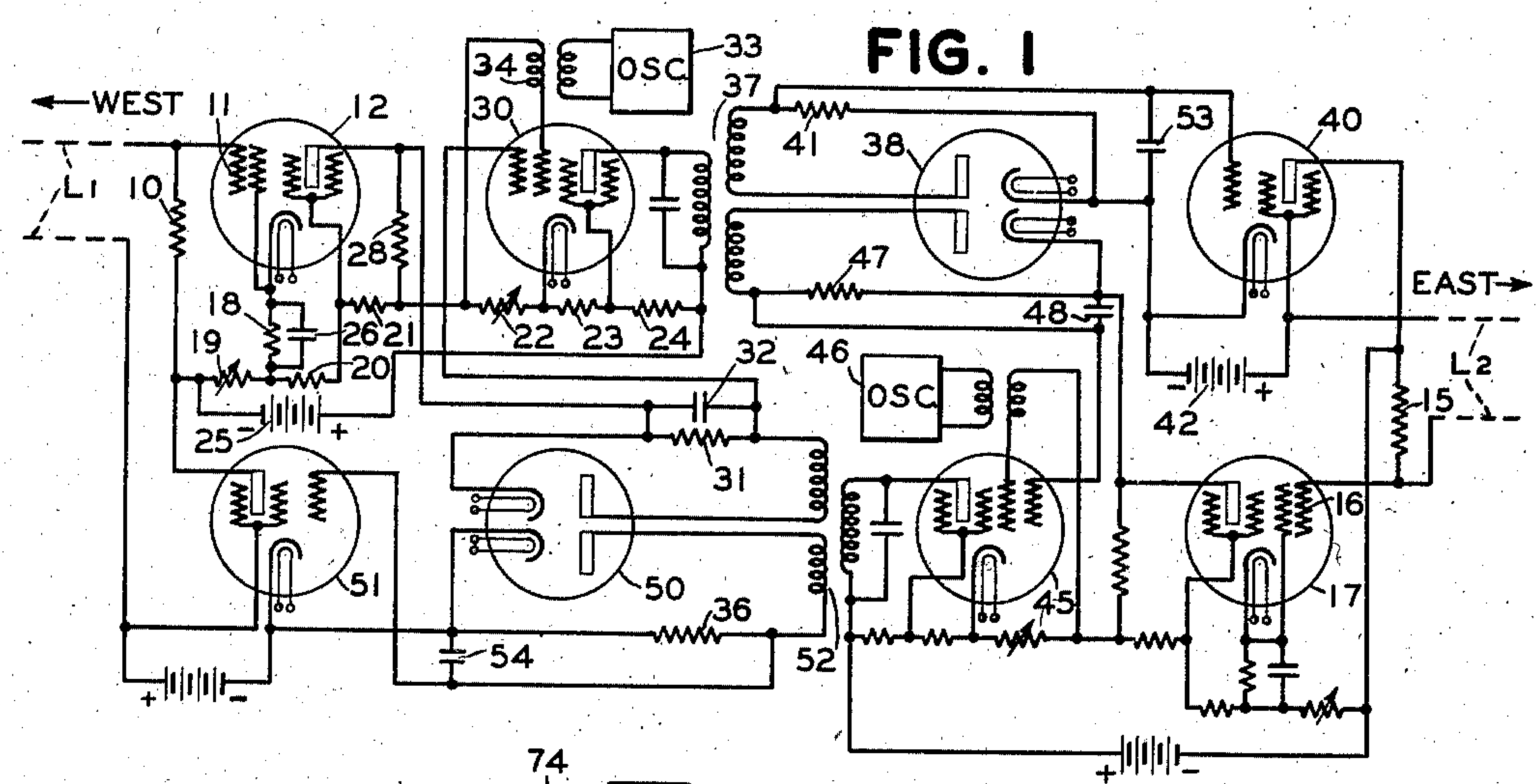
April 21, 1942. L. W. FRANKLIN 2,280,308

ELECTRONIC REPEATER

Filed Dec. 3, 1938

FIG. 1



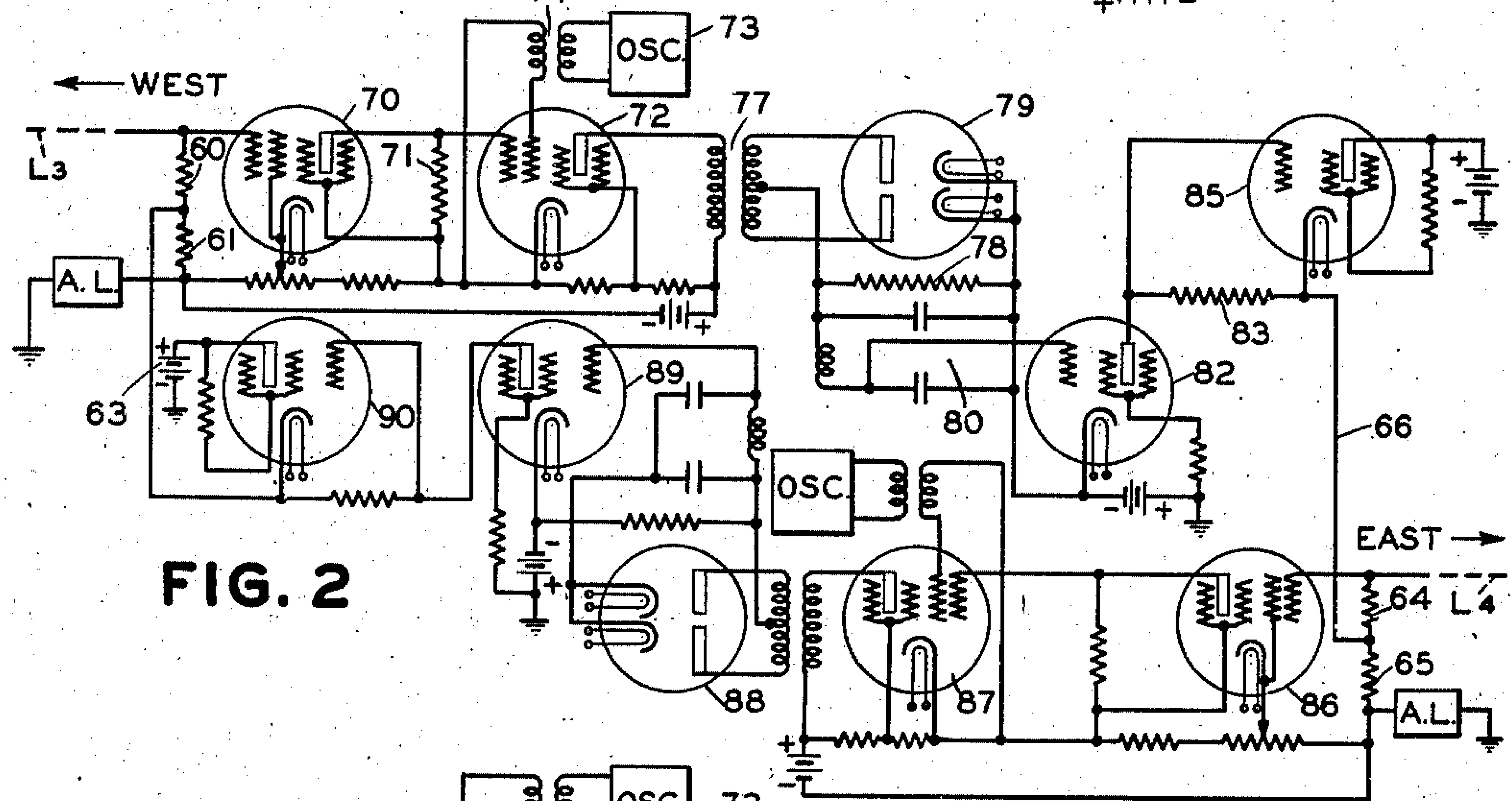


FIG. 2

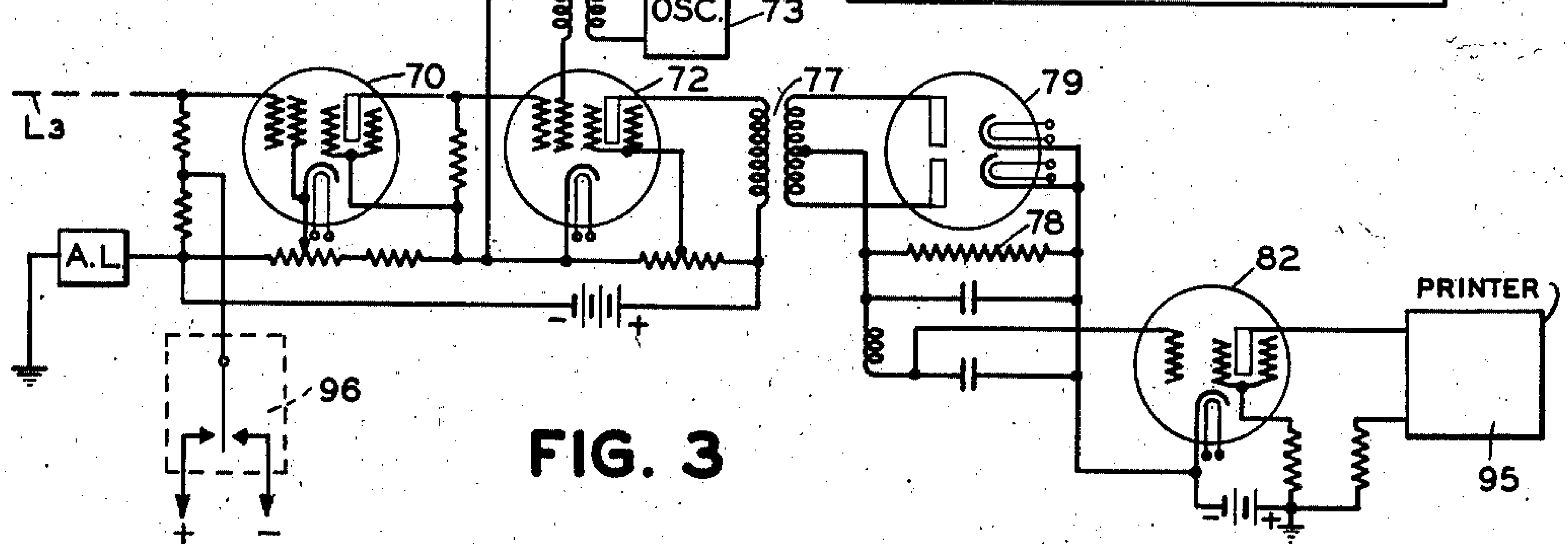


FIG. 3

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ELECTRONIC REPEATER

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7 Claims. (Cl. 178—71)

This invention relates to systems and apparatus for transmitting and receiving electric currents and more particularly to vacuum tube repeaters or terminal sets.

Heretofore vacuum tube or electronic repeaters for signaling currents have been commonly employed for amplifying continuous waves such as voice currents, and repeaters utilizing magnetic relays have been commonly used for shaping and repeating square-topped waves such as are used in telegraphy. In certain cases vacuum tube repeaters have been designed for repeating comparatively low-frequency signals sent over cables or other channels of large capacitance, but these repeaters have not been adapted for regenerating and repeating high-speed printer signals consisting of code combinations of short, substantially square-topped impulses. The vacuum tube or thermionic valve has been considered suitable for reproducing variable intensity signals without distortion but the electromagnetic relay has been considered more practical for the purpose of correcting distortion in and repeating telegraph or printer signals. However the electromagnetic relay involves moving parts which are subject to wear and change in adjustment so that considerable maintenance is required to maintain repeaters utilizing such relays in operation. Furthermore electromagnetic relays require a definite time for operation and cannot be employed for repeating signals above a certain rate which is often reached in practice. If this transmitting rate is exceeded or if the relays get out of adjustment the repeater will not function satisfactorily.

In general terms it is the object of the invention to provide a simple and practical repeater or signal-shaping system utilizing space-discharge devices such as vacuum tubes or thermionic relays which is capable of regenerating and/or repeating telegraph signals at any desired rate and which does not change in adjustment or require any maintenance other than the replacement of worn out parts.

Another object of the invention is to provide an improved two-way electronic telegraph repeater which may be embodied either in a system for transmitting make-and-break signals or polar signals.

Another object of the invention is to provide a vacuum tube repeater for high-speed printer signals which is adapted to reshape the received signals and in which the character and bias of the repeated signals may be altered as required by changes in the character of the received signals owing to changes in line or other conditions affecting the signals.

Other objects and advantages of the invention will appear from the following description of the preferred embodiments thereof shown in the accompanying drawing, wherein

Fig. 1 is a diagram showing one arrangement of a two-way electronic repeater for make-and-break signals suitable for practicing the invention;

Fig. 2 is a similar diagram of a repeater embodying the invention adapted to be used for repeating polar signals; and

Fig. 3 is a diagram of a further modification adapted for use as a terminal set.

According to the invention the direct current telegraph signals are impressed upon a space-discharge device or vacuum tube relay. A source of alternating current is provided and the connection of this source to the line or receiving printer is controlled by said relay, the alternating current being rectified and used to control the outgoing line or printer. The repeater is arranged to impress impulses of uniform amplitude upon the outgoing line so that the signaling impulses are reshaped and any amplitude distortion of the received signals is overcome.

In the application of the invention to a two-way non-duplexed single-channel repeater, the two ends of the repeater are electrically separated as by the alternating current coupling transformers between the alternating current source and the outgoing lines. An interlock is also provided whereby the repeater will not lock open when the signal appears in an outgoing side of the repeater which is connected to one input side because the repeater is arranged to repeat signals in both directions. The interlock is preferably accomplished by suitably biasing the vacuum tube relay or other element at one input terminal of the repeater when signals from the other input terminal through the repeater are impressed upon the outgoing circuit.

The invention may also be embodied in a two-way repeater of the duplex type adapted to repeat either make-and-break or polar signals. In this case no interlock is necessary because of duplexing of the input and output circuits and, in the case of polar signals, the impressed signals are arranged to reverse the current flow in the outgoing circuit.

As applied to a terminal set, a vacuum tube relay is provided for controlling a local source of alternating current which is rectified and impressed upon a printer or other receiving device. Thus the system is arranged to correct distortion of or regenerate the received signals in substantially the same manner as in the repeater circuit.

In the system diagrammatically shown in Fig. 1, make-and-break signals are received over either of the line circuits or channels L1, L2. The lines L1, L2 constitute two sections of a single channel as distinguished from a duplex system comprising duplex channels over which signals may be transmitted simultaneously in both directions. In the single channel two-way repeater illustrated, signals may be transmitted in either direction but not in both directions simultaneously. The lines L1, L2 may be metallic circuits as shown, or one wire of each line may be replaced by a ground connection such as is usual in the art. These lines are normally closed and adapted to be opened to transmit a spacing signal either by conventional transmitting means (not shown) at the remote end of each line to transmit signals to the repeater or at the repeater to repeat signals over the respective line circuits.

Assuming that both line circuits are closed to correspond to the rest or marking condition, the line current flowing through the space-discharge path between cathode and anode of the normally conductive tube 51 and resistor 10 maintains a positive bias on the control grid 11 of the space-discharge device or vacuum tube relay 12 relative to the potential of the cathode of said device. The resistor 10 may have a resistance of 300 ohms. The space-discharge device 12 may be an amplifier tube of any type adapted to amplify the signal variations impressed upon the input circuit thereof or may be omitted from the system in case the received signals are of sufficient magnitude. If the tube 12 is omitted, the grid-cathode connections to resistor 10 must be reversed. A sharp cut-off voltage amplifier pentode tube, such as the type 6J7, as shown is preferred in the preliminary amplifier stage since this tube provides stable high gain amplification of signals of the character impressed thereon. In a similar manner the flow of line current in the resistance 15 associated with the line L2 maintains a positive bias upon the control grid 16 of the space-discharge device or vacuum tube relay 17 which as shown corresponds in construction and connection to the device or relay 12 associated with the line L1. Since a positive bias is impressed upon the control electrodes of the tubes 12 and 17, both of these tubes are conducting or have a large anode current flowing through the output circuit thereof. The connections of the cathode, anode, shield grid and suppressor grid of the tubes 12 and 17 are conventional and require no further explanation.

When a spacing signal is received over the line L1 as upon the momentary interruption of the line circuit at the remote station, the current flowing through the resistor 10 is interrupted, the positive bias potential on the control grid 11 becomes negative and the tube 12 becomes non-conducting. The extent of the negative bias on the grid 11 depends upon the drop in potential in the resistors 18 and 19 in the input circuit of said tube. Since no current is flowing through the resistor 18 when the tube 12 is biased to cut-off, the potential drop across the resistor 18 rapidly falls to zero. The resistor 19, however, is connected in a bleeder circuit including resistors 20, 21, 22, 23 and 24 in series across the terminals of a source of current 25.

It will be apparent that the drop of potential across the respective resistors 19, 20 and 21 is utilized for the energization of the elements of the space-discharge device 12. The resistance of said resistors is dependent upon the characteristics of the tube 12. In a similar manner the drop in potential across the respective resistors 22, 23 and 24 is utilized to energize the several elements of a second space-discharge device or vacuum tube relay 30, the input circuit of which is connected to the output circuit of the tube 12 and includes a series resistor 31. The resistor 31 and the similar bias resistors 36, 41 and 47 are shunted by condensers 32, 54, 53 and 48 to filter the rectified alternating current signals into essentially direct current impulses. For ordinary printer signals, the condensers may have a capacity of about 0.00025 mf. if the alternating current frequency is of the order of 400 or 500 kilocycles.

The space-discharge device or tube 30 connected to the output circuit of tube 12 is arranged to control the connection of a source of alternating current, such as an oscillator 33, to the line L2 in order to repeat the signals received over the line L1 into said second line. The connection of the source of current 33 to the outgoing line from the repeater or to control the current in said line may be accomplished in various ways, but in accordance with the preferred embodiment of the invention shown, a hexode mixer tube, such as a type 6L7, is employed having two control electrodes or grids, one of which is connected to the circuit upon which the signals to be repeated are impressed, and the other is connected through a transformer 34 to the source of alternating current 33. Thus alternating current of a desired frequency is continually impressed upon one of the control grids of the tube 30 but the space-discharge path in the tube presents a high impedance to the passage of this current so long as the other control grid is biased to a predetermined negative value whereby under these conditions no alternating current appears in the output circuit of the tube. However when the negative bias of the first control electrode of the tube 30 is reduced to approximately zero as a result of the plate current of the tube 12 being cut off by the negative voltage on grid 11 in response to a spacing signal, the alternating current from the source 33 appears in the anode or output circuit of the tube 30 and is impressed through a coupling transformer 37 upon a rectifier 38. The bias on the first control grid of the tube 30 is also affected by the drop in potential across the bias resistor 31, as will be explained below.

The transformer 37 is provided with two secondary windings as shown, and may be an air-core radio frequency transformer if the source of current 33 is of relatively high frequency, for example of the order of 450 kilocycles. The employment of a relatively high frequency of this order is preferred as simple and efficient radio frequency transformers for this frequency may be employed and the apparatus is able to repeat signals of much higher frequencies than have heretofore been possible, for example, of several thousand cycles per second. However, the source 33 may be of a frequency of three or four thousand cycles per second, in which case an iron-core audio transformer would be employed in place of the radio frequency transformer 37. Under these conditions the repeater would respond to signals of several hundred cycles per second.

It will be apparent that, as pointed out above, when a spacing signal is impressed upon the control electrode 11 of the vacuum tube 12, the positive bias on the electrode 11 is changed to a negative bias and the tube 12 becomes non-conductive, the point at which the tube operates being controlled by adjustment of the value of the resistor 19 in order to enable the bias of the regenerated signals to be controlled if desired. An adjustment of this character is not essential but in cases of severe line leakage a readjustment of the operating point of tube 12 by means of resistor 19 is desirable. When the tube 12 becomes non-conductive as described, in response to a spacing signal, the negative bias on the first control grid of the tube 30 is reduced owing to the drop in potential across the coupling resistor 28 in the output circuit of the tube 12 being reduced, and alternating current from the source 33 is impressed upon the rectifier 38 by the tube 30 and the transformer 37.

The rectifier 38 is shown as a double diode rectifier, for example of the 6H6 type, having two separate rectifying paths connected to separate secondary windings of the transformer 37. Obviously if desired separate rectifiers might be employed. The rectified current, caused by a spacing signal in the line L1, from one secondary winding of the transformer 37 is impressed across resistor 41, filtered by condenser 53, and upon the grid-cathode circuit of a space-discharge device or vacuum tube 40 which is normally conductive as long as the rest or marking condition obtains in the line L1. The tube 40 is shown as a beam power amplifier of the 6L6 type, for example, since this tube is adapted to handle the current required in normal telegraph operation but any other suitable amplifier tube may be employed. Upon the flow of alternating current from the source 33 in the upper secondary winding of the transformer 37, a rectified current flows through the resistor 41 in such a direction that the drop of potential across said resistor biases the control electrode of the tube 40 negative to cut off, thereby interrupting the current flow in the line L2 and transmitting a spacing signal corresponding in duration to the spacing signal received over the line L1. It will be apparent that the lines L1 and L2 are electrically separated from each other by means of the coupling transformers 37 and 52, the received signals being converted to alternating current signals, transmitted through the windings of the transformers and then rectified and impressed upon the outgoing line. Any distortion in the received signals is corrected since the magnitude and wave shape of the signals transmitted over the line L2 are independent of variations in the received signals resulting from the inductance and capacity of the line L1 or from inductive interference so that regenerated signals are transmitted from the repeater over the line L2. It will be also apparent that when the line L1 is reclosed, the energization of transformer 37 from the source 33 is interrupted and the bias on the tube 40 is removed, thereby reestablishing the flow of current in the line L2.

In order to prevent the transmission of the spacing signal over the line L2 as described above from being reflected back into the repeater through the discharge device or relay 45, corresponding to the discharge device 30, which would render the repeater inoperative, the lower secondary winding of the transformer 37 and the associated rectifying means are arranged to bias the vacuum tube relay 45 in such a manner as to maintain the alternating current source 46 disconnected from the line L1. The source of alternating current 46 corresponds to the source 33 associated with the vacuum tube 30 and a single source of alternating current may be employed for both relays 30 and 45. The flow of rectified current through the resistor 47 corresponding to the resistor 31 associated with the vacuum tube relay 30 applies a negative bias to one control electrode of the vacuum tube 45 to maintain said tube non-conductive irrespective of the change in bias thereof produced by the first stage amplifier tube 17. Thus the interruption of the current in the line L2 for repeating a signal to a remote station does not affect the part of the repeater which is normally operative to repeat spacing signals received over the line L2 to the line L1.

The lower half of the repeater comprising the space-discharge devices or vacuum tubes 17, 45, 50 and 51 and their associated elements corresponds precisely to the upper half of said repeater and therefore a detailed description of the operation thereof to repeat signals from the line L2 to the line L1 is unnecessary. It will be apparent that if a spacing signal is received over the line L2, this signal is amplified by the tube 17, translated into an alternating current signal by the tube 45 and the resulting signal rectified and impressed upon the line L1 through the tubes 50 and 51 in the same manner as described above in connection with the repeating of signals from the line L1 to the line L2 by the discharge devices 12, 30, 38 and 40.

The transformer 52 corresponds to the transformer 37 of the other half of the repeater and serves to insulate the line L2 from the line L1 for repeating signals from L2 to L1. When a spacing signal is impressed upon the amplifier 17, the alternating current from the source 46 is impressed upon transformer 52, is rectified by the rectifier 50 and causes a potential drop across the terminals of the resistor 31 to bias the first control electrode of the discharge device 30 to prevent reflection of signals through the repeater as described above in connection with the discharge device 45 for signals in the opposite direction.

The action of resistor 18 and condenser 26 in the cathode circuit of the tube 12 serves to greatly reduce "characteristic distortion," or time distortion as distinguished from amplitude distortion, by control of the grid bias of said tube. It also serves to improve operation over circuits where the interference level is high relative to the signal level. The action of this circuit is fully described in the copending application of F. E. d'Humy et al., Serial No. 114,460, filed December 5, 1936. The value of the resistor 18 is dependent on the value of resistor 10 and may be 5000 ohms where resistor 10 is 300 ohms. The higher the value of 10, the higher 18 must be in proportion. The capacity of condenser 26 should be such that in combination with 18, a time-constant of the same order as the minimum signal length is obtained. For example, the condenser would have a capacity of from 0.5 to 1 mf. for a signal frequency of about 100 cycles per second.

Among the outstanding advantages of the repeater described may be mentioned the high rate of signal transmission that may be utilized and the absence of all mechanical or moving parts requiring maintenance and adjustment. In many cases where repeaters using mechanical relays are employed, it is often necessary to bias the receiving relay in one direction due to the transmitting relay being biased in the other direction, which adjustments may be marginal and difficult to maintain. In any event, a repeater employing mechanical relays requires continual supervision and maintenance, which is avoided by the present invention. Furthermore, in the described repeater incoming signals are received as a voltage across a series resistor in a line circuit so that there is no inductance in the line as in the case of a repeater employing mechanical relays having coils in the line circuit. In this manner the distortion resulting from additional inductance in the line circuit is avoided.

The principles embodied in the repeater shown in Fig. 1 may be applied to systems utilizing polar or two-element (positive and negative) signals and may be embodied in repeaters associated with duplex circuits as well as in a single channel system such as illustrated in Fig. 1. Fig. 2 shows a repeater adapted for repeating and regenerating polar signals from one duplex line L3 to a second duplex line L4 and vice versa.

The duplex channel L3 is of the bridge type having two resistors **60** and **61** connected between the line circuit and the artificial line. Thus the polar signals received over the "west" line circuit appear as opposite voltages across the outer terminals of the series resistors **60** and **61**, whereas the signals transmitted from the repeater "west" are applied to the midpoint of the bridge through the conductor **63** and have no effect upon the total potential drop across the two resistors. In a similar manner the duplex system associated with the line L4 comprises resistors **64** and **65** to the midpoint of which is connected conductor **66** for repeating signals from the repeater "east."

The operation of the repeater shown in Fig. 2 is similar in most respects to that shown in Fig. 1. The discharge device or primary amplifier tube **70**, which may be of the 6J7 type as shown, is normally conducting during rest or marking conditions during which it is assumed that positive potential impressed upon the control grid of said discharge device **70** maintains a current flow in the output circuit of said device. Consequently, the drop of potential across a resistor **71** in said output circuit thereof maintains the first control grid of the space-discharge device or vacuum tube **72**, for example of the 6L7 type, negative, thereby interrupting the flow of alternating current from the source **73** to the transformer **74** and the second control grid from appearing in the output circuit of the discharge device **72**. However, when a spacing signal is received and the polarity of the signal potential across the bridge of the duplex circuit is reversed, the control grid of the discharge device **70** becomes negative, the potential drop across the resistor **71** is reduced and the discharge device **72** becomes conductive to alternating current from the source **73**. The flow of alternating current through the primary winding of the transformer **77** in the output circuit of the discharge device **72** generates a direct current potential across the terminals of the resistor **78** which is connected in series with a double-wave rectifier tube **79**, for example of the 6H6 type, to the secondary winding of said transformer **77**. The potential drop across resistor **78** is smoothed by the filter circuit **80** and impressed upon the control electrode of the space-discharge device **82**. The discharge device **82** is normally conductive during the rest or marking condition, but is biased to cut-off by the potential drop in the resistor **78** when spacing signals are received over the line L3. The discharge devices **82** and **85**, which may be of the 6L6 type, jointly control the polarity of the signals impressed upon the line L4 at the repeater, as will be explained.

It will be apparent that as long as the space-discharge device **82** is conductive, a path of low resistance is provided from negative battery through the cathode and anode of the discharge device **82**, the resistor **83**, the conductor **66** and the resistor **64** connected to the line L4. In this case it will be seen therefore that as long as positive or marking conditions persist on the line L3, the line L4 is maintained negative so that the repeater effects a reversal of the character of the signals, positive marking signals being transposed into negative marking signals. Similarly when a spacing signal is received over line L3 applying negative potential to the grid of the amplifier tube **70**, as described above, the space-discharge device or tube **72** is biased to cut-off thereby disconnecting the negative battery associated with the cathode of said tube from the line L4 and said line is connected through a cathode and anode of the space-discharge device or tube **85** to positive battery. The tube **85** is non-conductive as long as the line current flows through the resistor **83** and the cathode-anode circuit of the tube **82** since the drop in potential in the resistor **83** biases the control electrode of the tube **85** to a negative potential with respect to its cathode. In this manner the marking potential on the line L4 is discontinued and positive or spacing potential applied for the duration of the negative spacing signal received over the line L3.

It is not necessary to reverse the polarity of the regenerated signals unless desired as the connections of the line L3 and the artificial line associated therewith may be reversed if desired in order to invert the response of tube **70** to the polarity of the received signals. In a similar manner if a reversal in the polarity of the signals corresponding to marking and spacing conditions in the line L4 is desired, the connection of the preliminary amplifier tube **86** to the outer terminals of resistors **64** and **65** may be reversed in order to render the tube responsive to signals of the opposite polarity or the connections to the line L4 and the corresponding artificial line AL may be reversed as described above.

The bottom half of the repeater shown in Fig. 2 corresponds precisely to the upper half of said repeater, the tubes **86**, **87**, **88**, **89** and **90** corresponding in arrangement and function to the tubes **70**, **72**, **79**, **82** and **85**, respectively. It will be apparent that this portion of the repeater is adapted to repeat and regenerate signals received over the line L4 to the line L3 in the same manner as the upper half of the repeater repeats signals from the line L3 to the line L4.

Fig. 3 illustrates how the repeater shown in Fig. 2 may be split and utilized as a terminal set with the tubes **70**, **72**, **79** and **82** being connected to the line L3 in exactly the same manner as shown in Fig. 2. The printer **95** is connected to be operated by the make-and-break signals in the output circuit of the tube **82**, the polar signals received over the line L3 being converted into make-and-break signals, and regenerated by the elements of the terminal set in the same manner as in the repeater. A transmitter **96** is shown associated with the line **L3** for transmitting polar signals over said line. In view of the similarity between the elements of the terminal set shown in Fig. 3 and the repeater shown in Fig. 2, it is believed that no further description of the terminal set is necessary.

It will be apparent that the described signal repeating and regenerating means, having no moving mechanical elements, is operative at almost unlimited transmitting rates and requires no adjustment or maintenance. It is operative to regenerate the wave shape of high-speed printer signals, which are usually substantially square-topped waves, and correct the distortion resulting from the characteristics of the line circuit and from interference. The characteristics of a repeater embodying the invention are thus of practical value.

Various modifications of the specific systems shown and described for the purpose of explaining the invention will occur to those skilled in the art and may be made without departing from the scope of the invention as set forth in the appended claims.

I claim:

1. In a telegraph system, two lines, means for impressing code telegraph signals on one of said lines and a repeater for relaying said signals to the other line, said repeater comprising an oscillation generator, a thermionic relay having input and output circuits, a rectifier having its output circuit connected to said other line, a connection of variable impedance between said oscillation generator and said rectifier, said variable impedance connection comprising a mixer tube having two control electrodes or grids, one connected to said oscillation generator and the other connected in the output circuit of said thermionic relay, means to impress said code signals on the input circuit of said thermionic relay, and means including said thermionic relay for varying the impedance of said connection to impress signals through said rectifier on said other line corresponding to those impressed on said thermionic relay.

2. In a telegraph system, two lines, means for impressing high-speed direct current printer signals on one of said lines and a repeater for relaying said signals to the other line, said repeater comprising an oscillation generator of relatively high frequency compared to the frequency of said signals, a vacuum tube relay provided with a cathode, an anode and two control electrodes, input and output circuits for said tube associated with the respective lines, said input circuit including one of said control electrodes and a connection from said oscillation generator to the other of said control electrodes.

3. In a telegraph system, a line, means for impressing high-speed direct current printer signals on said line and means for regenerating said signals, said last-mentioned means comprising a space-discharge device provided with a cathode, an anode and two control electrodes, an oscillation generator connected to one of said control electrodes, means for impressing said printer signals on the other control electrode and thereby driving said space-discharge device from beyond cut-off to the condition of normal space-current flow with each signal and means for rectifying the output of said space-discharge device.

4. In a telegraph system, two single-channel circuits adapted to transmit signals in only one direction at a time, means for impressing marking and spacing signals on both of said circuits and a two-way repeater adapted to repeat signals from either of the said circuits to the other circuit, said repeater comprising a source of alternating current, means for rectifying said alternating current and applying the rectified current to either circuit in accordance with signals received over the other circuit and means responsive to the reception of spacing signals at the repeater for locking out the repeater with respect to transmission in the opposite direction from which said spacing signals are to be transmitted.

5. In a telegraph system, two lines and a repeater for repeating and regenerating signals from one of said lines to the other line, said repeater comprising a source of alternating current, rectifier means and means for controlling the connection of said alternating current source and said rectifier means to either of said lines in accordance with signals received over the other line.

6. In a telegraph system, a line, means for impressing high-speed direct current printer signals on said line, receiving means and means connected to said line and said receiving means for regenerating said signals, said last mentioned means comprising an oscillation generator of relatively high frequency compared to the frequency of said signals, a space-discharge device of the mixer type provided with a cathode, an anode and two control electrodes, a connection between one of said control electrodes and said line, a connection between the other of said control electrodes and said oscillation generator, and a connection between the cathode-anode circuit of said device and said receiving means.

7. In a telegraph system, a line, means for impressing high-speed direct current printer signals on said line, receiving means responsive to said signals, a source of alternating current, and a space-discharge device between said line and said receiving means, said space-discharge device being provided with a cathode, an anode and two control electrodes, one of said control electrodes being connected to said line and the other to said source of alternating current, input and output circuits for said space-discharge device including said one of said control electrodes connected to the line and said anode, respectively, and means whereby alternating current signals are generated from said source in the output circuit of said space-discharge device corresponding to the direct current printer signals in said line.

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