June 23, 1931. R. V. MORGENSTERN 1,811,824

VACUUM TUBE REPEATER AND TERMINAL SET FOR SUPERPOSED TELEGRAPH SYSTEMS

Filed Feb. 20, 1930 2 Sheets-Sheet 1

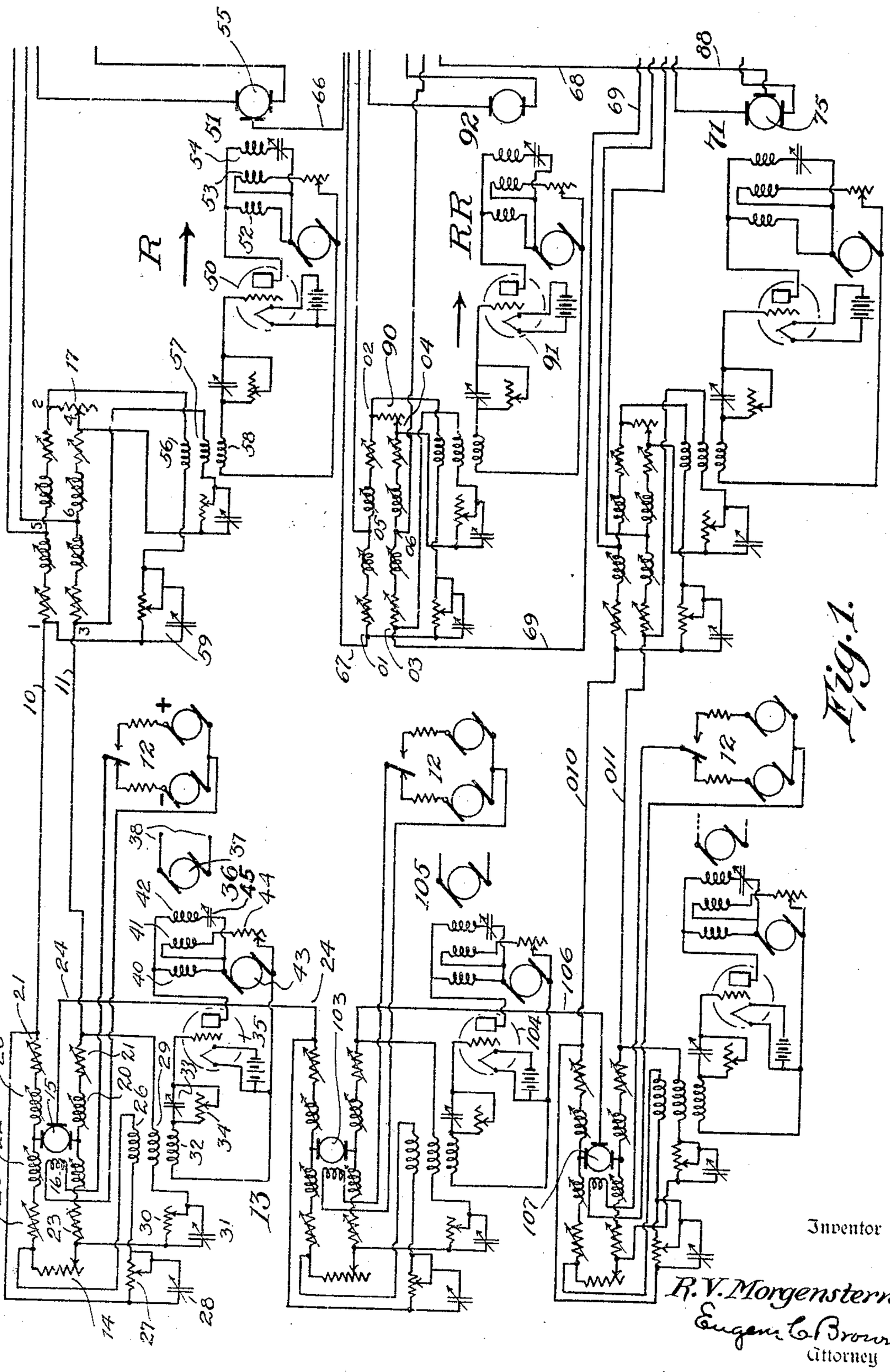

Fig. 1.

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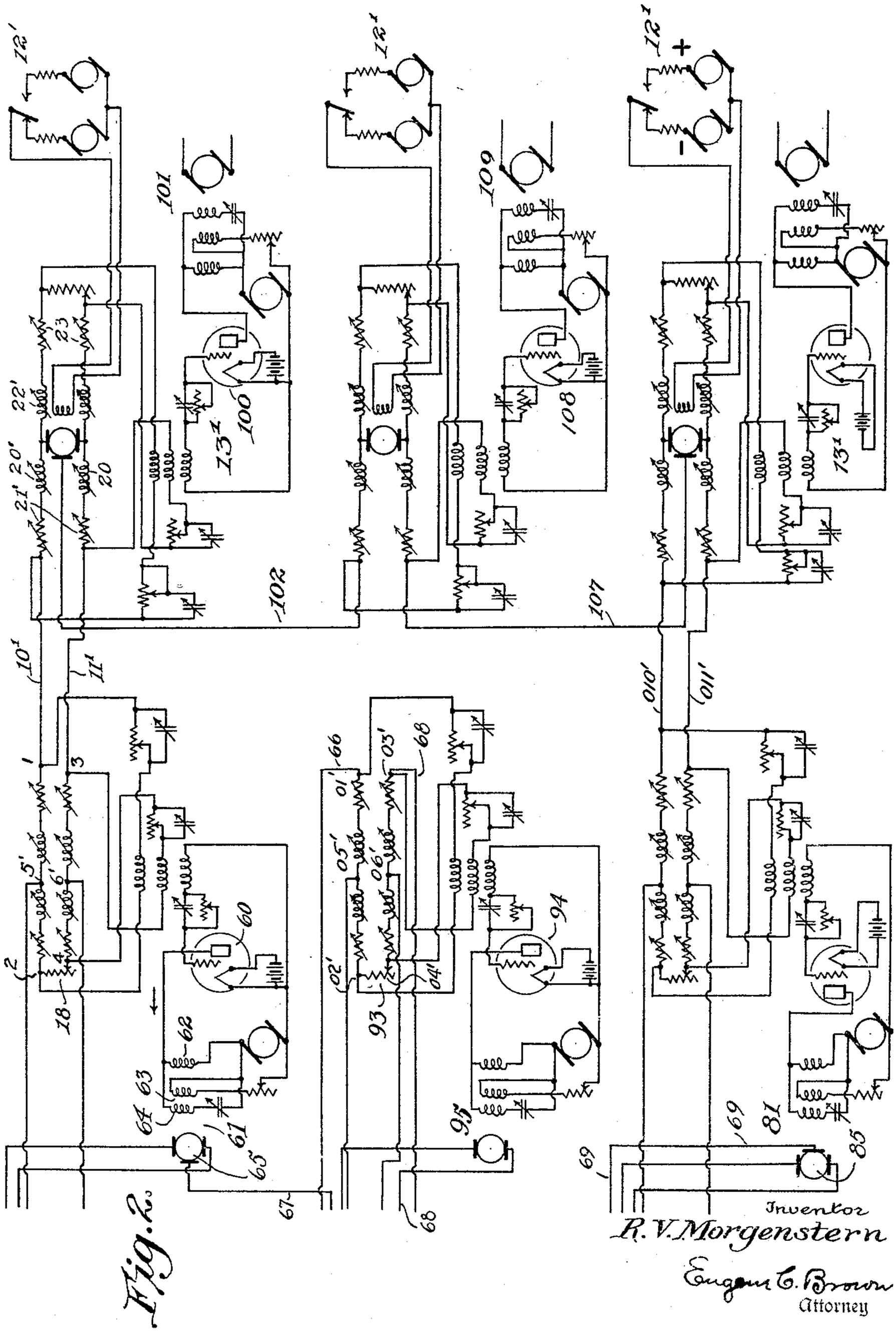

Fig. 2.

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UNITED STATES PATENT OFFICE

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VACUUM TUBE REPEATER AND TERMINAL SET FOR SUPERPOSED TELEGRAPH SYSTEMS

Application filed February 20, 1930. Serial No. 430,075.

This invention relates to telegraph circuits and to novel apparatus therefor comprising vacuum tube repeaters and vacuum tube terminal sets.

In particular it relates to a complete superposed system including terminal sets and repeaters showing the application of a vacuum tube arrangement to superposed systems.

More specifically, it relates to a superposed system in which the terminal sets or the repeaters, or both, for the side circuits or the superposed circuits, or both, of a superposed telegraph system, are arranged to provide amplification of the signal currents by dynamo electric devices, or generators, which are excited and controlled by the amplified currents in the output circuit of a three electrode thermionic vacuum tube the input circuit of which is supplied with signal current.

The invention involves a novel method of providing for duplex operation over the metallic circuits or the superposed circuits, or both, by means of bridges, the elements of which are designed to reshape the wave form of the signal current supplied to the input circuit of the vacuum tube in the terminal set or repeater.

The invention also involves a method of compensating in the input circuit or output circuit, or both, of the vacuum tube, for the distortion of the received signal wave which may result from unequal attenuation during transmission of signal currents of different frequencies.

The invention also relates to the specific method of connecting the superposed circuit terminal sets and repeaters to the metallic circuit conductors and their associated terminal sets and repeaters, so that duplex operation may be carried on over each metallic circuit and over the superposed circuit without interference between the superposed circuit and either metallic circuit, or between the transmissions in opposite directions upon the superposed circuits or upon either metallic circuit.

Other objects and results of this invention will appear from the following description when read in connection with the accompanying drawings, the two sheets of which, comprising Figs. 1 and 2, are designed to be matched end to end and to illustrate the principles of the invention applied to a superposed system.

The line conductors 10, 11 and 10′, 11′ are arranged in the usual manner for duplex metallic circuit transmission by apparatus at the terminal and repeater stations which is specially designed in accordance with this invention to permit the superposition of an additional circuit thereon. The terminal set for the line conductors 10, 11 comprises a transmitting means or transmission path indicated diagrammatically at 12 and a receiving means or receiving path indicated generally at 13. An artificial line 14 is arranged to balance the line 10, 11 so that the transmitting and receiving paths shall be conjugate with respect to one another, whereby side circuit transmission may be carried on in both directions without interference at the terminal set.

The terminal set for the line conductors 10′, 11′ may duplicate that for line conductors 10, 11. Duplex transmission is provided between the two terminal sets by way of a two-way repeater station indicated generally at R. For this purpose the line conductors 10, 11 are balanced at the repeater station by an artificial line 17 and the line conductors 10′, 11′ by an artificial line 18, in a well known manner, to provide two mutually conjugate paths extending from conductors 10, 11 to conductors 10′, 11′ through vacuum tube repeater apparatus to be described hereinafter.

A second metallic circuit is indicated as comprising similar terminal sets and repeater.

The transmitting means 12 of the metallic circuit terminal set comprises a generator the armature 15 of which is connected to the line conductor 10 through inductance 20 and resistance 21 in series, and to line conductor 11 through similar inductance and resistance in series. In like manner, the armature 15 is connected to the conductors of artificial line 14 through inductances 22 and resistances 23. The inductances 20, 22 and resistances 21 and 23 may be, and preferably are, variable, for a purpose which will be explained hereinafter.

The terminal set for the superposed circuit is connected to the line conductors 10, 11 by a conductor 24 extending to the midpoint or electrical center of the armature 15 of the transmitter generator. The details of the transmitting means 12 are not shown, but it is to be understood from the diagrammatic showing that the numeral 12 represents a transmitter comprising means for applying to the field winding of the generator having the armature 15 positive and negative currents of suitable wave form.

The receiving means at the metallic circuit terminal station comprises a bridge including four arms in each of which is included an adjustable inductance and an adjustable resistance. The inductive portion of the bridge consists of the four tapped coils 20, 20, 22, 22 wound on a common core. The arms of the bridge are connected together in pairs to form a pair of common points which are later referred to as "split points" of the bridge. One arm of each pair is connected, as shown, in series with a line conductor 10 or 11, and one arm in series with artificial line 14. The exact design of artificial line 14 is immaterial providing that its network can be correctly adjusted to balance the real line and distant terminal apparatus over the frequency range in which it is desired to work.

Across each pair of bridge arms 20, 21, 22, 23 is connected a primary coil of a transformer having a common core and a single secondary. The primary 26 has connected in series with it a condenser 28 shunted by a resistance 27, both condenser and resistance being variable. The primary 29 has connected in series with it, similarly, a variable condenser 31 and variable resistance 30. The primary coils 26 and 29 are connected in opposition to each other as viewed from a given point on the bridge, and these primaries are identical, that is, they have the same number of turns and occupy the same relative position on the core. Likewise condensers 28 and 31, and resistances 27 and 30, are identical.

The secondary 32 of the transformer is connected to the input circuit of a vacuum tube 35, which, as illustrated, is of the three element thermionic type. In series with the secondary 32 in the grid circuit of the vacuum tube is a variable condenser 33 and variable resistance 34. The function of condensers 28, 31 and 33 and their associated resistances is obviously to shape the wave form of the incoming signal wave.

The output circuit of vacuum tube 35 contains the field coils of a generator 36 the armature 37 of which is connected to the circuit 38 of a terminal relay. As illustrated, this generator has three windings, 40, 41 and 42 of equal number of turns and preferably though not necessarily wound parallel.

Winding 40 is connected directly in series with the plate filament or output circuit of the vacuum tube 35. The second winding 41 is connected to the same source of potential 43 used to supply plate current through a variable resistance 44. Windings 40 and 41 are connected in opposition to each other. Winding 42 is also connected in series with the output circuit of the vacuum tube but included in the connection is a condenser 45.

The operation of the metallic circuit terminal set is as follows: Suppose, to start, that there is no signal on the line. The potential across the input circuit of tube 35 will then be zero. There will be a certain plate current known as zero grid current flowing through the field winding of the generator tending to set up a magnetic flux and to cause a voltage to be produced across the armature 37 of the generator. The resistance 44 is adjusted so that the same current flows in winding 41 of the generator as flows in winding 40, and since these windings are connected in opposition to each other there will be no generator field flux and hence no armature voltage.

Now assume that a signal is incoming from the line conductors 10, 11 to the input circuit of vacuum tube 35 through the bridge arms including inductances 20, 22 and resistances 21, 23. All of the arms must be adjusted to have the same final values of inductance and resistance. When the correct values of inductance and resistance and the correct relations between these two have been obtained the bridge will act as a shaping device to correct for distortion on incoming signals.

The received signal currents flow through the primaries 26 and 29 and their associated correcting networks in directions such that their effects are additive with respect to the secondary 32. Since the function of the networks 27—28 and 30—31 is to provide further shaping where necessary, it is obvious that they may be omitted if desired. The values of the condensers and their shunt resistances may be adjusted to fit the inductances of their associated primaries.

Let it be assumed that the voltage induced in the secondary 32 and applied across the grid-cathode circuit of vacuum tube 35 is such as to make the grid more negative. This will cause a decrease in current in field winding 40 of the generator, while the current through winding 41 will not be changed. A field flux will consequently be set up in a direction to send a negative current from the armature 37 over the path 38 to the terminal relay, not shown. If the incoming signal is positive the current through winding 40 will predominate over that of winding 41, and in consequence positive line current will be transmitted from the armature of the generator.

The third field winding 42 which is con-

nected in parallel to winding 40 through adjustable condenser 45 performs the very important function of signal shaping. By proper adjustment of condenser 45 in relation to the inductance of the field winding 42 the current through this portion of the field circuit can be made to increase as the frequency increases. In consequence the armature voltage will increase as the signal frequency increases. Since the effect of a line is to attenuate the high frequency signals to a greater extent than the low frequency, the final effect of increasing the armature voltage with an increase in frequency is to compensate for the unequal attenuation of the line, so that the signals arrive at the terminal relay as if they had all been attenuated equally in passing over the line.

The effectiveness of this third portion of the field circuit will depend largely upon its ratio to the total impedance of the circuit of the tube, and so a tube with a low plate impedance should in general be employed.

Signals originating at the metallic circuit terminal set are applied to the line 10, 11 and to the artificial line 14 at the terminals of the armature 15 of the transmitter-generator by way of the four bridge arms. Because of the balanced condition of the bridge, voltages induced in the armature 15 of the transmitter-generator will have no effect on the input circuit of vacuum tube 35, and will therefore cause no signaling voltages in the armature 37 of the generator connected to the circuit of the terminal relay. Accordingly signals originating at the terminal set will not cause operation of the terminal relay of the same set.

It is obvious that the terminal transmitter may if desired be of the same type as that which transmits the received signals over the path 38 to the terminal relay. That is, the armature 15 may be the armature of a generator, the field of which is energized from the plate circuit of a vacuum tube like tube 35. The generator may have a signal shaping winding designed to regulate the magnitude of the voltage induced in the armature 15 so that it will increase when the signal frequency increases.

The repeater station R comprises two one-way transmission paths designed for transmissions in opposite directions, in the usual manner. One path includes a vacuum tube 50 and its associated generator 51, the latter having field windings 52, 53, 54 and an armature 55 connected to supply amplified signaling currents from line 10, 11 to the split points of the bridge between the line 10′, 11′ and its balancing artificial line 18. The other path includes a vacuum tube 60 and its associated generator 61, the latter having field windings 62, 63, 64 and an armature 65 connected to supply amplified signaling currents, from the line 10′, 11′, to the split points of the bridge between the line 10, 11 and its balancing artificial line 17.

The vacuum tubes are connected in input relation to their respective lines by bridge units similar to that described in connection with the terminal set for line 10, 11. These bridge units are similar in construction and a description of one will suffice for all. Each bridge unit comprises four arms and three pairs of connection points or terminals. The line conductor terminals bear the numerals 1, 3, conductor 10 being connected to terminal 1 and conductor 11 to terminal 3. The artificial line terminals are marked 2, 4. The third pair of terminals 5, 6 are the split points of the bridge and in the particular bridge under discussion they lead from the armature 65 of the generator 61, which repeats the signals received from line 10′, 11′.

Signals received at the repeater from line 10, 11 are transmitted to the vacuum tube 50 by the primaries 56 and 57 and the secondary 58 in the grid circuit of tube 50. The primary 56 is connected in series with a signal shaping network 59 to the terminals 1 and 2 of the bridge. The primary 57 is connected in series with a similar and identical signal shaping network to the terminals 3 and 4 of the bridge, and is wound opposite to primary 56 as viewed from a given point on the bridge. A signal shaping network may be connected also in the grid circuit of tube 50.

The repeater R serves for the amplification of signals transmitted in both directions over the metallic side circuit. In order that superposed signals may also be amplified, a connection is made between line conductors 10 and 11 in parallel and line conductors 10′ and 11′ in parallel through a superposed circuit repeater RR. This repeater as illustrated has the same general construction as the metallic or side circuit repeater R. That is, it comprises a pair of one-way paths, each including a generator controlled by an exciting field in the plate circuit of a three-electrode thermionic vacuum tube, and each balanced by a bridge unit and artificial line to be conjugate with respect to the other path.

The repeater RR is associated with the metallic circuit conductors 10, 11 and 10′, 11′ in a novel manner by means of conductors 66 and 67 which connect to the armatures 55 and 65, respectively, of the repeater-generators 51 and 61. In similar manner the repeater RR is associated with the other pairs of line conductors 010, 011 and 010′, 011′ by means of conductors 68 and 69 which connect to the armatures 75 and 85 respectively of the repeater-generators 71 and 81.

The conductors 67 and 69 connect to the line terminals 01 and 03 of a superposed circuit bridge unit similar to that forming part of the metallic circuit repeater R. The conductors 66 and 68 connect to the line terminals 01′

and 03′ of another superposed circuit bridge unit. These two superposed bridge units with their balancing artificial lines 90 and 93 are arranged to provide conjugate repeating paths one of which extends through from conductors 69 and 67 and its bridge unit to vacuum tube 91 and its repeating generator 92, the latter having its field windings in the plate circuit of the vacuum tube 91. The armature of generator 92 is connected to the terminals 05′ and 06′ of the other bridge units and thence by conductors 66 and 68 and generators 51 and 71 to the superposed circuit including conductors 10′, 11′ and 010′, 011′ in parallel.

Similarly, the conductors 66 and 68 lead to the line terminals 01′ and 03′ of one of the superposed circuit bridge units and through vacuum tube 94 and its associated repeater generator 95 to the terminals 05 and 06 of the other bridge unit, and thence by conductors 67 and 69 to the superposed circuit including conductors 10, 11 and 010, 011 in parallel.

The side circuit terminal set, and the repeaters for side circuit and superposed circuit have been described in detail. The terminal set for the superposed circuit is similar to that described for the side circuit, and need not be described in detail.

It is obvious that there will be four terminal sets for the side circuits, two terminal sets for the superposed circuit, at least two side circuit repeaters and at least one superposed circuit repeater. Of these sets and repeaters each is illustrated as comprising a dynamo electric unit in the form of a generator having its field winding energized by the amplified output of a signal-excited three electrode thermionic vacuum tube. The input circuit of the vacuum tube is in each case supplied from a pair of terminals of a bridge made up of four arms, each arm consisting of two portions, one composed of inductance and the other a resistance, each of which is adjustable so that all the arms shall have the same final values of inductance and resistance. The inductive portions of each bridge are wound on a common core. In addition to the adjustment which makes the four arms of the bridge identical, the values of inductance and resistance and their relations to each other are adjusted so that the bridge will act as a shaping device for the signal current supplied to the grid circuit of the amplifying tube. When the resistances and inductances are adjusted correctly, the vacuum tube produces increased amplification for increased frequency, and compensate to some extent for the greater attenuation at increased frequency which the signal current suffers during transmission over the line. Where additional correction is necessary or desirable, each or any of these sets or repeaters may include signal shaping networks in the circuit connected between the bridge and the grid circuit of the amplifying tube, or in the grid circuit itself, or in the field of the generator, which forms part of the output circuit of the amplifying tube.

The operation of the complete system may be described as follows:—

If the artificial line 14 balances the line 10, 11 properly and if the inductances 20 and 22 are identical and the resistances 21 and 23 also identical, then signals outgoing from the armature 15 of the terminal transmitter will produce equal voltage drops across 20—21 and 22—23. Accordingly there will be no tendency for current to flow through either primary 26 or 29, and hence no flux in the core to set up a voltage in the secondary 32 of the transformer. With no voltage applied across the secondary 32 the vacuum tube 35 is not excited. If the field windings 40 and 41 in the output circuit are adjusted to be equal but opposite in their effects, the resultant field with no grid excitation of tube 35 is zero, and no voltage is induced in the armature 37 of generator 36. Hence signal current applied to line conductors 10 and 11 from the terminal transmitter will have no effect on the terminal relay connected in circuit with generator 36.

Since the conductor 24 leading to the superposed circuit terminal set is connected to the midpoint of armature 15, this conductor is neutral with respect to currents induced in the armature 15. Hence outgoing signal current from the terminal transmitter of the metallic or side circuit will have no effect on the terminal relay of the superposed circuit.

It may be noted that the bridge inductances 20, 20 22, 22 are so wound on a common core that the resultant flux produced by current induced in the armature 15 is zero. For metallic circuit outgoing signals therefore this bridge acts merely as a resistance.

It is otherwise, however, with the bridge at the input side of the repeater R. Incoming signal current from the metallic or side circuit terminal set flows through the arms of the repeater bridge in such a way that the fluxes due to the four bridge inductances on the common core add. The inductances and resistances of the bridge cooperate to reshape the incoming wave as it is impressed on the vacuum tube amplifier 50, so that the tube will produce a relatively greater amplification for those frequencies which have suffered greater attenuation during transmission over the line 10, 11.

The incoming signals will produce a difference in potential between points 1 and 2 and also between points 3 and 4 of the bridge. Furthermore, points 1 and 3, and 2 and 4 will have opposite relationships with respect to each other, that is, if point 1 is negative with respect to point 2, point 3 will be positive with respect to point 4. The current flow

through the two primaries 56 and 57 of the transformer will tend to set up flux in the same direction in the core upon which they are wound. Therefore the effects of these primaries on the secondary 58 are additive, and a voltage is impressed across the grid circuit of the vacuum tube. In this applied voltage the higher frequencies are accentuated by reason of the correcting or reshaping action of the resistance and inductance of the repeater bridge, and by the additional correcting action of the shaping networks in series with the primaries 56 and 57 and secondary 58 of the vacuum tube input transformer if these additional networks are used.

The signal voltage, thus reshaped, produces alternate increases and decreases in the normal potential of the grid of the tube 50, and as a result, corresponding amplified variations in the current flowing through the winding 52. The current flow through the winding 53 does not change, and the resultant flux due to the opposed action of the constant field 53 and the varying field 52 thus varies in accordance with the variations in voltage of the reshaped signal voltage applied to the grid of the tube. An additional variation in the field is produced by the winding 54, which introduces variations in accordance with the frequency of the signal wave. As a result of the combined effect of the windings 52, 53 and 54 there is produced in the armature 55 of the generator 51, an amplified current which varies substantially in accordance with the received signal wave, but which has an improved wave form due to the correcting action of the various networks introduced into the repeater for that purpose.

The amplified, corrected signal current is applied from the terminals of armature 55 to the split points 5′, 6′ of the repeater bridge on the output side of the repeater R. Due to the balanced condition of the bridge there is no tendency for current to flow through the primaries of the input transformer of vacuum tube 60. Hence no voltage is applied across the grid circuit of that tube and the generator 61 which is under control of tube 60 does not feed back the repeated signal current to the line 10, 11 in which it originated. In other words, there is no tendency of the repeater R to sing.

The metallic or side circuit signal current incoming at the repeater R produces no effect on the superposed circuit repeater RR because the conductor 67 leading to the repeater RR is neutral with respect to these incoming signal currents. Hence the vacuum tube 91 is unaffected by the side circuit signals. The amplified signal currents from the generator 51 of repeater R have no effect on the repeater RR, because the conductor 66 leading to that repeater is connected to the midpoint of the armature 55 of that generator, and is therefore neutral with respect to it. In other words, no voltage can be applied from the generator 51 across the input of vacuum tube 94 by way of the neutral conductor 66.

Thus, the supported circuit repeater is protected from interference due to side circuit signal currents because of the fact that both conductors 66 and 67 are connected to neutral points of the repeating elements or generators of the side circuit repeater.

To return to the amplified signal current which is applied from generator 51 to the line 10′, 11′: This current when received at the distant terminal set may be distorted but the inductance and resistance of the bridge effect at least a partial correction for the line distortion. The correcting networks in series with the windings of the input transformer for tube 100 aid in this correction. The positive and negative impulses applied to the grid of tube 100 cause the production in generator 101 of amplified positive and negative currents of corrected wave form which are applied to the terminal relay, not shown.

The side circuit signal impulses received at the distant terminal set do not affect the superposed circuit terminal relay since the superposed circuit conductor 102 leading to the superposed terminal set is neutral with respect to the received side circuit signal currents.

Side circuit transmission is carried on in a similar manner from the terminal set connected to line conductors 010 and 011 of the other metallic circuit, or, in the opposite direction, from the distant terminal set connected at the end of line conductors 10′, 11′ or that at the end of line conductors 010′, 011′. As has already been pointed out, duplex transmission may thus be carried on simultaneously over both metallic circuits without interference to the superposed circuit.

Consider now the operation of the system when a signal is transmitted over the superposed circuit:

Signals from the transmitter of the superposed circuit terminal set cause the production of a signal current in the armature 103 of the transmitter generator set which may be of any suitable type, if desired, of the vacuum tube type in which the field winding of generator 103 is in the output circuit of a vacuum tube. Current induced in armature 103 will have no effect on the vacuum tube 104 and hence no effect on the superposed circuit terminal relay, not shown. This terminal relay is in circuit with the generator 105 which is controlled by tube 104 in the manner described in connection with generator 36 and its associated tube 35.

Signal current from the superposed circuit transmitter is impressed across the conductors 24 and 106 and applied to the midpoints of the armatures 15 and 107 and thence

over the line conductors 10 and 11 in parallel and the line conductors 010 and 011 in parallel to the repeater RR.

The signal current flowing by way of conductor 24 to the bridge with which armature 15 is connected, impresses equal voltages across the terminals of the paths including primaries 26 and 29. The primaries 26 and 29 are connected in opposition to each other with respect to current from the superposed circuit. Hence there will be no flux set up in the core of the transformer and consequently no voltage in the secondary 32 of the transformer or across the grid circuit of tube 35. Thus current from the superposed circuit will not cause interference on the terminal set under discussion.

When signal current from the superposed circuit is received at the repeater station the voltage drop across the points 1 and 2 is the same as the voltage drop across the points 3 and 4, since the parallel paths for the superposed signal are identical. Furthermore, points 1 and 3 will have the same relationship, i. e. either positive or negative with respect to points 2 and 4. Since, therefore, the two primaries 56 and 57 of the input transformer are connected in opposition to each other between points 1 and 2, and 3 and 4, any current through these primaries will flow in opposite directions. Hence there will be no flux set up in the core of the transformer and consequently no voltage in the secondary 58 of the transformer. Thus current from the superposed circuit will not cause interference on the repeater set R.

The superposed signal current will, however, find a ready path through the two halves of the armature 65 of generator 61 to conductor 67 thence to the bridge on the input side of the superposed circuit repeater RR. This path is completed, obviously, by way of conductor 69 and the two halves of the armature 85 of generator 81 to the line conductors 010 and 011 in parallel.

The superposed signal current impressed across points 01 and 03 of the superposed circuit bridge by way of conductors 67 and 69 is reformed by the inductance and resistance elements of the bridge to compensate for the distortion suffered during transmission over the line. The bridge with its associated apparatus connected to conductors 67 and 69 functions with respect to superposed signals incoming over conductors 67 and 69 in generally the same manner as does the side circuit bridge with respect to side circuit signals incoming over conductors 10 and 11. The superposed signal current flows through the two primaries of the input transformer for tube 91 in directions such that their effects on the secondary are additive and the output circuit of tube 91 supplies to the field of generator 92 an amplified, corrected signal wave. The correction is provided by the bridge elements, the correcting networks in series with the windings of the transformer, and the third or correcting winding of the generator 92.

Amplified, corrected superposed signal currents are applied at points 05 and 06 of the superposed circuit bridge on the output side of repeater RR. Because of the conjugate relation of the two paths associated with this bridge these amplified signal currents have no effect on the vacuum tube 94 in the other path of the repeater, and thus singing of repeater RR will not occur.

The amplified superposed signal currents are transmitted by way of conductors 66 and 68 to the midpoints of the armatures 55 and 75 of the generators 51 and 71 respectively. Thence they are transmitted over conductors 10′, 11′ in parallel and over conductors 010′, 011′ in parallel to the distant terminal set for the superposed circuit.

The amplified current supplied over conductor 66 to the points 5′ and 6′ of the bridge connected to conductors 10′ and 11′ will not cause interference in the repeater R for the following reason: The potential drop caused by the superposed circuit between point 1 and point 2 is the same as that between 3 and 4, both in value and direction. Accordingly, any current flow in the primaries of the transformer connected to tube 60 due to the drop through the bridge from the superposed circuit will be in such a direction in the two primaries that no flux will be set up and hence no voltage impressed upon the grid circuit of tube 60.

Thus current from the superposed circuit will not cause interference on the repeater set R either before or after its amplification by the repeater RR.

The side circuit repeater connecting line sections 010—011 and 010′—011′ is protected in the same manner from the effects of superposed signals either before or after their amplification by repeater RR.

It is obvious that in the same way superposed signals coming into the repeater RR from the opposite direction, that is, by transmission over lines 10′, 11′ and 010′, 011′, will be prevented from affecting the side circuit repeaters on the two metallic or side circuits. Accordingly the superposed circuit will not cause interference with the side circuit repeater sets.

Returning now to the amplified superposed signal current which is transmitted from repeater RR over the conductors 66 and 68 and the line conductors of the metallic circuits in parallel: The amplified current finds a ready path through the halves of the armatures of the side circuit transmitters and by way of conductors 102 and 107 to the superposed circuit bridge and the input transformer of tube 108. The various correcting networks reshape the distorted wave and it is amplified

and transmitted to the field winding of generator 109, the construction and operation of which may be the same as that of generator 36, already described in detail. The corrected, amplified current produced in the armature of generator 109 serves to operate the superposed circuit terminal relay, not shown.

For reasons which will be obvious, the superposed current will not interfere with the side circuit terminal sets at the distant ends of lines 10′, 11′ and 010′, 011′.

It will thus be evident that duplex transmission may be carried on over both side circuits and over the superposed circuit without interference between the various circuits or their associated terminal sets and repeaters. By the means disclosed provision is made for amplifying and reshaping the signal currents on either side circuit or on the superposed circuit by means which are effective only in the circuit for which it is intended. For example, the side circuit bridge unit comprising four identical inductances on a common core and four identical resistances, serves to reshape the incoming signal wave to correct for line distortion, but it acts merely as a resistance, without inductive effect, with respect to the superposed circuit signals. A special superposed circuit bridge serves to correct the incoming superposed signals, and this bridge has no effect on the side circuit signals because it is connected in a conductor which is neutral with respect to the side circuit.

It will be noted that the superposed circuit repeater transmitting in one direction, from left to right in the figure, for example, is connected to the midpoints of the armatures of the metallic circuit repeaters which transmit in the opposite direction, i. e. from right to left in the example given. That is, superposed signal currents incoming from conductors 10, 11 in parallel are transmitted in parallel over the two halves of the armature of the generator 61, which itself supplies amplified signal currents incoming from the signal conductors 10′ and 11′ in series.

It will be obvious that, although only one repeater is shown, a plurality of repeaters may be supplied for amplifying the metallic circuit and superposed circuit signals at a plurality of points on the line.

Although the invention has been disclosed in connection with a circuit superposed on a pair of metallic circuits, it is obvious that it may be embodied in a grounded circuit as well.

Although but one form of vacuum tube set has been illustrated in the terminal sets and repeaters of the system, it is obvious that other forms may be used. It is within the limits of this invention to use for the terminal sets any of the various forms of vacuum tube sets disclosed in copending application of Ronald V. Morgenstern entitled "Repeaters for signaling circuits", Serial No. 426,676, filed February 7, 1930. The specific form of set illustrated in this application is shown also in Figure 1 of the copending application of Morgenstern & Teter Ser. No. 422,194, filed Jan. 20, 1930.

The type of vacuum tube repeater applicable to the system according to this invention is that particularly adapted for use where it is necessary or desirable that the direct current as well as the alternating current components of the telegraph signals originally transmitted shall be repeated.

It is within the limits of this invention to provide in the various terminal sets and repeaters, a generator of the type utilizing a small shunt field. It is to be understood that the diagrammatic showing of the generators in the drawings shall represent the use of such a shunt field where desired. The particular advantage of the use of such a shunt field is explained in connection with Figure 3 of the above identified copending application.

With transformer coupling, voltage applied to the input circuit of the vacuum tube will be applied only as long as the current through the primary of the transformer is changing. As soon as the steady state condition is reached there will be no potential applied to the grid filament or input circuit of the tube although there is a D. C. potential across the transformer primary. However, a small shunt field placed across the armature of the generator will generate a flux, which must of necessity be small but which will be sufficient to transmit a steady potential to the line connected across the generator.

The shunt field will continue to keep the outgoing potential of the same polarity, positive or negative, as the potential last applied to the grid of the tube. Suppose the last signal which impressed a potential across the grid filament circuit is of such a nature as to make the grid of the vacuum tube positive with respect to the filament. Then the shunt field will continue to keep the outgoing potential plus after the current through the primary of the transformer reaches a steady state and hence the voltage across the grid filament circuit of the tube has dropped off to zero.

If the next incoming signal applied potential which makes the grid of the vacuum tube negative with respect to its filament, the field coils of the generator included in the output circuit of the vacuum tube will overcome the shunt field and reverse the direction of the generated potential of the armature circuit, after which the shunt field will aid the field coils in the output circuit and when potential across the input circuit of the vacuum tubes drops off to zero will continue to apply negative to the outgoing circuit of the repeater.

It is to be understood also that the specific

form of repeater herein illustrated is not essential but that it is within the spirit of this invention to substitute therefor, or for any of the sets shown on the drawings, a set such as either of those disclosed in a copending application of Ronald V. Morgenstern entitled "Repeater systems", Serial No. 429,421, filed February 18, 1930.

The method of coupling the superposed circuit to the side circuit or circuits by way of the center tap of the armature of the transmitting generator is claimed broadly in a copending application of Ronald V. Morgenstern and Paul Teter, entitled "Superposed telegraph circuits", Serial No. 424,194, filed January 20, 1930.

I claim:

1. In a superposed telegraph system, a metallic circuit repeater comprising a dynamo electric unit, a superposed circuit repeater and a conductor connecting the superposed circuit repeater to the midpoint of the armature of said dynamo electric unit.

2. In a superposed telegraph system, a metallic circuit repeater comprising a vacuum tube repeater and generator having a field winding in the output circuit of said vacuum tube, a superposed circuit repeater and a conductor connecting the superposed circuit repeater to the midpoint of the armature of said generator.

3. In a superposed signal transmission system, a pair of metallic circuits, a circuit superposed thereon, a repeater comprising a dynamo electric unit connected in each metallic circuit, a repeater for said superposed circuit and means for connecting the superposed circuit repeater to the electrical center of the armature of a dynamo electric unit in each of said metallic circuits.

4. In a superposed signal transmission system, a pair of metallic circuits, two way repeaters in said metallic circuits each comprising a pair of one-way dynamo electric repeaters, a circuit superposed on said metallic circuits and a two-way repeater in said superposed circuit comprising a pair of one-way units with means to connect each one-way unit between the midpoints of the armatures of a dynamo electric repeater in each metallic circuit.

5. In combination in a superposed telegraph system a bridge comprising four identical arms connected in pairs, a metallic line connected between outer terminals of the pairs and a balancing line between the other outer terminals of the pairs, oppositely wound primaries connected across the terminals of the respective pairs, a vacuum tube amplifier coupled to said primaries, a generator having its armature connected across the common points of the arms and a transmitter connected to the electrical midpoint of said armature.

6. In combination in a superposed telegraph system, a bridge comprising four identical arms having their inner terminals connected together in pairs and comprising four identical inductances mounted on a common core, a transmission line and a balancing line connected symmetrically between the outer terminals of said arms, a signal transmitting path connected across the common points of said pairs, a superposed signal transmitter connected to the electrical midpoint of said path, the inductances being wound in series aiding relation for currents incoming over the conductors of said transmission line in series but in neutralizing relation for currents from said superposed signal transmitter.

7. In combination in a superposed telegraph system, a bridge comprising four identical arms connected in pairs to form a pair of common points, each arm comprising a resistance and an inductance, the inductances being wound on a common core in neutralizing relation with respect to side circuit and superposed circuit voltages applied at said common points.

8. In combination in a superposed telegraph system, a bridge comprising four identical arms connected in pairs between a transmission line and a balancing line to form a pair of common points, each arm comprising a resistance and an inductance, the inductances being wound on a common core in neutralizing relation with respect to voltages applied at said common points but in series aiding relation with respect to voltages from the conductors of said transmission line in series.

9. In combination in a superposed telegraph system, a bridge comprising four identical arms connected in pairs between a transmission line and a balancing line to form four terminals and a pair of common points, a vacuum tube having a pair of input circuits connected to said terminals, each arm of said bridge comprising a resistance and an inductance, the inductances being wound on a common core in neutralizing relation with respect to voltages applied at said common points but in series aiding relation with respect to voltages applied from said transmission line to said vacuum tube.

10. In combination in a superposed telegraph system, a pair of transmission lines, a pair of balancing lines, a pair of bridges each comprising four identical arms connected in pairs between a transmission line and its associated balancing line to form four terminals and a pair of common points, a one-way repeater path connected between the four terminals of one bridge and the common points of the other bridge, a one-way repeater path similarly connected between the common points of the one bridge and the four terminals of the other bridge, and a superposed circuit repeater connected to neutral points in the said one-way paths.

11. In combination in a superposed tele-

graph system, a pair of balancing lines, a pair of bridges each comprising four identical arms connected in pairs between a transmission line and its associated balancing line to form a pair of common points, a pair of repeater paths extending between said bridge each comprising a generator having an armature connected to the common points of one of the bridges and a connection from the electrical midpoint of said armature to a superposed circuit repeater.

12. In combination in a superposed telegraph system, a pair of transmission lines, a pair of balancing lines, a pair of bridges each comprising four identical arms connected in pairs between a transmission line and its associated balancing line to form four terminals and a pair of common points, a pair of repeater paths extending between the four terminals of one bridge and the common points of the other bridge, a vacuum tube and a generator in each path, with the field winding of the generator connected in the output circuit of the vacuum tube, and a superposed circuit repeater connected to the midpoints of the armatures of the generators.

13. In a superposed signal transmission system, a metallic circuit, a repeater for said circuit comprising separate repeating paths for signal currents transmitted over the metallic circuit in opposite directions, a repeater for the superposed circuit comprising one-way paths transmitting in each direction, each path including a portion of the metallic circuit repeater path transmitting in the opposite direction.

14. In a superposed telegraph system, a metallic circuit comprising two or more sections, an artificial line and a balancing bridge for each section arranged to provide a pair of one-way, conjugate paths between each two sections, a generator in each path having its armature connected to the split points of the bridge, and a connection from the electrical midpoint of one armature to a superposed circuit signaling set.

15. In a superposed telegraph system, a metallic circuit comprising two or more sections, an artificial line and a balancing bridge for each section arranged to provide a pair of one-way conjugate paths between each two sections, a generator in each path having its armature connected to the split points of the bridge, a repeater for the superposed circuit arranged for duplex operation by means of a superposed circuit bridge and means for establishing a connection from a terminal of said superposed circuit bridge to the split points of a metallic circuit bridge by way of the corresponding armature.

16. In a superposed telegraph system, a pair of metallic circuits each circuit comprising two or more sections, an artificial line and a balancing bridge for each section arranged to provide a pair of one-way conjugate paths between each two sections, a generator in each path having its armature connected to the split points of a bridge, a two-way repeater for the superposed circuit comprising superposed circuit artificial lines and bridges, and means for connecting the superposed circuit repeater to the metallic circuits, said means comprising conductors extending from the armature midpoints of the metallic circuit generators to the terminals of the superposed circuit bridges.

17. In combination in a superposed telegraph system, a bridge comprising four identical arms each including an inductance and a resistance, a metallic circuit transmitter connected to apply a signal voltage across the split points of the bridge, a superposed circuit transmitter connected to apply superposed signal voltage to said four arms in parallel by way of the split points of the bridge, a metallic circuit receiver connected across the outer terminals of said arms, the inductances of said arms mounted on a common core in series aiding relation with respect to signals incoming to said receiver.

18. In a superposed telegraph system, a metallic circuit repeater comprising a vacuum tube repeater and a generator having its field winding in the output circuit of said vacuum tube, means in circuit with said vacuum tube for reshaping the wave form of the incoming metallic circuit signal, a superposed circuit repeater, a conductor connecting the superposed circuit repeater to the midpoint of the armature of said generator and separate means in circuit with the superposed circuit repeater for reshaping the wave form of the incoming superposed signal.

19. A superposed telegraph system comprising a metallic circuit, artificial line and bridge therefor, a transmitter and a receiver connected for duplex operation by means of said bridge, means in said bridge for reshaping the metallic circuit signal current supplied to said receiver and means for transmitting superposed signal current to the conductors of said circuit in parallel by way of the said transmitter and the said signal shaping means.

20. A superposed telegraph system comprising a metallic circuit divided into a plurality of sections, means for balancing each section for duplex operation, terminal sets and repeaters for said metallic circuit each comprising dynamo electric units and means for superposing a circuit on said metallic circuit by way of the electrical midpoints of the dynamo electric units of said terminal sets and repeaters.

In testimony whereof I affix my signature.

RONALD V. MORGENSTERN.