Oct. 1, 1940. W. D. CANNON 2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 1

Fig. 1.

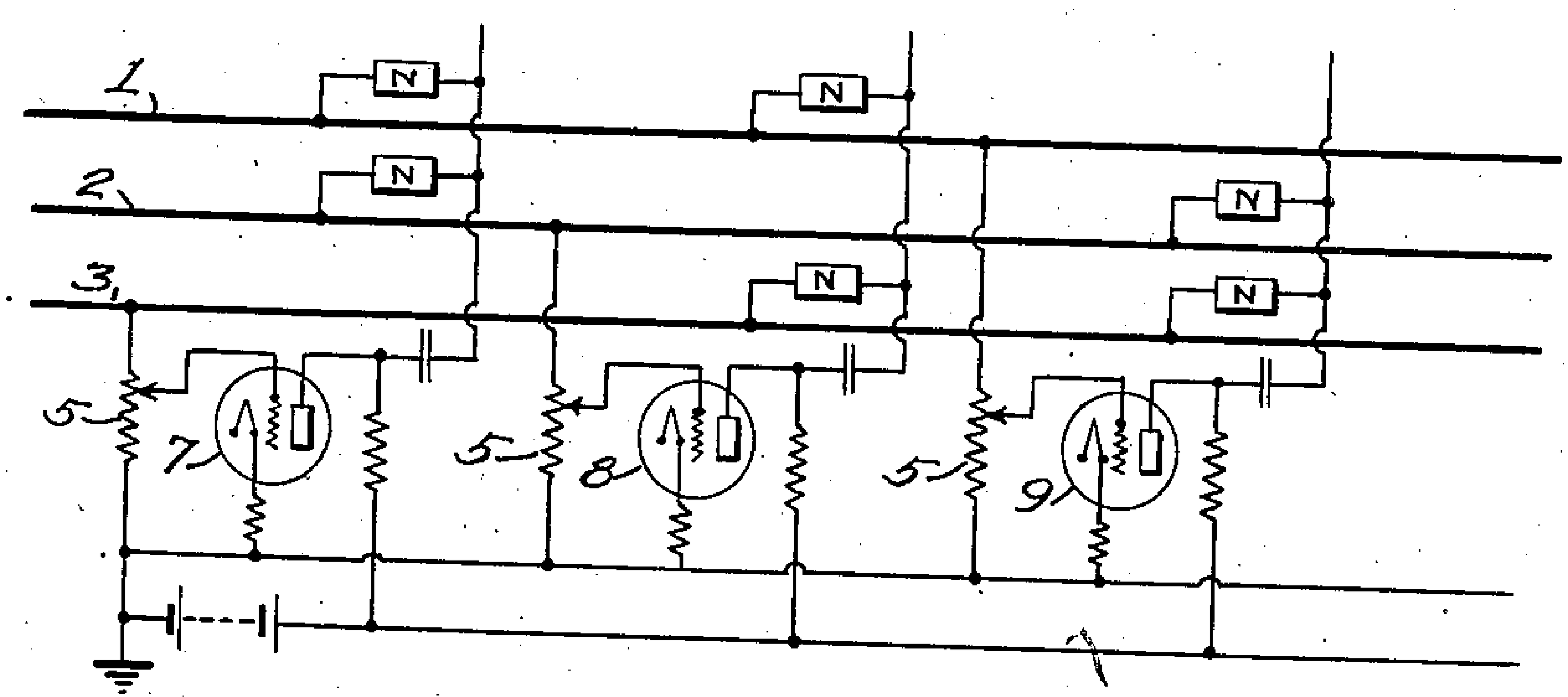


Fig. 1a

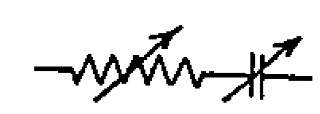


Fig. 2

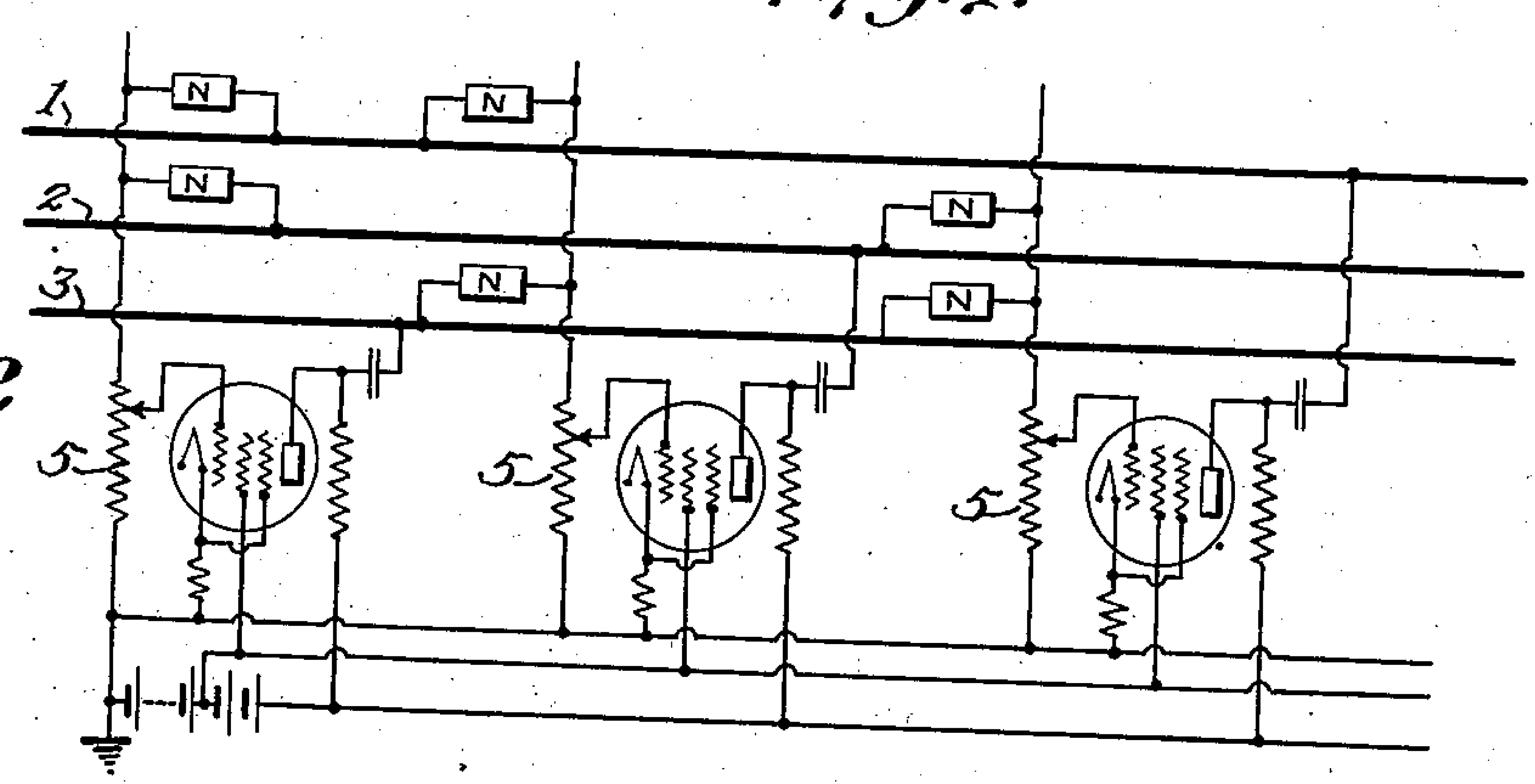
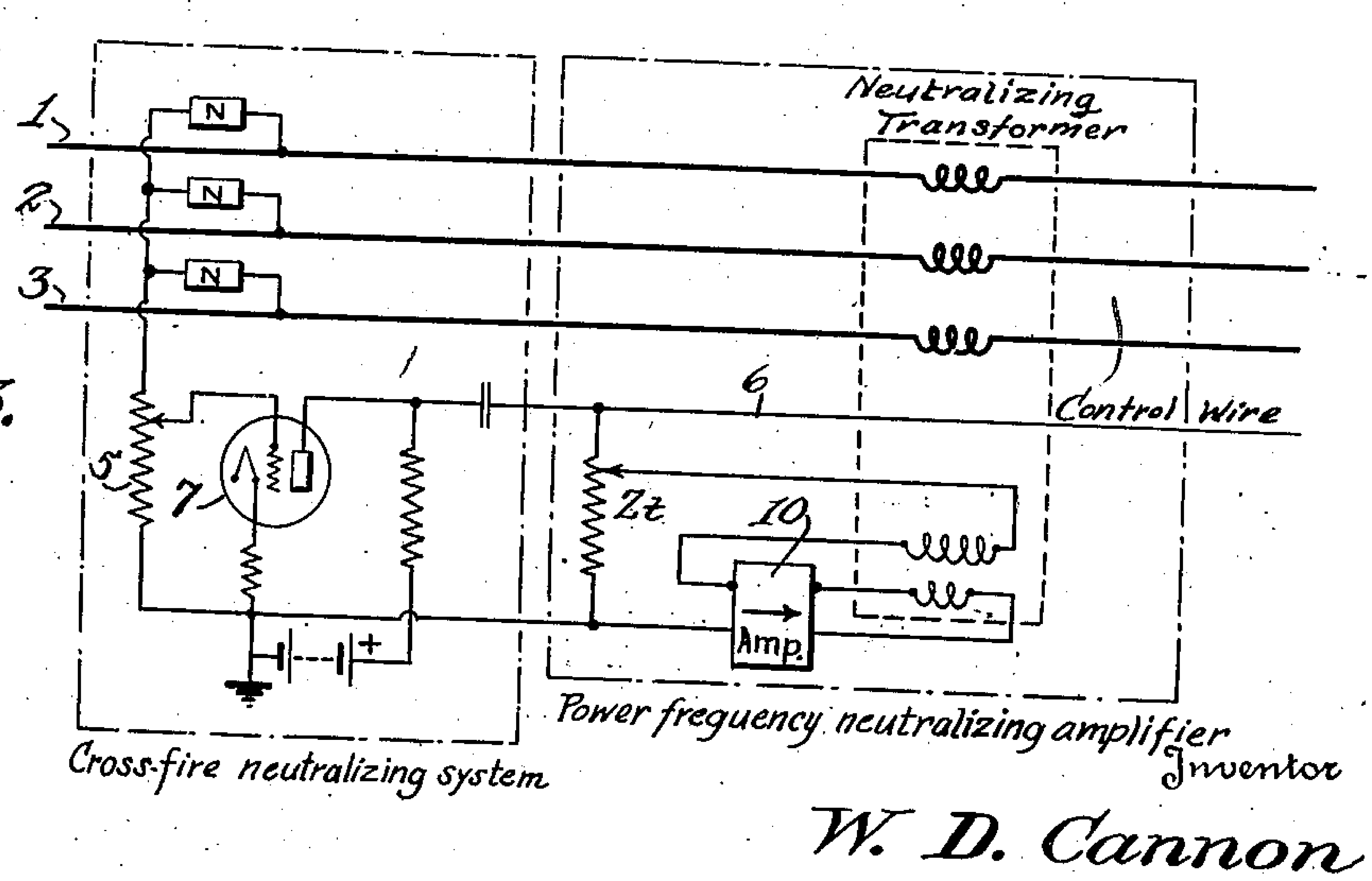


Fig. 3.



Inventor

W. D. Cannon

Eugene C. Brown

Attorney

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 2

Fig. 4.

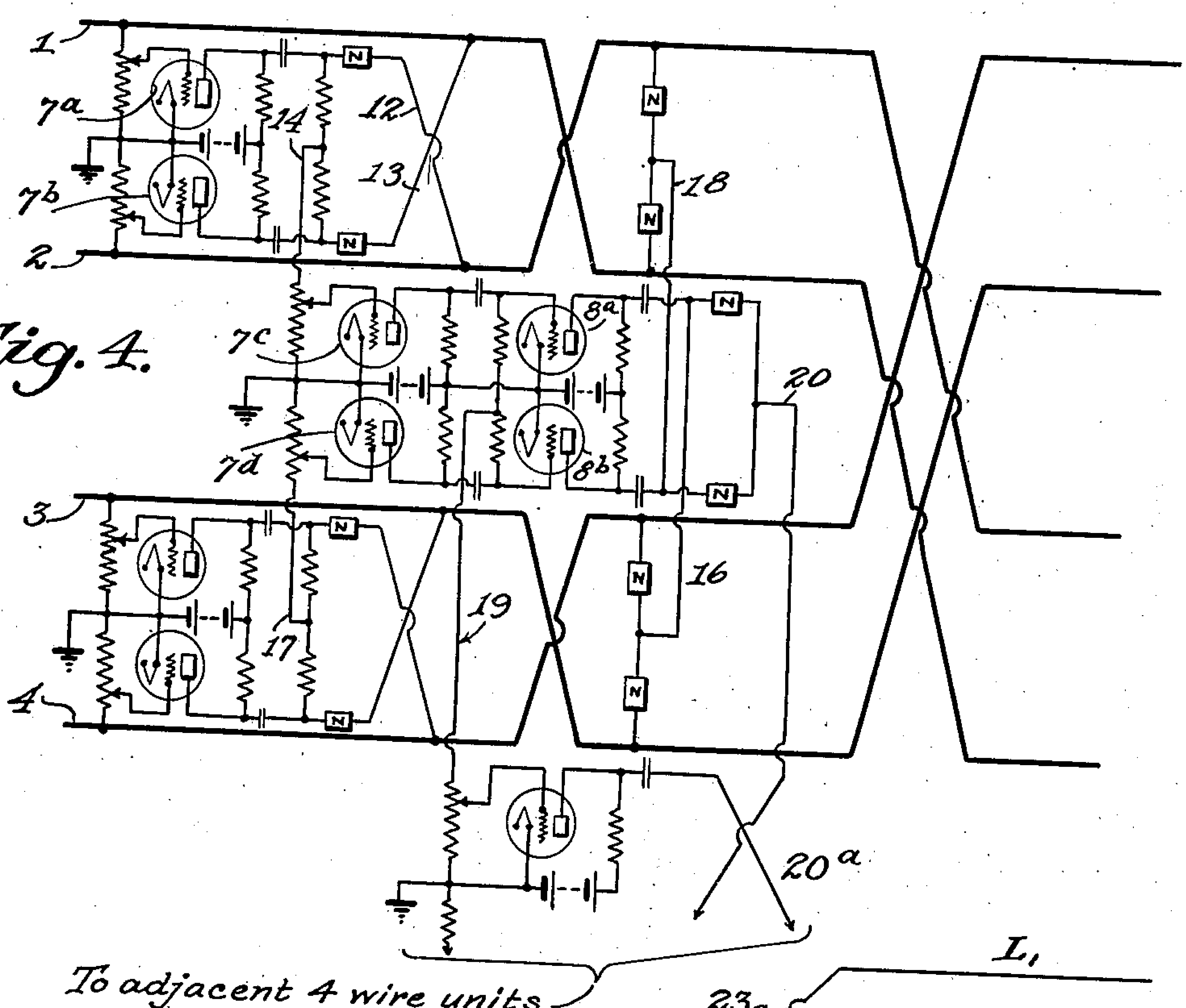
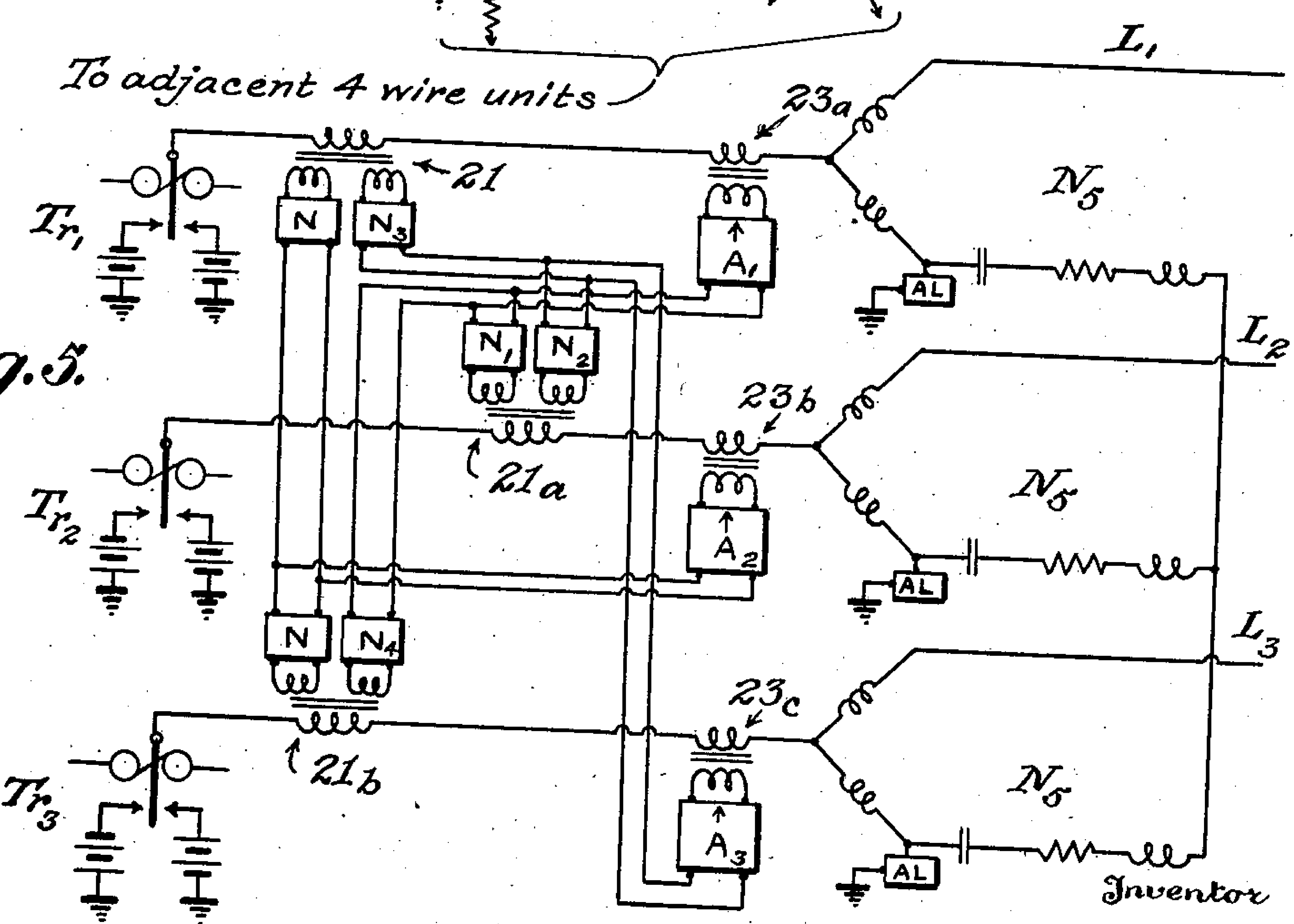


Fig. 5.



Inventor

W. D. Cannon

Eugene C. Brown

Attorney

Oct. 1, 1940. W. D. CANNON 2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 3

Fig. 6.

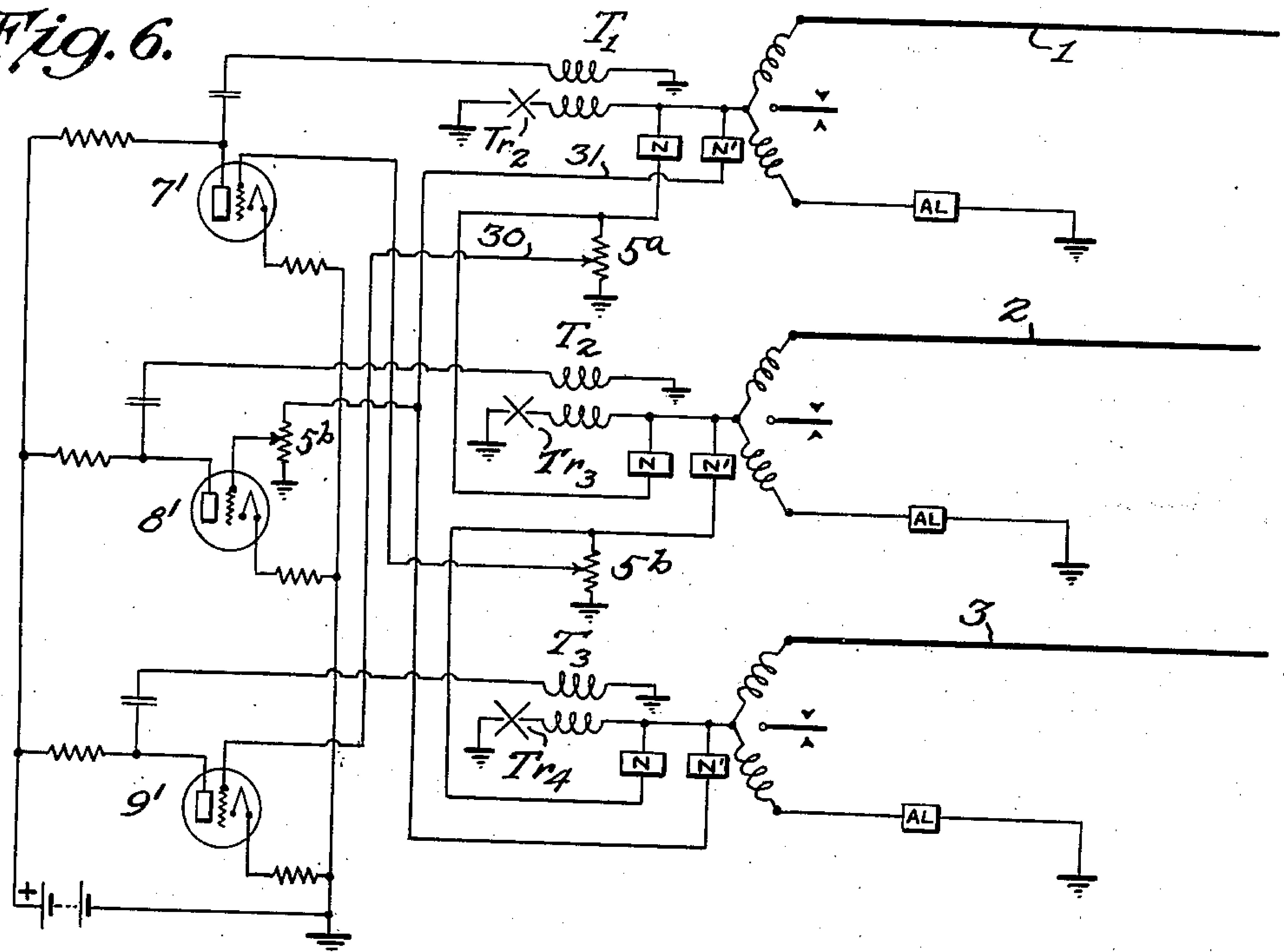
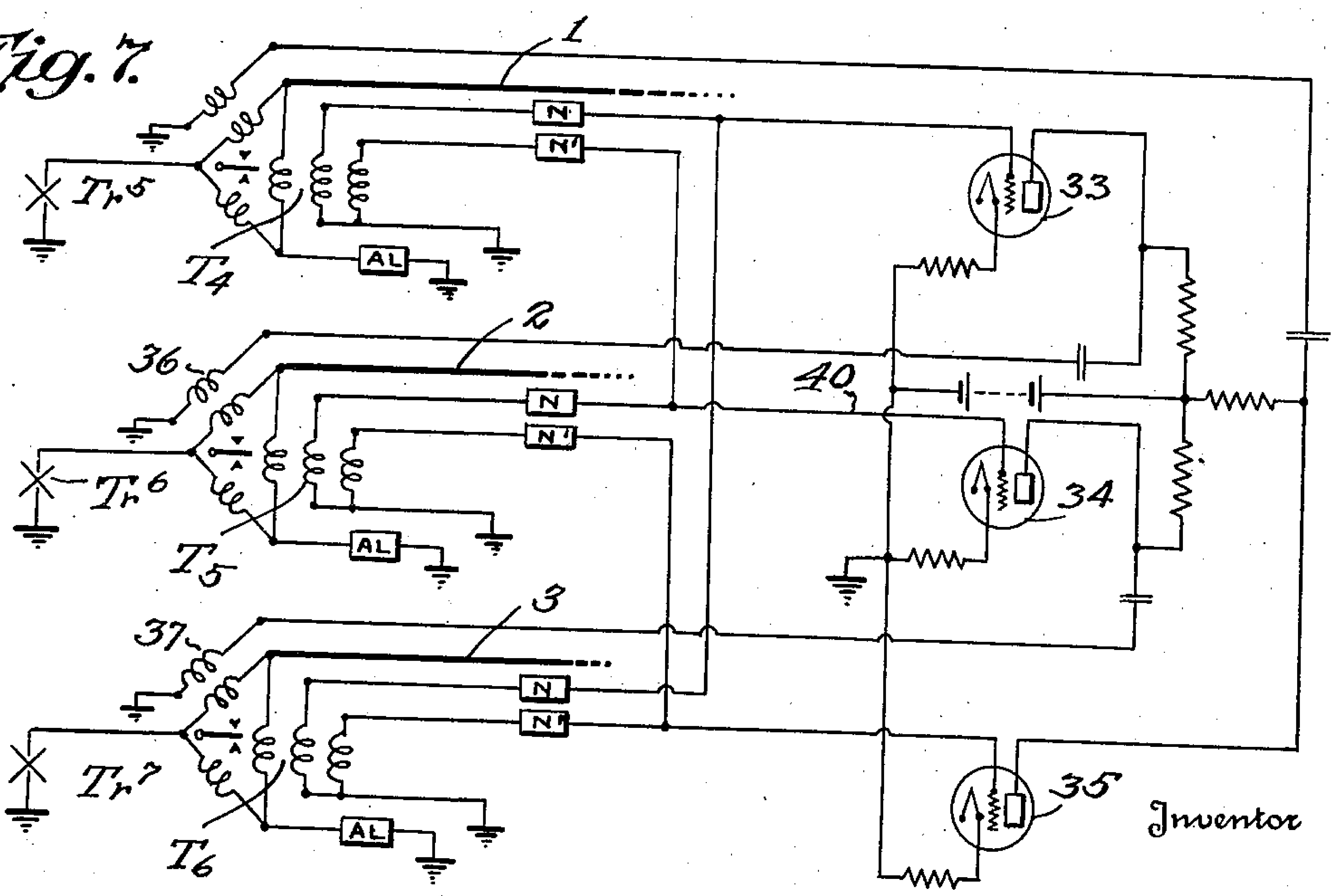


Fig. 7.



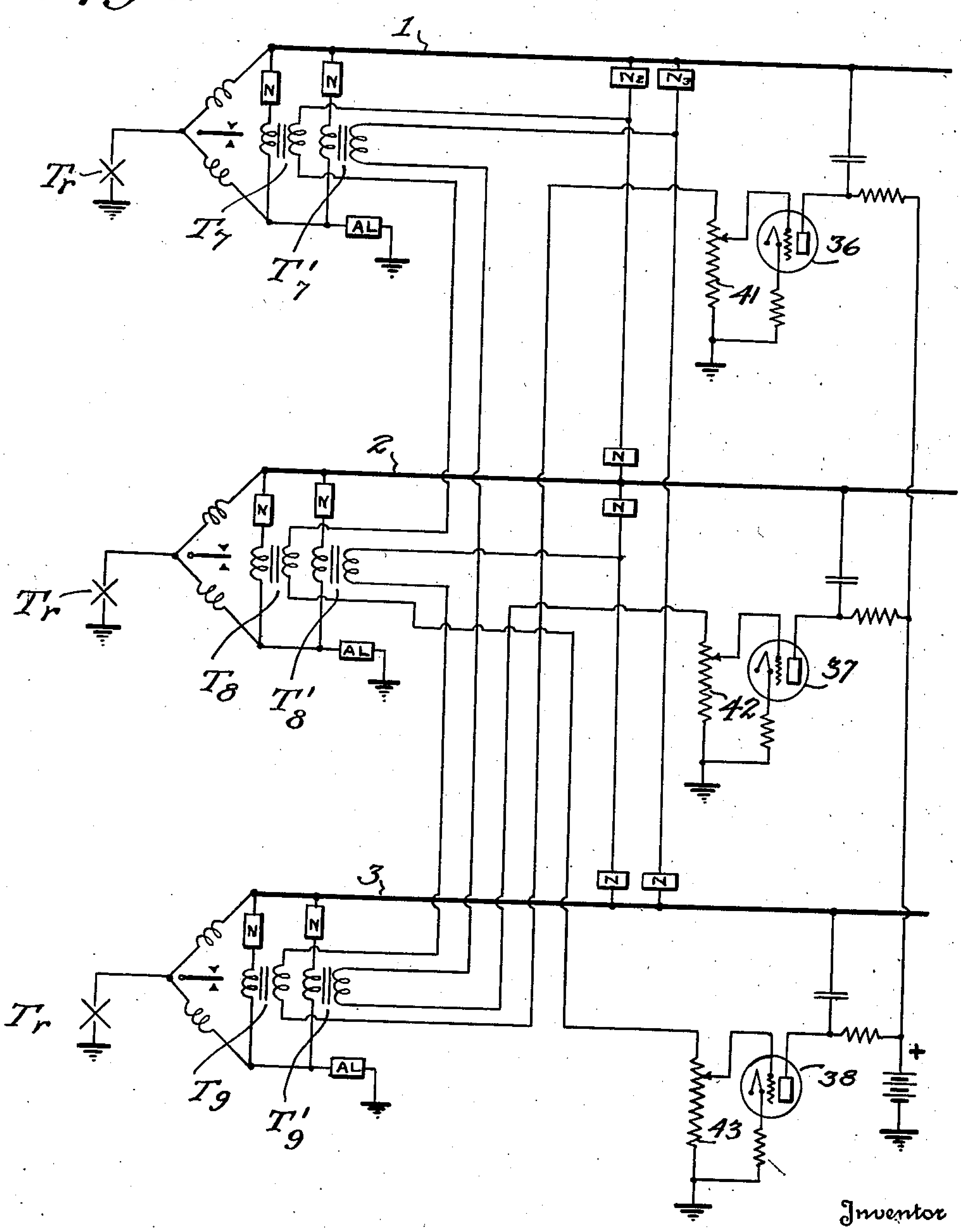
Inventor

W. D. Cannon

Eugene C. Brown

Attorney

Fig. 8.



Inventor

W. D. Cannon

Eugene C. Brown

Attorney

Oct. 1, 1940. W. D. CANNON 2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 5

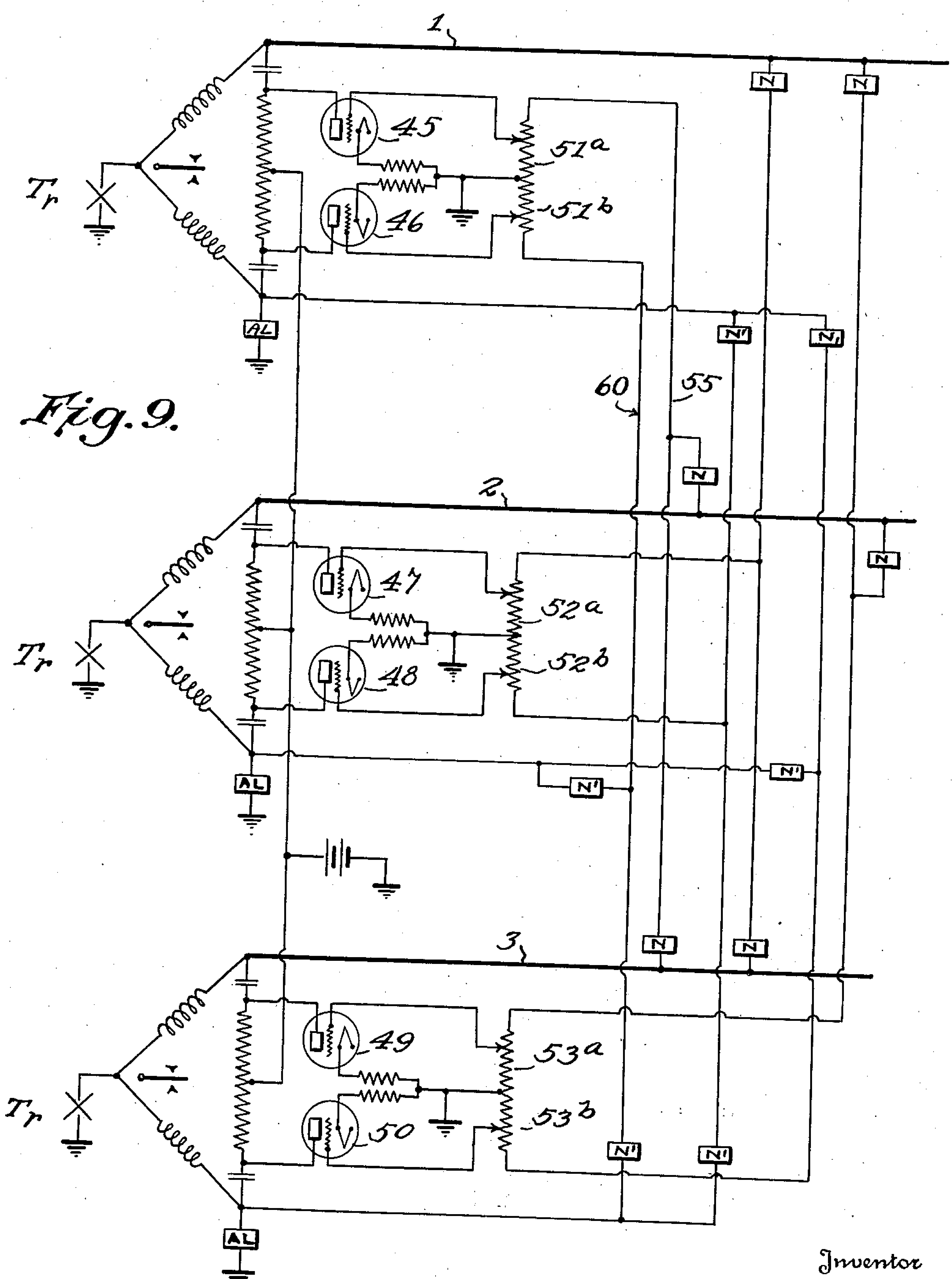


Fig. 9.

Inventor

W. D. Cannon

Eugene C. Brown

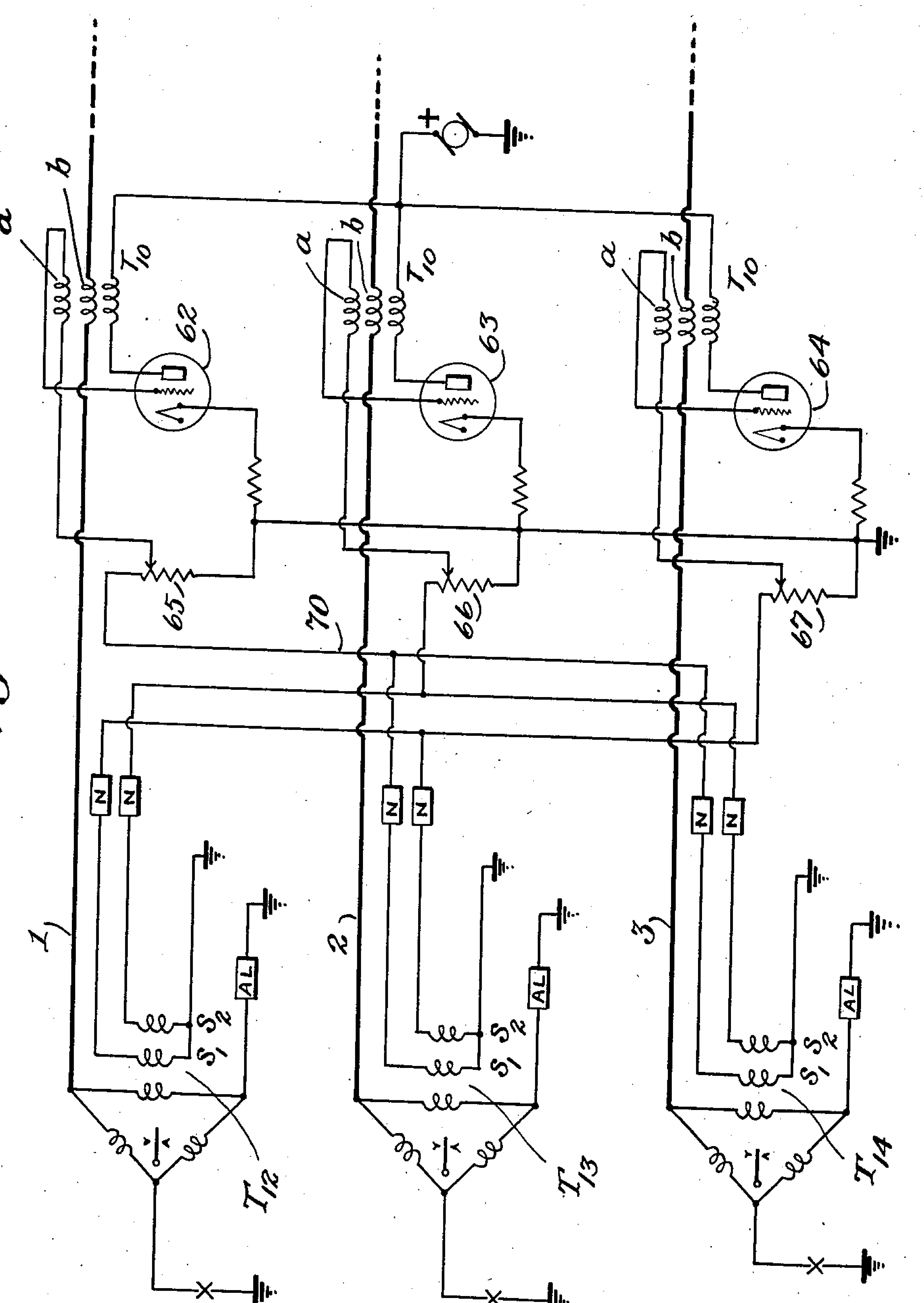
Attorney

Oct. 1, 1940. W. D. CANNON 2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 6

Fig. 10.



Inventor

W. D. Cannon

Eugene C. Brown
Attorney

Oct. 1, 1940. W. D. CANNON 2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

Filed March 30, 1938 7 Sheets-Sheet 7

Fig. 12.

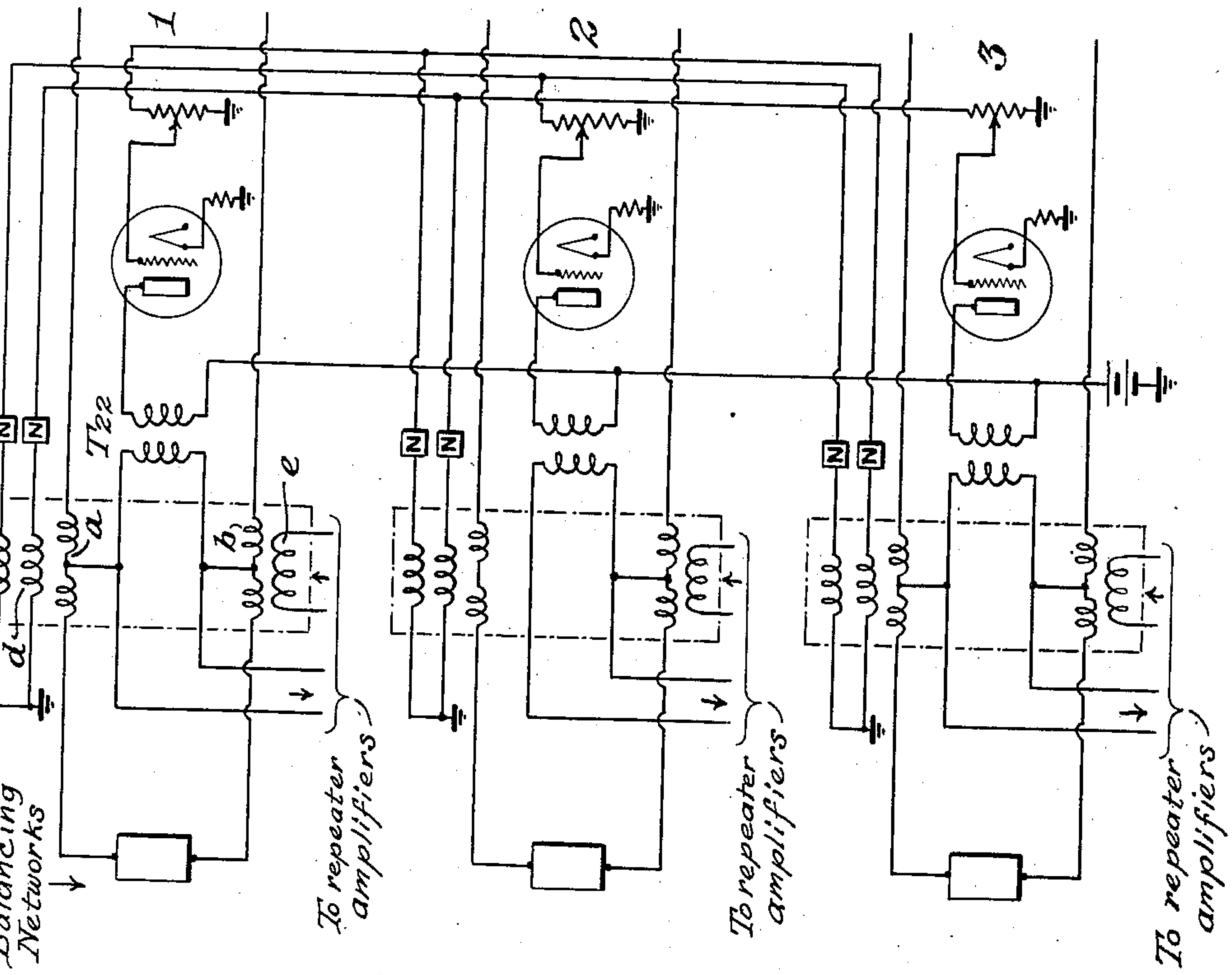
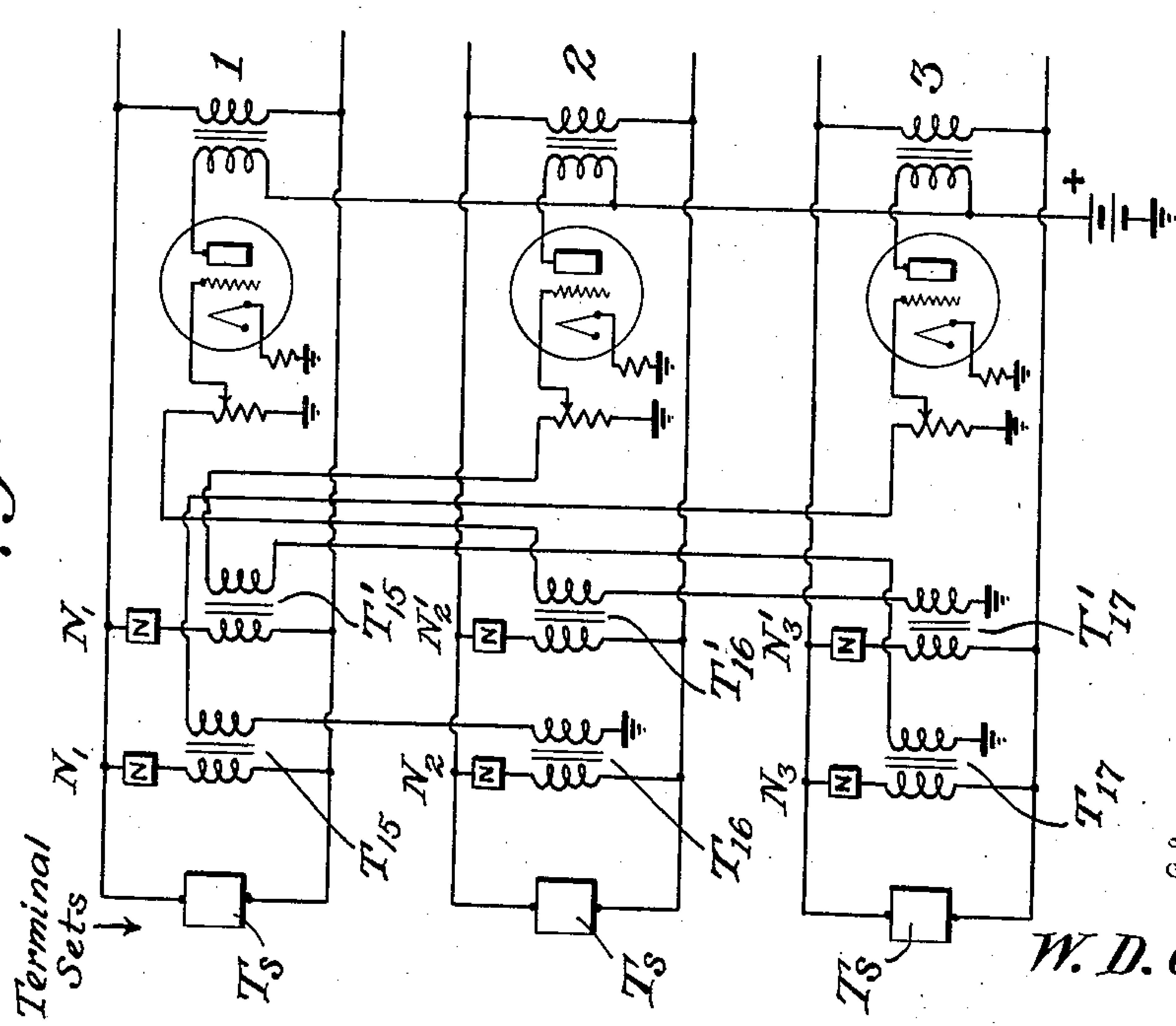


Fig. 11.



Inventor

W. D. Cannon

Eugene C. Brown

Attorney

Patented Oct. 1, 1940

2,216,545

UNITED STATES PATENT OFFICE

2,216,545

SYSTEM FOR ELIMINATING CROSSFIRE IN TELEGRAPHIC CIRCUITS

William D. Cannon, Metuchen, N. J., assignor to The Western Union Telegraph Company, New York, N. Y., a corporation of New York

Application March 30, 1938, Serial No. 198,997

20 Claims. (Cl. 178—69)

This invention relates to a system designed to eliminate "crossfire" between parallel conductors of communication circuits and may also have application to the elimination of cross talk and interference in other types of circuits.

Interference or crossfire between parallel circuits comprises the major cause of signal loss on grounded telegraph circuits operated over heavy pole line leads. The interference levels in the various circuits are different, due to the non-uniform mutual exposures. At any terminal this crossfire interference is roughly divisible into two portions; that due to the local transmitters, known as "sending-end" crossfire and that due to the distant end transmitters, known as "far end" crossfire. The near end crossfire ordinarily predominates. Since most telegraph circuits terminate in a duplex arrangement of apparatus, it is common to provide interconnections between the artificial line terminals of the duplex apparatus for the various wires so that each terminal set sends a correcting pulse through a properly adjusted network to the sets located on all of the neighboring wires. If the correcting system includes all of the conductors of the pole line and the correcting networks are properly designed, a very satisfactory degree of neutralization of the sending-end crossfire may be effected.

Receiving-end crossfire, however, may only be neutralized by introducing into the signaling portion of the disturbed line or the terminal equipment, a neutralizing impulse from the disturbing line of proper phase and magnitude to neutralize the intercepted crossfire disturbance. It is common to perform this correction by sending a neutralizing pulse into the disturbed line from the transmitter of the disturbing line either by means of an auxiliary relay or through a transformer coupling. These methods involve either relatively low impedance shunts from the line to ground or a low impedance coupling between the lines and are thus objectionable because of their effect on signal transmission.

The object of the present invention is to provide a circuit arrangement for substantially eliminating receiving-end telegraph crossfire or both receiving and sending-end crossfire, which functions with negligible impairment to the transmission of telegraph signals. For this purpose I have disclosed herein a crossfire neutralizing system employing therminonic tubes which possess the advantage of very high impedance input and relatively high impedance output circuits, whereby it is possible to provide the interconnections between lines without serious effect upon the transmission of signals.

Other and further objects of this invention will be apparent from the following description, when read in connection with the accompanying drawings, in which—

Figure 1 is a diagram illustrating an embodiment of my invention wherein the input circuit of a thermionic tube is adjustably connected to each line via a high impedance and the respective output circuits are connected to each of the other lines in parallel.

Figure 1[a] illustrates a simple network which may be employed to interconnect the various lines.

Figure 2 shows a crossfire neutralizing system wherein the output of each thermionic tube is connected to an individual line wire while the input is connected to the disturbing lines in combination.

Figure 3 shows the application of my crossfire neutralizing system in association with a power induction system such as disclosed in my application, Serial No. 28,359, filed June 25, 1935.

Figure 4 illustrates the application of my crossfire neutralizing system to an arrangement wherein the wires are divided into quads; the two conductors of each pair being neutralized for each other and the two pairs being then neutralized against each other; the quad also constituting a third unit to be neutralized against the neighboring quads.

Figure 5 shows a crossfire neutralizing arrangement for nullifying the receiving-end crossfire in a system having several adjacent circuits, while the sending-end crossfire is neutralized by the usual anti-induction networks connected to the artificial lines of said several circuits.

Figure 6 discloses an arrangement for supplementing the neutralization obtained in the manner shown in Figs. 1 and 2, by introducing an additional neutralizing pulse at the sending end of such value as to provide the requisite shape and amplitude when it reaches the distant end, thus neutralizing the receiving-end crossfire.

Figure 7 shows an arrangement for picking up a neutralizing potential at the receiving end of each wire for introduction into the receiving apparatus of the adjacent wires.

Figure 8 shows the manner in which the system adapted to neutralize both sending-end and receiving-end interference, such as disclosed in Figs. 1 and 2, may be combined with an additional correction, using a system such as that shown in Fig. 6.

Figure 9 shows an arrangement similar to that of Fig. 2 but including additional means for neutralizing sending-end crossfire via the artificial line connections of the terminal duplex telegraph sets.

Figure 10 shows an arrangement for picking up a neutralizing potential at the receiving end of each wire in a manner similar to that of Fig. 7, but which is introduced through transformer directly into the adjacent wires.

Figure 11 illustrates the adaptation of my crossfire neutralizing arrangement to a system embodying a plurality of adjacent circuits comprised of pairs of wires rather than single wires, as in Fig. 2.

Figure 12 illustrates the application of my neutralizing system to a group of adjacent circuits in such a manner that the possibility of singing or feedback from the output to the input circuits of the amplifiers is substantially reduced.

In Fig. 1 I have illustrated a crossfire neutralizing arrangement which may be adapted to neutralize both sending-end and receiving-end interference, wherein the input circuit of a thermionic vacuum tube for each line is connected via a high impedance **5**, and the respective output circuits are then adjustably connected to each of the other lines through suitable networks N. The vacuum tube units serve to provide a one-way coupling from each line as a disturbing line to the other lines as disturbed lines, at the same time operating to reverse the phase of the correcting pulse by 180° to thereby neutralize the disturbing potentials. The input impedances **5**, connected from each line to ground are of high value and are therefore negligible in their effect on the line characteristics, while the networks N, which interconnect the various lines are also high in value, so that they are productive of but small mutual interference. This mutual interference, due to the networks N, is itself neutralized through the adjustment of the neutralizing system, which is designed to have a sufficient excess of capacity to neutralize the interference which it introduces of itself. The networks N may be of any suitable nature which will admit a neutralizing voltage of proper magnitude and phase. Usually a simple network such as that shown in Fig. 1*a* has been found sufficient. Resistance-capacity output coupling for the tubes is shown, but any other of the common types of coupling may be used instead, which will handle the requisite power and frequency range.

Thus when an interfering voltage is impressed upon the line **3**, a fraction of said voltage is obtained by selecting a portion of the drop across the high impedance **5**, which is impressed upon the input of amplifier tube **7**, and causes the output of the tube to impress a compensating voltage on the lines **1** and **2**, of the proper phase and amplitude to neutralize the voltage induced in said lines, due to said interfering voltage in line **3**, and in a similar manner disturbing voltages induced in lines **1** and **3** by line **2**, and in lines **2** and **3** by line **1**, are neutralized by the tubes **8** and **9** respectively. Thus the neutralizing system acts mutually upon all of the wires.

The neutralizing arrangement disclosed in Fig. 2 differs from that shown in Fig. 1 in that the output of each tube is connected to an individual line, while the input is connected to the disturbing lines in combination. I have illustrated "pentode" type tubes which have a high gain and high plate impedance, but other types of tubes may be used.

The crossfire neutralizing system disclosed herein is useful in connection with certain types of power induction neutralizing systems, such as that disclosed in my prior application issued May 23, 1939, as Patent No. 2,159,927. In power induction neutralizing transformers as shown in said patent, a control wire is used to pick up the disturbing current and apply it in proper phase and magnitude to neutralize the like interference intercepted by the disturbed signal conductors. It is apparent that telegraph crossfire picked up by the control wire will also tend to be introduced into the other conductors. It will be seen that a certain portion of this cross-fire in the control wire may be utilized in the neutralizing amplifier to neutralize the like disturbance in the other wires which traverse the neutralizing transformer. However it is desirable to eliminate all telegraph disturbances in the control wire over and above that which functions to eliminate the crossfire in the other wires. In Fig. 3, I have illustrated the use of the crossfire neutralizing system disclosed herein, to neutralize the crossfire in the control wire **6** of the power neutralizing system, but which is so adjusted that a portion of said crossfire, sufficient to neutralize the crossfire in the telegraph lines, is permitted to remain in the control wire.

In Figure 4 I have shown a neutralizing arrangement embodying my invention in which the communication line wires are divided into quads. The two conductors of each pair are neutralized for each other and the two pairs are then neutralized against each other, while the entire quad constitutes a third unit to be neutralized against neighboring quads.

The operation of the neutralizing arrangement shown in Figure 4 will be evident from the previous description of Figure 1. Thus the disturbing voltages in line **1** impressed upon the input of tube **7**ᵃ, cause the output of said tube to transmit a neutralizing voltage through the conductor **12** to the opposite conductor **2**. Likewise disturbing voltages in line **2** transmit neutralizing voltages through conductor **13** to line **1**. In a similar manner disturbing voltages between lines **3** and **4** are mutually neutralized.

The combined disturbing effect of the pair of lines **1** and **2** is then neutralized with respect to the pair of lines **3** and **4**. Disturbing voltages of the pair of lines **1** and **2** are impressed through the conductor **14** upon the input of tube **7**ᶜ, thereby causing the output of tube **8**ᵃ to transmit neutralizing impulses through the conductor **16** to the pair of lines **3** and **4**. In a similar manner disturbances in the combined lines **3** and **4** are impressed through the conductor **17** upon the input of tube **7**ᵈ and cause the output of tube **8**ᵇ to transmit neutralizing voltages through the conductor **18** to the pair of lines **1** and **2**. In a similar manner the disturbing effects of the quad consisting of the two pairs of wires are neutralized in a neighboring quad by neutralizing voltages transmitted thereto through the conductors **19** and **20**ᵃ, while a neutralizing voltage from the other wires is received via conductor **20**. It will be seen, therefore, that the neutralizing system acts severally or reciprocally upon all other wires.

For most of the amplifiers a single stage of amplification is sufficient to provide a suitable neutralizing potential but with some circuits the second stage is necessary in order to preserve the 180° phase relation. This need not be the case, however, if transformer coupled amplifiers are used.

The high impedance coupled vacuum tube systems may also be used for reciprocal reduction of receiving-end crossfire alone, while the sending-end crossfire is taken care of by the anti-induction networks. I have illustrated such an arrangement in Fig. 5. When signalling impulses are sent over line L_1 from transmitter Tr_1, neutralizing impulses of the proper phase and amplitude are impressed through transformer **21**, network N, amplifier A_2 and transformer **23**$_b$ to the line L_2. Neutralizing impulses are likewise impressed upon line **3**, through transformer **21**, network N_3, amplifier A_3 and transformer **23**$_c$. When impulses are transmitted over line L_2 from transmitter Tr_2 neutralizing impulses are impressed upon line L_1, through transformer **21**$_a$ network N_1 amplifier A_1 and transformer **23**$_a$. Likewise neutralizing impulses are impressed upon line L_3, through transformer **21**$_a$, network N_2 amplifier A_3 and transformer **23**$_c$. In a similar manner when impulses are transmitted from transmitter Tr_3 over line L_3, neutralizing impulses are impressed upon lines L_1 and L_2. In this manner receiving-end crossfire is nullified in all lines while sending-end crossfire is nullified by the usual anti-induction network N_5 connected between the artificial lines. While two lines only have been illustrated in Fig. 4, it is to be understood that the system may be extended to a larger number of lines by reciprocally connecting the input of an amplifier for each line to all the other lines according to the principle of Fig.2, or by the converse arrangement, as shown in Fig. 1.

Another arrangement for nullifying the receiving-end crossfire is shown in Fig. 6 wherein a neutralizing pulse is introduced into the circuit at the sending end of such value as to provide the requisite neutralizing shape and amplitude when it reaches the distant end. The operation of this arrangement will be evident from the previous description of Figs. 1 and 2. Thus when a signal is transmitted from the transmitter Tr_2 over the line **1**, a neutralizing pulse is impressed upon the input of tube **9**^{1} over the network N, a portion of the high impedance **5**^{a} and conductor **30**, causing the output of said tube **9**^{1} to induce an impulse through the transformer T_3 into the circuit of line **3**. Simultaneously a corresponding neutralizing impulse is introduced into the circuit of line **2** by an impulse through network N^1, conductor **31**, a portion of high impedance **5**^{b}, to the input of tube **8**^{1}, thereby causing the output of said tube to induce a neutralizing impulse of the proper phase and amplitude through the transformer T_2 into the circuit line **2**. In like manner signals transmitted over line **2** cause neutralizing impulses to be introduced into the circuits of lines **1** and **3**; and signals transmitted over line **3** cause neutralizing impulses to be introduced into the circuits of lines **1** and **2**. In this manner receiving-end crossfire at the distant end is nullified by introducing into the circuits at the sending end, neutralizing impulses of such value as to provide the requisite neturalizing shape and amplitude when they reach the distant end. The sending-end crossfire may be taken care of by the usual anti-induction networks.

The receiving-end crossfire may be neutralized by a neutralizing potential picked up at the receiving end of each wire for introduction into the receiving apparatus of the adjacent wires in the manner shown in Fig. 7. In this arrangement a transformer coupling to the bridge of a duplex set picks up the potential, and the neutralizing current is applied to the winding of the receiving relay. Thus the primary coil of transformer T_4, bridged across the receiving relay of line **1**, picks up impulses from the received signals and induces voltages in its secondary windings. The voltage induced in one secondary coil is impressed through the shaping network N upon the input of tube **33**, thereby causing an impulse from the output of said tube to be impressed through the coil **36** upon the receiving relay of line **2**. Likewise an impulse from the other secondary coil of transformer T_4 is impressed through the network N^1 and conductor **40** upon the input of tube **34**, whereby a neutralizing impulse of the proper phase and amplitude is transmitted through the coil **37** to the receiving relay of line **3**. It will be seen, therefore, that neutralizing impulses picked up at the receiving end of each wire are introduced into the windings of the receiving relays of the adjacent wires of the requisite neutralizing shape and amplitude. The correcting impulses may also be introduced into the receiving system through the agency of an additional winding on the transformers T_4, T_5, T_6.

While systems such as those shown in Figs. 1 and 2, are adapted to neutralize both sending end and receiving end interference, the best adjustment for the one may not be the most effective adjustment for the other. It is possible to supplement an incomplete correction thus obtained by an additional correction, using an arrangement such as shown in Figs. 5 and 6 or the two systems may be combined into one, as illustrated in Fig. 8.

Signalling impulses received over the line **1** induce voltages in the secondary coil transformer T_7 which traverse also the secondary coil of the bridge transformer T_8 of the line **2** and produce a voltage drop across the high impedance **43**, a selected portion of which is impressed upon the input of tube **38**, having its output connected to line **3**. Said signalling impulses received over line **1** likewise induce voltages in the secondary of bridge transformer T''_7 which traverse also the secondary coil of transformer T''_9 and then produce a voltage drop across high impedance **42**, a selected portion of which is impressed upon the input of tube **37**, having its output connected to line **2**. A voltage from the outgoing signals over line **1** is also introduced into the circuits just mentioned through the networks N_2 and N_3 respectively to control the input of tubes **37** and **38** in providing the requisite neutralizing impulses in the lines **2** and **3**, due to disturbance produced by the line **1** and thereby nullifying any tendency to crossfire between the adjacent lines.

I have shown in Fig. 9 an arrangement similar to that of Fig. 2, but including additonal means for neutralizing sending-end crossfire via the artificial line connections of the terminal duplex telegraph sets. It will be seen that the receiving-end crossfire is nullified through the medium of the upper tube in each pair and that the sending-end crossfire is neutralized through the medium of the lower tube in each pair. Thus the lines **2** and **3** operate jointly through the networks N connected to the conductor **55** to produce a voltage drop across the high impedance **51**$_a$, a selected portion of which is impressed upon the input of tube **45**, to neutralize receiving-end crossfire in the receiving relay of line **1**. Sending-end crossfire which would be produced in line by the transmission of signals over lines **2** and **3**, is nullified in line **1** by impulses transmitted over conductor **60** from the artificial lines, associated with lines 2 and 3, these impulses being transmitted through the networks N^1 connected to said conductor and causing a voltage drop across the high impedance 51_b, a selected part of which is impressed upon the input of tube 46. In this manner the tendency both to receiving-end crossfire and sending-end crossfire is effectively nullified in line 1. In a similar fashion reciprocal connections via other networks N and N_1 to wires 1, 2 and 3, serve to neutralize the crossfire induced in lines 2 and 3.

In Fig. 10 I have shown an arrangement for neutralizing the receiving-end crossfire in communication lines by introducing the neutralizing voltage directly into the line, instead of into the receiving instrument, such as shown in the arrangement of Fig. 7. The operation of the arrangement of Fig. 10 will be obvious from the previous description of Fig. 7. The disturbing crossfire induced in line 1 by the currents received in lines 2 and 3 is nullified by voltages induced in the secondary coils of bridge transformers T_{13} and T_{14}. The voltages induced in the secondary coils s_1 of said transformers produce a current through networks N, conductor 70 and resistance 65. A selected portion of the drop across said resistance is applied to the input of tube 62 which causes the transformer T_{10} in the output of said tube to introduce a voltage of the proper magnitude and phase to neutralize the receiving-end crossfire in the line 1.

Since the frequencies involved are rather low, the necessarily large inductance of the transformer T_{10} is harmful to telegraph transmission. In order to neutralize this impedance, I introduce tertiary windings a in the transformer which feed back into the input of the amplifier 62, a potential sufficient to overcome the losses introduced into the line circuit by the main line windings b. It will be evident that the sending-end crossfire in the arrangements shown in Figs. 7 and 10 may be neutralized using in addition the sending-end neutralizing means shown in Figs. 1, 2 or 5.

Interference neutralizing systems are preferably set up at each end of the line, where they provide protection for the terminal apparatus. Due to the high impedances of the interconnections, the mutual coupling between wires in the arrangements herein described is inappreciable, yet the wires approach a freedom from interference normally possessed only by isolated wires or metallic circuits.

The vacuum tubes for the neutralizing system herein described, should preferably have a relatively high power output and should be of high impedance inasmuch as they are connected between the various lines or between the lines and ground. Pentode types of tubes have proved very satisfactory for this purpose. In some of the systems described there is an apparent coupling between the input and output of the various amplifiers, which may be expected to produce undesirable oscillation. In most instances, this tendency is negligible under conditions of proper adjustment.

I have not illustrated the terminal apparatus in Figs. 1 to 4 inclusive but it is to be understood that the wires are available for either one way or two way telegraph, or for other purposes, without substantial impairment to transmission. In some cases when duplex terminal sets are used it may be desirable to include in the artificial line passive networks to balance the networks N or other elements connected to the real lines.

In the arrangements previously described the neutralizing system has been applied particularly for neutralizing transient disturbances but it is also adapted for neutralizing disturbances of a continuous type. For example, it may be employed for neutralizing interference, such as "crosstalk," in telephone or other voice frequency or higher frequency circuits induced by the mutual coupling between the wires. This involves merely the adaptation of the arrangements previously described to circuits comprised of pairs of wires rather than single wires.

In Figure 11 I have shown my neutralizing system applied to a group of adjacent circuits, each composed of a pair of wires. This arrangement is analogous to that shown in Fig. 2 and its operation will be readily understood from the description of that figure. Transformer coupling of the neutralizing system to the line circuits is indicated merely because of its economy and convenience. Obviously resistance coupling may be used and it would then be necessary to employ push-pull amplifiers as shown in Fig. 9, if common grounded batteries are to be used. Otherwise the pairs would suffer an unbalance to ground.

I have illustrated in Figure 12 the application of my neutralizing system to a group of conductors in such a manner that the possibility of singing or feedback from the output to the input circuits of the amplifier is substantially reduced. In this figure the three line circuits 1, 2, and 3 terminate in the balanced hybrid coils of standard 22 type telephone repeaters. Such a repeater is illustrated in Patent 1,227,114, and need not be further described. Supplementary windings c and d are added to each hybrid coil for the purpose of picking up potentials which may be applied in conjugate fashion for neutralizing the disturbances induced in the other circuits. As indicated, the windings associated with each pair but one, are joined in parallel to the input of an amplifier whose output is then connected to the input of an amplifier whose output is then connected to the transformer T_{22} which is connected across the bridge points of the hybrid coil of the remaining pair. Since the supplementary windings and the transformers T_{22} bear a conjugate relation to each other, the input circuits of all the amplifiers will be entirely independent of the output circuits of all the amplifiers. It will be understood that only one-half of each repeater is shown. The second half would be similarly equipped for neutralizing the interference of the succeeding line section.

The neutralizing system of the invention may also be applied to regular 4-wire telephone circuits, such as are illustrated in Patent 1,352,786. In the 4-wire system, however, two neutralizing groups will be required inasmuch as the outgoing or sending currents are confined to one pair while the incoming or receiving currents are confined to the other pair. For neutralizing near end, or sending end, crosstalk it will be necessary to separately neutralize the interference from each sending pair into each of the adjacent receiving pairs, while a second group as in Figure 11 will be required to mutually neutralize the interference between all of the receiving pairs. Adaptations of the various methods previously illustrated to 4-wire circuits will be evident to engineers.

I claim:

1. In a communication system comprising several adjacent line circuits wherein different levels of interference are produced, due to non-uni-

form mutual exposures, the method of nullifying crossfire between said several circuits, which consists in selecting a portion of each current impulse transmitted over the respective lines, dividing said lines into a plurality of groups, separately amplifying the selected impulses from each of said groups, and supplying said amplified impulses mutually and reciprocally to all of the line circuits.

2. In a communication system comprising several adjacent line circuits wherein different levels of interference are produced, due to non-uniform mutual exposures, the method of nullifying crossfire between said several circuits, which consists in deriving a selected portion of each current impulse traversing the respective lines, dividing said lines into a plurality of groups, separately amplifying the selected impulses from each of said groups, and mutually and reciprocally impressing the same upon all of the line circuits.

3. In a telegraph signaling system comprising a plurality of adjacent line circuits, the method of nullifying receiving-end and sending-end crossfire between the respective line circuits wherein different levels of interference are produced, due to non-uniform mutual exposures, which consists in amplifying inductively derived portions of the signaling impulses received over any one of said respective circuits and applying the same mutually and reciprocally to the line conductors of all of the other circuits, and applying amplified portions of conductively derived impulses transmitted over any line mutually and reciprocally to all of the other lines of the system.

4. An electric system comprising a plurality of adjacent transmission line circuits having different levels of interference, due to non-uniform mutual exposures, means for eliminating mutual interaction between said lines comprising a separate amplifier individually associated with each line and having its input connected to its respective line circuit and impedance networks connecting its output to all of the other lines, whereby the input energy is always free of the energy of that line to which the output of said amplifier is connected.

5. An electric system comprising a plurality of adjacent transmission line circuits having different levels of interference, due to non-uniform mutual exposures, means for eliminating mutual interaction between said lines comprising a separate amplifier associated with each line and connected to its respective line circuit via its output, and shaping networks connecting all of the other remaining line circuits to its input.

6. In a communication signaling system embodying a plurality of adjacent transmission line circuits and having terminal equipment provided with transmitter and receiver adapted to separate the incoming and outgoing currents, means for eliminating mutual interference between said line circuits, comprising an amplifier associated individually with each line and having its output connected inductively to the transmitter of its respective line, and shaping networks connecting the input of the respective amplifiers to the transmitters of all of the remaining line circuits.

7. In a communication system a plurality of line circuits having different levels of interference, due to non-uniform mutual exposures, a separate amplifying element individual to each line circuit having input and output circuits, said output circuits being connected severally each to a different line circuit and said input circuits being connected severally to all the other line circuits whereby a voltage from each line circuit is introduced into each remaining line circuit for the purpose of neutralizing mutual interference among said lines.

8. In a telegraph system embodying a plurality of adjacent circuits terminated in duplex sets equipped with artificial lines, the method of eliminating mutual interference between said circuits which comprises mutually and severally joining all lines but one through high impedance paths to the input of an amplifier, amplifying a voltage received over said paths and impressing the resulting voltage upon the other of said lines severally to thereby nullify the receiving end crossfire and a portion of the sending end crossfire in all of said lines, and correspondingly interconnecting the artificial lines of said circuits to thereby nullify the remaining sending end crossfire.

9. In a communication system embodying a plurality of adjacent circuits having different levels of interference, due to non-uniform mutual exposures, and having terminal equipment adapted to separate the incoming and outgoing currents, the method of neutralizing interference between said circuits (due to incoming currents) which comprises the selection from each wire of a portion of the received current, separately amplifying said currents, and applying said amplified currents mutually and reciprocally to the line conductors of each of the remaining circuits.

10. In a communication system embodying a plurality of adjacent circuits and having terminal equipment adapted to separate the incoming and outgoing currents, the method of neutralizing interference between said circuits which comprises the selection from each wire of a portion of the received currents therein, separately amplifying said currents, and applying said amplified currents mutually and reciprocally to impedances connected to the line conductors of all of the other circuits, and additional means for neutralizing the effect of said impedances upon said line circuits.

11. In a telegraph signaling system comprising a plurality of adjacent line circuits having different levels of interference, due to non-uniform mutual exposures, the method of nullifying receiving-end crossfire between adjacent circuits when signaling impulses are impressed upon any one of said circuits, which consists in producing in all of the other adjacent circuits, derived amplified impulses in proper phase relation to neutralize the interfering impulses produced at the distant receiving station thereof by the transmission of signaling impulses over said one of said circuits.

12. In a telegraph signaling system comprising a plurality of adjacent line circuits, the method of nullifying receiving-end crossfire between adjacent circuits when signaling impulses are impressed upon one of said circuits, which consists in inductively deriving impulses at the receiving end of a crcuit when signaling impulses are received thereover, amplifying said derived impulses and inductively impressing them upon the circuit of the receiving instrument.

13. In a system for neutralizing current induction in a plurality of adjacent line wires which traverse the coils of a compensating transformer, and provided with a control wire external to said transformer and exposed to the same induction with said line wires, said control wire being connected to a coil of said transformer, of means for the elimination of crossfire between the line wires and the control wire, comprising a thermionic tube provided with input and output circuits, said tube having its input circuit con-

nected to said wires and its output circuit connected to said control wire.

14. In a communication signaling system embodying a plurality of adjacent transmission circuits, an arrangement for the elimination of mutual interference between said circuits, which consists in means for neutralizing interference between the conductors of separate pairs of said circuits, means for neutralizing interference between one and another of said pairs of circuits, and means for neutralizing interference between said combined pairs considered as a quad and another like quad consisting of a similar group of two pairs which have been likewise neutralized against each other.

15. In a telegraph system embodying a plurality of adjacent transmission wires, means for eliminating crossfire, comprising a series of thermionic tubes provided with input and output circuits, each tube having one of said circuits connected to only one of said transmission wires and its other circuit connected to all of the remaining wires.

16. In a telegraph system embodying a plurality of adjacent transmission wires, means for eliminating crossfire, comprising a series of thermionic tubes provided with input and output circuits, each tube having its input circuit connected to only one of said transmission wires and its output circuit connected to all of the remaining wires.

17. In a telegraph system embodying a plurality of adjacent transmission wires, means for eliminating crossfire, comprising a series of thermionic tubes provided with input and output circuits, each tube having its output circuit connected to only one of said transmission wires and its input circuit connected to all of the remaining wires.

18. In a communication system comprising several adjacent line circuits, each circuit embodying a pair of conductors, the method of nullifying crossfire between said several circuits, which consists in combining selected portions of the current impulses simultaneously transmitted over all but one of said circuits, amplifying the resultant current impulse and supplying said resultant to said one circuit, and simultaneously applying said operation to each of the several individual line circuits.

19. An electric system including several adjacent transmission circuits wherein different levels of interference are produced, due to non-uniform mutual exposures, each circuit embodying a pair of conductors, means for eliminating mutual interaction between said circuits, comprising separate amplifiers, each connected to its respective circuit via its output, and impedance networks interconnected to the other circuits of the systems, connected to the input of the amplifier.

20. In an electric system including a plurality of adjacent transmission circuits, each of said circuits embodying a pair of conductors, the method of neutralizing interference between said circuits, due to incoming currents, comprising inductively selecting from each said circuit a portion of the received current, amplifying said portions jointly from all of said circuits but one, applying the amplified current to said last named circuit in conjugate relation to the inductively selected portion and simultaneously applying the same operation to each of said circuits.

WILLIAM D. CANNON.