Jan. 25, 1938. H. S. BLACK 2,106,337
TRANSMISSION SYSTEM
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FIG. 1

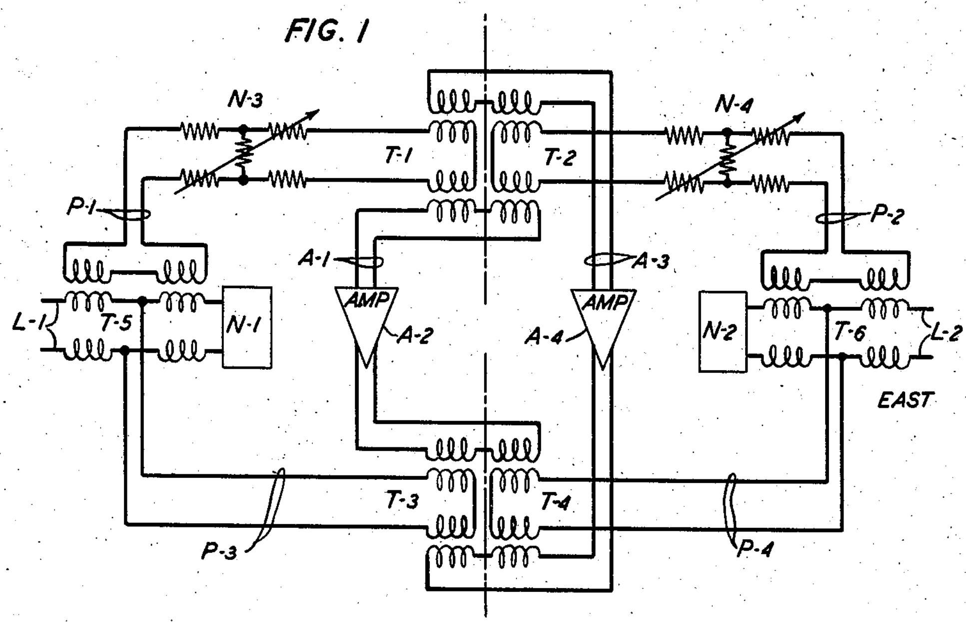

FIG. 2

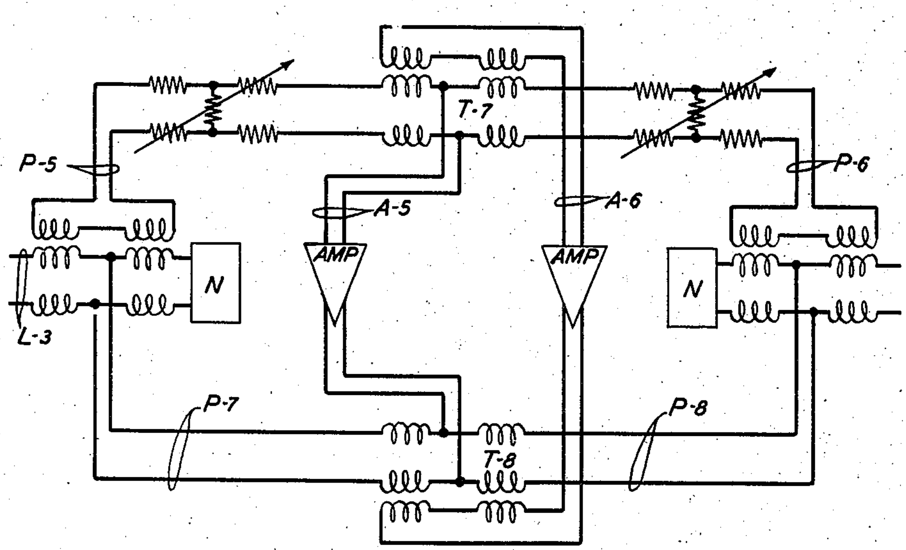

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FIG. 3

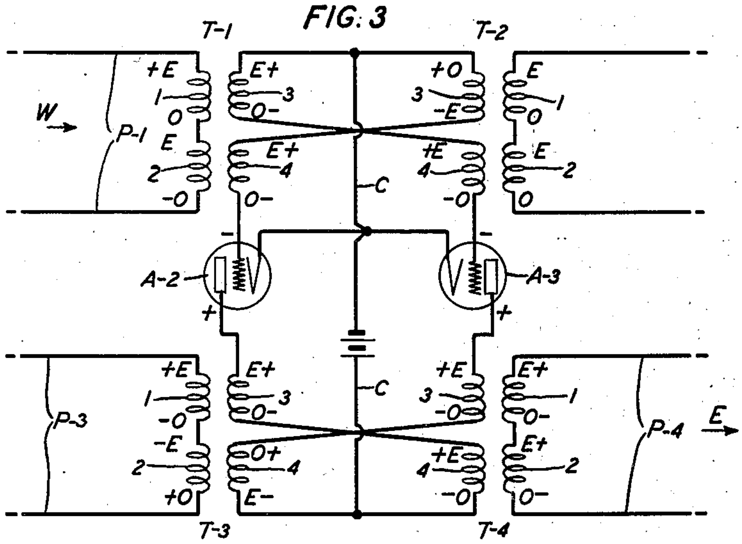


FIG. 4

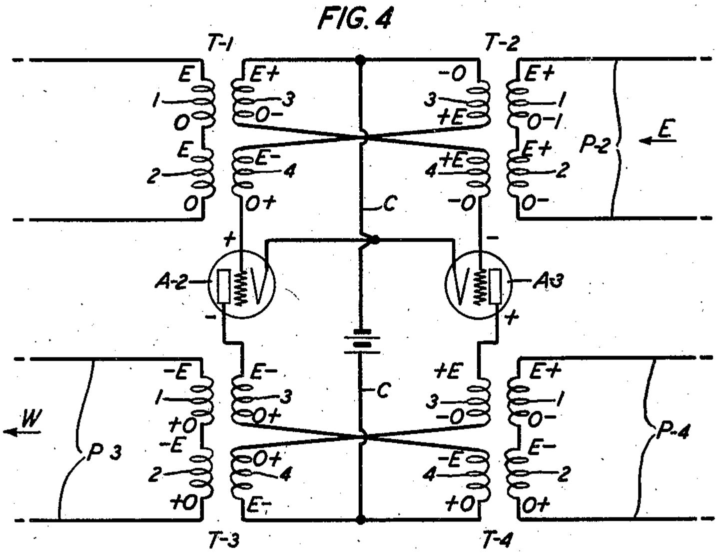
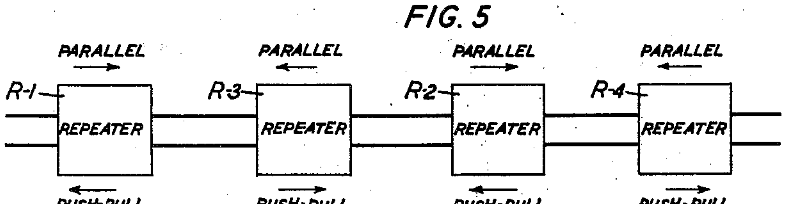


FIG. 5



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TRANSMISSION SYSTEM

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Application January 9, 1936, Serial No. 58,320

3 Claims. (Cl. 178—44)

This invention relates to two-way signal wave transmission systems and particularly to the two-way repeaters used therein.

The objects of the invention are to enable a more efficient use of the repeating elements of a two-way repeater; to increase the output energy; to enable the simultaneous use of a plurality of repeater elements for transmission in either direction; to permit the gain for both directions to be separately controlled; and to effect other improvements in systems of this character.

These objects are attained by a circuit arrangement which employs two amplifiers to give two-way amplification of signals in a manner similar to that of the well-known 22-type repeater, and in which both amplifiers are used simultaneously for each direction of transmission. In one embodiment the oppositely-directed repeating paths are associated with the two two-way lines between which signals are to be transmitted by hybrid transformers and associated balancing networks as in the usual 22-type repeater, and the two amplifiers are pointed in the same direction and are connected in common to both repeating paths by auxiliary hybrid transformers. Objectionable echoes and singing are prevented by the balance of the east line against the east network or the west line against the west network according as transmission is west to east or east to west, respectively.

A feature of the invention is a two-way repeater in which both repeating elements are coupled to both transmission lines through a combined input circuit and are coupled to both transmission lines through a combined output circuit and in which the combined input circuit and the combined output circuits are so arranged that the two repeating elements operate in parallel for one direction of transmission and in push-pull relation for the other direction of transmission. With this arrangement the even-order frequency components of modulation leave the combined output circuit and flow back toward the speaker only for one direction of transmission, say east to west, and these even-order components leave the output circuit and flow forward toward the listener only for transmission in the opposite direction, west to east.

Another feature of the invention is to take advantage of the suppression characteristics of the repeater just described by reversing the direction of alternate repeaters in a transmission line so that for each direction of transmission alternate repeaters are directed for parallel operation and the remaining alternate repeaters are directed for push-pull operation. This reduces the number of repeaters which permit the flow of harmonics either forward to the listener or backward to the speaker to half the total number of repeaters for either direction of transmission.

A further feature of the invention is the provision of gain-control mechanism in each of the oppositely-directed repeating paths. With this arrangement one of these mechanisms can be adjusted to obtain the desired gain for both repeating elements when transmission is in one direction and the other mechanism adjusted to give the desired gain for both repeating elements when transmission is in the opposite direction. This provision for separately and independently controlling the gains for the two directions of transmission together with the arrangement for balancing both lines independently of each other and of the repeating paths make it possible to place the successive repeaters in the transmission system without particular regard to the relative lengths of adjacent lines or the spacings between repeaters.

A further feature is a repeater of the kind above mentioned in which the couplings between the two amplifiers and the repeating paths are arranged so as to provide a through direct current path between the two transmission lines to facilitate the transmission of direct current signals and dialing impulses.

Other features and advantages of this invention will be described more fully in the following detailed specification, which should be considered in connection with the accompanying drawings in which:

Fig. 1 is a diagram of a two-way repeater incorporating the features of this invention;

Fig. 2 is a modification of the repeater illustrated in Fig. 1;

Figs. 3 and 4 are circuit diagrams of the repeater of Fig. 1 showing the detail connections of the repeating elements. Fig. 3 illustrates the polarities of the different elements when transmission is in one direction and Fig. 4 illustrates the polarities when transmission is in the opposite direction; and

Fig. 5 is a diagram of a transmission system containing a plurality of repeaters in accordance with the invention.

Referring first to Fig. 1, there are here illustrated two transmission lines L—1 and L—2. Line L—1 entering from the west is connected through the primary windings of a hybrid transformer T—5 of the usual and well-known type to a balancing network N—1. The other transmission line L—2 entering from the east is connected through the primary windings of a hybrid transformer T—6 to a balancing network N—2. The transformer T—5 through its secondary windings couples the line L—1 to a one-way input repeating path P—1 which terminates in the primary windings of transformer T—1. Similarly the secondary windings of the hybrid transformer T—6 couple the east line L—2 to a one-way input repeating path P—2 which terminates in the primary windings of transformer T—2. One of the secondary windings of transformer T—1 and one of the secondary windings of transformer T—2 are connected together and serve to couple both of the paths P—1 and P—2 to a one-way amplifying circuit A—1 which contains the amplifier A—2. Likewise the other pair of secondary windings of transformers T—1 and T—2 are connected together and serve to couple both of the repeating paths P—1 and P—2 to a second one-way amplifying circuit A—3 which includes the amplifier A—4. The amplifying circuit A—1 on the output side of the amplifier A—2 terminates in a pair of primary transformer windings, one for each of the transformers T—3 and T—4 which serve to couple the amplifying circuit A—1 to each of two one-way output repeating paths P—3 and P—4. Likewise the amplifying circuit A—3 on the output side of the amplifier A—4 terminates in another pair of primary windings of the transformers T—3 and T—4 which couple the amplifying circuit A—3 to both of the one-way output repeating paths P—3 and P—4. The output repeating path P—3 is connected across the line L—1 between the primary windings of the hybrid transformer T—5 and the output repeating path P—4 is similarly connected across the line L—2 between the primary windings of the hybrid transformer T—6. A variable transmission circuit N—3 is included in the repeating path P—1 and a similar transmission circuit N—4 is included in the repeating path P—2.

When transmission is in the direction from west to east the energy entering by way of line L—1 passes into the network N—1 and through the hybrid transformer T—5 into the repeating path P—1. From here it passes through the gain-controlling circuit N—3 into the primary windings of the transformer T—1. At this point the energy divides, part of it passing to the amplifying circuit A—1 and part of it to the amplifying circuit A—3. The energy in the circuits A—1 and A—3 is amplified by the amplifiers A—2 and A—4, respectively, and is then delivered to the combined output circuit comprising the windings of the transformers T—3 and T—4. Depending upon the manner in which the transformer coils are wound, all or part of the components of the output energy is prevented from passing into the path P—3 and returning as a reflection toward the speaker, whereas the desirable components of the output energy of the two amplifiers A—2 and A—4 are caused to pass into the path P—4 and thence into the transmission line L—2. When transmission is in the opposite direction the energy entering over the line L—2 passes into the repeating path P—2 through the gain-control circuit N—4 and into the windings of the transformer T—2. At this point it divides in a similar manner, part of it entering the amplifying circuit A—1 and part of it entering the amplifying circuit A—3. After amplification in the two circuits A—1 and A—3, the output energy of the amplifiers is applied to the combined circuit including the coils of the transformers T—3 and T—4 and again according to how the windings of the transformers are disposed, some or all of the components are prevented from returning toward the speaker by way of the path P—4, whereas the useful components of the energy are transferred to the output repeating path P—3, thence over the transmission line L—1.

When the windings of the transformers T—1, T—2, T—3, and T—4 are connected in a particular manner as will be explained more fully later, the two amplifiers A—1 and A—2 operate in parallel when transmission is in a given direction, say from west to east, and in a push-pull manner when transmission is proceeding in the opposite direction. By connecting the repeaters in the transmission system in the proper manner the advantages of both the parallel and the push-pull operation are utilized. For example, when the amplifiers are operating in parallel it is possible to prevent any of the transmission components from returning toward the speaker by effectively balancing out the fundamental and all harmonics in the combined output circuit of the amplifiers. With transmission in the opposite direction and the amplifiers working in a push-pull manner it is possible to cancel the even harmonic components from the energy flowing toward the listener and to prevent the fundamental and all odd harmonics from returning to the speaker.

The transmission controlling devices N—3 and N—4 enable independent gain adjustments to be made for the two directions of transmission. By adjusting the mechanism N—3 any desired ratio may be obtained between the energy entering the repeater over the line L—1 and the amplifier energy delivered by the repeater to the line L—2, and by adjusting the mechanism N—4 any desired ratio may be obtained for transmission in the opposite direction. These two adjustments may be made independently of each other; therefore, the repeater may be set for a relatively high gain for one direction of transmission and at the same time for a relatively low gain for transmission in the opposite direction. This means that the repeater may be located in the transmission system without restrictions as to the relative lengths of the incoming and outgoing transmission lines. Moreover, since the transmission lines are balanced separately by artificial lines N—1 and N—2 it is possible to operate the amplifiers A—2 and A—4 over a wide range of input energy without producing singing, distortion or other undesirable effects. While the control devices N—3 and N—4 are illustrated diagrammatically as attenuation networks, any suitable kind of energy controlling mechanism may be used.

Referring now to Figs. 3 and 4 which illustrate one embodiment of the repeater of Fig. 1 somewhat more in detail, an explanation will be given of the manner in which the various windings of the transformers T—1, T—2, T—3, and T—4 are wound and how the various component parts of the transmission energy are disposed of. These figures are alike except Fig. 3 shows the polarities of the different windings at a given instant when transmission is proceeding from west to east, and Fig. 4 shows the polarities of the different windings at a given instant with transmission proceeding from east to west. These figures also illustrate the details of the amplifiers A—2 and A—3 which as shown are three-electrode space discharge devices of the well-known type. The grid elements of the amplifiers A—2 and A—3 are connected, respectively, to the lower terminals of windings 4 of transformers T—1 and T—2, and the plate elements of amplifier tubes A—2 and A—3 are connected, respectively, to the upper terminals of the windings 3 of transformers T—3 and T—4. The upper terminals of the windings 4 of transformers T—1 and T—2 are connected respectively to the lower terminals of the windings 3 of transformers T—2 and T—1. The upper terminals of the windings 3 of transformers T—1 and T—2 are connected together. The lower terminals of the windings 3 of transformers T—3 and T—4 are respectively connected to the upper terminals of the windings 4 of transformers T—4 and T—3, and the lower terminals of the windings 4 of transformers T—3 and T—4 are connected together. The cathodes or filament electrodes of the amplifying tubes A—2 and A—3 are joined together and connected by way of a common conductor C to a point between the upper terminals of coils 3 of transformers T—1 and T—2. The common circuit C also joins the cathode elements to a point between the lower terminals of windings 4 of the transformers T—3 and T—4. A source of plate potential is connected in the usual manner in the common circuit C. Other elements such as condensers and impedance coils may be included in the system wherever necessary. Each of the windings of the transformers T—1, T—2, T—3, and T—4 has its two terminals designated by the letters E and O to indicate the direction of the flux when current is flowing through the winding. For example, if one winding has its even terminal E connected to the odd terminal O of a second winding, the windings are aiding and current flowing through them will produce fields which add together. On the other hand, if two windings have their like terminals connected together, they are in differential relation and a current flowing through them will establish opposing fields.

Considering first that transmission is from west to east as illustrated in Fig. 3, it may be assumed that at a given instant the current flowing in the repeating path P—1 is in such a direction that the even terminal of winding 1 of transformer T—1 is positive and the odd terminal of winding 2 is negative. From this it follows that the voltages induced in the windings 3 and 4 of transformer T—1 and the voltages thereby produced across the windings 3 and 4 of transformer T—2 are such that the terminals of these several windings have the polarities indicated. Since the even terminal of winding 3 of transformer T—1 is positive and the odd terminal of winding 4 of said transformer is negative, the grid element of the amplifier A—2 is made negative with respect to its filament. Also, since the odd terminal of winding 3 of transformer T—2 is positive and the odd terminal of winding 4 of said transformer is negative, the grid element of amplifier A—3 is made negative with respect to the filament. Thus at the instant assumed both grid elements are negative; accordingly, the plate electrodes of these amplifiers are at this instant both positive so far as the signal is concerned. This is the condition for parallel operation of the two amplifiers. With the plate elements both positive, the even and odd terminals of the primary windings of transformers T—3 and T—4 have potentials of the polarities shown in the drawings. The windings 3 and 4 of transformer T—4 set up potentials in the windings 1 and 2 of that transformer of the polarities indicated. Since the windings 1 and 2 are connected in serial relation, these voltages add in the output path P—4. And since the tubes connected are working in parallel, the fundamental and all components that may be present are transmitted over the path P—4 toward the listener. At the same time the windings 3 and 4 of transformer T—3 induce potentials of the polarities shown in the output path P—3. In this case, however, the voltages in the windings 1 and 2 are in opposition for the reason that the primary windings 3 and 4 are connected in a sense opposite that of the primary windings 3 and 4 of the transformer T—4. Therefore, the fundamental and all existing components are completely neutralized in the transformer T—3 and none of them returns over the path P—3 toward the speaker. When an instant later the direction of current in the input path P—1 reverses, the polarities of the several windings and electrodes of the amplifiers also reverse but the result in the output paths P—4 and P—3 are similar to those just explained.

Referring now to Fig. 4 in which the transformers are connected the same and wound the same and all other elements are disposed the same as in Fig. 3, it will be assumed that transmission is coming in the opposite direction. At a given instant current flowing in the input path P—2 causes the even terminal of winding 1 of transformer T—2 to be positive and the odd terminal of winding 2 of that transformer to be negative. This results in the polarities shown for the other windings of the transformers T—2 and T—1. In this case the control or grid element of the amplifier A—2 is positive and the control element of the amplifier A—3 is negative, the condition for causing the two amplifiers to operate in a push-pull manner. Since one of the plate electrodes is positive and the other negative, the primary windings of transformer T—3 and T—4 assume the polarities indicated. The windings 3 and 4 of transformer T—3 induce potentials in the secondary windings 1 and 2 of that transformer having the polarities shown. Since the voltages across windings 1 and 2 are of the same polarities, they add and the resulting current flows over the path P—3 toward the listener. As is well known, the even-order components are in phase with each other in the common path C; therefore, they bear to each other a phase relation opposite that existing between the fundamental and odd-order components in the windings 3 and 4 of the transformer T—3. And it follows that these even-order components are canceled and do not produce any currents in the path P—3 toward the listener. An inspection of the polarities in the windings of transformer T—4 will show that the fundamental and odd-order components are canceled and do not produce currents in the path P—4 returning toward the speaker.

Since the even harmonic components are usually more objectionable it is possible to limit their effect both as regards the speaker and the listener. To do this the successive repeaters in a transmission system, such as the one illustrated in Fig. 5, are so connected to the adjacent transmission lines that the amplifiers in some of the repeaters operate in parallel and the amplifiers in others in push-pull for a particular direction of transmission. In Fig. 5, for example, alternate repeaters R—1 and R—2 are connected for parallel operation when transmission is from west to east and for push-pull operation when transmission is from east to west. Other alternate repeaters, such as repeaters R—3 and R—4, are connected for push-pull operation when transmission is from west to east and for parallel operation when transmission is from east to west.

The repeater disclosed in Fig. 2 is similar to that of Fig. 1 and has the added advantage that direct current signals may be transmitted over the line without obstruction by the repeating elements. In this case the input repeating paths P—5 and P—6 are connected to each other with the primary windings of the hybrid transformer T—7 in serial relation. The same is true of the output repeating paths P—7 and P—8. The amplifying path A—6 is coupled to the repeating paths in a manner similar to that shown in Fig. 1. The other amplifying path A—5, however, is coupled directly to the repeating paths at points between the primary windings of the hybrid transformers T—7 and T—8. With this arrangement it is possible to send direct current signals or dial impulses through the repeater from line L—3 to L—4 or in the opposite direction by way of the output repeating paths P—7 and P—8.

It will be understood that the amplifiers utilized in these repeaters are not limited by the invention to the form shown in the drawings. Any suitable form of amplifier may be used, such as the stabilized feed-back amplifier disclosed in H. S. Black's application, Serial No. 606,871, filed April 22, 1932.

What is claimed is:

1. In combination, two two-way signal wave transmission circuits, and a two-way repeater interconnecting said circuits, comprising two oppositely-directed one-way transmission paths coupled in conjugate relation with each other and in energy transmitting relation with said circuits, a plurality of conductively independent amplifiers and means coupling said amplifiers to said transmission paths so that said amplifiers are effective simultaneously to amplify signal energy transmitted between said circuits for each direction of signal transmission.

2. In combination, two two-way signal line sections and a two-way repeater interconnecting said line sections, comprising two one-way repeating paths for transmitting signals in opposite directions between said line sections, said paths being connected at their terminals in conjugate relation with each other and in energy transmitting relation with said line sections, a pair of wave amplifiers having conductively independent amplifying elements, and means coupling said amplifiers to said one-way paths so that they operate in push-pull to amplify the signal waves transmitted over one path and in parallel to amplify the signal waves transmitted over the other one-way path.

3. In combination, two two-way signal wave line sections, a two-way repeater therebetween comprising two oppositely directed one-way transmission paths coupled in conjugate relation with each other and in energy transmitting relation with the two line sections, a plurality of amplifying devices, transformer networks coupling said paths and said amplifying devices in such manner as to make all of said amplifying devices effective simultaneously to amplify signals transmitted over the one-way path for one direction, and also effective simultaneously to amplify signals transmitted over the one-way path for the other direction, and a continuous metallic circuit between said line sections through one of said networks and portions of said one-way paths.

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