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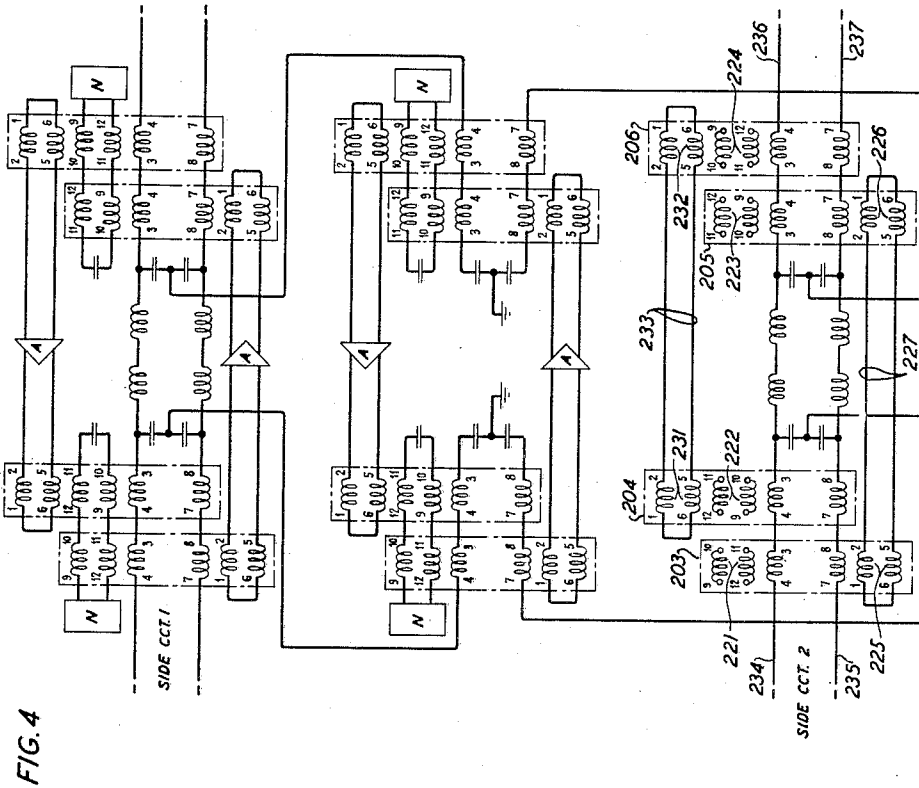
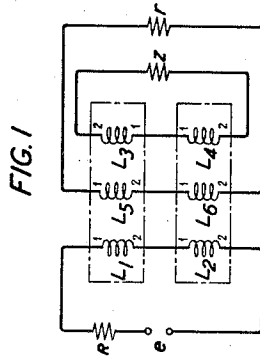
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2,328,434

SPEECH TRANSMISSION SYSTEM

Filed Feb. 28, 1942

3 Sheets-Sheet 1



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SPEECH TRANSMISSION SYSTEM

3 Sheets-Sheet 2



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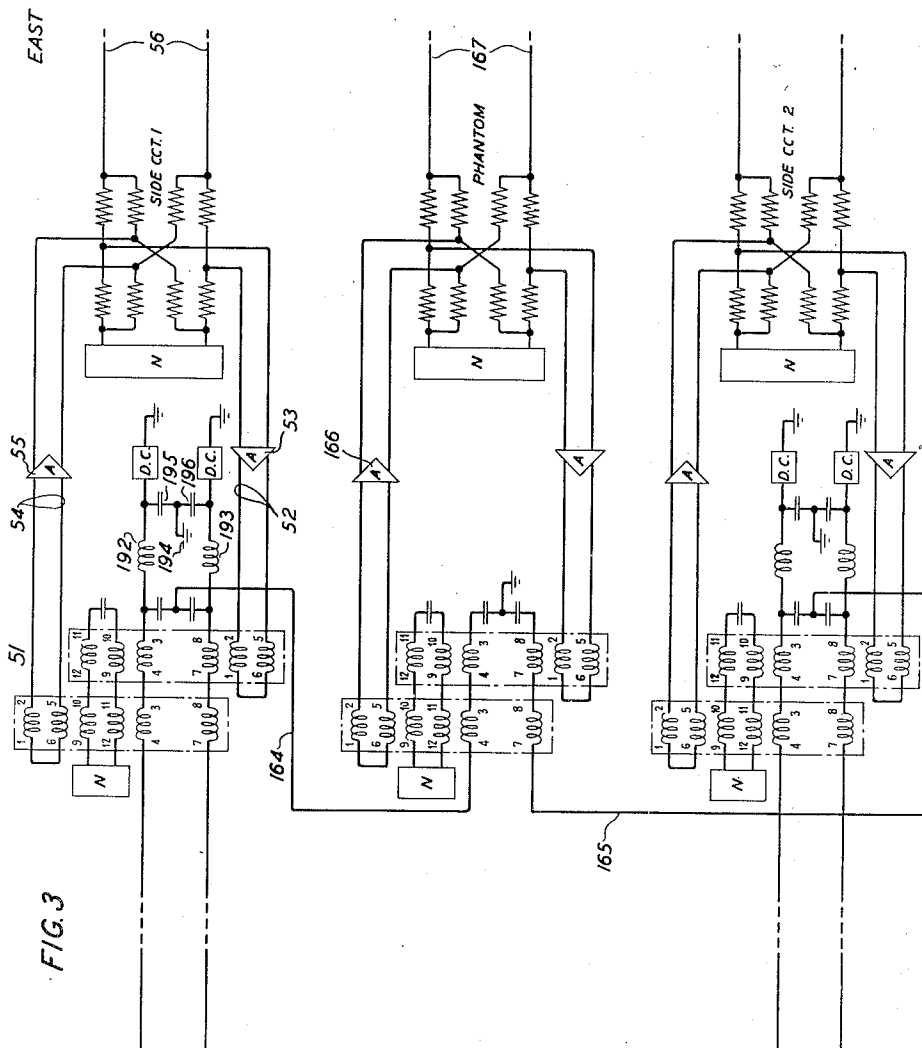
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,328,434

SPEECH TRANSMISSION SYSTEM

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Application February 28, 1942, Serial No. 432,811

6 Claims. (Cl. 179—15)

This invention relates to a speech transmission system of the type which includes telephone repeaters spaced at intervals along the transmission line and particularly to such a system utilizing repeaters of the type which include repeating coil hybrids.

An object of the invention is to enhance the adaptability of such systems to various operating situations.

Another object of the invention is to electrically simulate, by interconnecting windings of two repeating coils, a single repeating coil having an impedance ratio substantially the same as that of the two coils.

A more specific object of the invention is to permit one or two of the circuits of a phantom group to be dropped or carried through on a non-repeated basis while the remaining circuit, or circuits, is repeated, this being accomplished without noticeable reduction in the transmission efficiency of the overall system.

In Patent 2,282,464 issued May 12, 1942, to applicant and another, entitled, "Speech transmission system," there is disclosed (Figs. 4 and 5) a speech transmission system utilizing repeating coil hybrids; it is in connection with a system of this general nature that applicant's present invention is particularly applicable.

As disclosed in the patent referred to, the repeating coil hybrids ordinarily comprise two coils with separate cores. Each coil is provided with two line windings, the two "upper" line windings of the coils being connected in series with each other and with one side of the line and the two "lower" line windings being connected in series with each other and with the other side of the line. Two balancing network windings are provided on each core; these windings are connected to a balancing network common to the two coils. In addition, one coil of each hybrid is provided with an "out-amplifier" pair of windings and the other coil of the hybrid is provided with an "in amplifier" pair of windings. In the following description this arrangement will be generally referred to, when comparing it to the modification invented by applicant, as a "normal repeating coil hybrid."

In the use of a system of the general type referred to it often is found desirable that one or more of the circuits of a phantom group be dropped at an intermediate point or be carried through that point on a non-repeated basis while the remaining circuit, or circuits, of the group is repeated in the normal way. It is obvious, however, that it is at the same time

desirable that the overall system retain its previous electrical symmetry so that phantom balance will be maintained and for other reasons that will be discussed subsequently. Further, the condition requiring the above referred to modification of the circuits often is of a temporary nature and it may become desirable after a relatively short interval to restore all circuits of a phantom group to a repeated basis. It is desirable therefore that the arrangement be such that a change from one condition to the other can be accomplished readily.

A feature of the present invention is an arrangement of repeating coil windings whereby changing a circuit from a non-repeated to a repeated basis, or vice-versa, necessitates only a simple change in the interconnections of the windings.

A further feature of the invention is an arrangement of repeating coil windings whereby phantom balance is maintained regardless of the repeated or non-repeated condition of the circuits.

A still further feature of the invention is an arrangement of repeating coil windings whereby, in the instance of a repeater point at which certain circuits are on a non-repeated basis, direct current and low frequency alternating current signaling channels may be derived in the same manner as they are derived at repeater points where all circuits are on a repeated basis.

In accordance with a specific embodiment of the invention, the basic arrangement of the repeating coils is the same regardless of the number of circuits, if any, of a phantom group that are non-repeated. In the event that a circuit is on a non-repeated basis, however, a novel manner of rearranging the interconnections of certain of the repeating coil windings is followed whereby phantom balance is maintained and other desirable operating characteristics are assured.

A complete understanding of the various novel arrangements contemplated by the present invention as well as appreciation of the various desirable features thereof will be gained by consideration of the following detailed description in connection with the annexed drawings in which:

Fig. 1 is a schematic showing of a transformer circuit provided to facilitate explanation of the underlying theory of the present invention;

Figs. 2 and 3 illustrate schematically a speech transmission system utilizing combined repeating coil hybrids, certain of the circuits being dropped

at the intermediate repeater point and certain of the repeating coil windings being modified in accordance with features of the present invention; and

Fig. 4 illustrates schematically the intermediate repeater section of a system of the nature illustrated by Figs. 2 and 3; certain of the circuits being carried through on a non-repeated basis.

Referring now to Fig. 1 there is shown schematically a transformer circuit which includes three pair of series connected windings distributed on two magnetic cores. It is believed that a short description here of certain facts discovered by applicant in connection with this general type of circuit will facilitate subsequent description of practical application of these discoveries.

This circuit is intended to illustrate the general principles involved in the repeating coil hybrid referred to above, it being obvious that the various single windings L_1, L_2 , etc., may represent two winding sections connected in series on the same core. As a general principle it may be stated that when transformers are connected with primaries and secondaries in series (in Fig. 1 we may consider for purpose of discussion that L_1 and L_2 are the primary windings and that L_5 and L_6 are the secondary windings) the ampere turns of the primary must balance the ampere turns of the secondary on a given coil. So long as the arrangement is symmetrical no difficulty arises. If, however, the arrangement is not symmetrical, the result is the equivalent of a high series impedance and the circuit is inoperative. Applicant has observed, however, that if a third pair of series windings link the two cores and if the three sets of windings be so poled that two sets are series aiding and the third set series opposing then the flux will be so distributed that the ampere turns are balanced. It will be seen that the arrangement of windings illustrated in Fig. 1 is as just described, the two sets of windings L_1, L_2 and L_5, L_6 being series aiding and the third set of windings L_3, L_4 being series opposing. If the three sets of windings are connected to R, r and Z , respectively as illustrated, an electromotive force can be connected to any of the branches and the power divided among the three impedances; or any one of the three impedances can be short-circuited and an electromotive force connected in series with one of the remaining impedances to supply power to the other impedance. According to applicant's theory, the short-circuiting of one winding corresponds to holding stationary one set of gears in a planetary transmission, and the resulting transformer ratios represent the gear ratios of the free gear members. When power is transmitted through the transformer to two impedances it is distributed to each according to the ratios and to the loads as it would be in the gear system.

Referring again now to Fig. 1 for a specific illustration of the above-described theory, let us assume for the moment that windings L_3 and L_4 and the associated circuit are not provided. Now if $L_1=L_2$ and $L_5=L_6$ the arrangement is symmetrical in the sense referred to above and is operative. However, if $L_1=L_2$ but $L_5 \neq L_6$, the system is unsymmetrical and as pointed out above would therefore be inoperative for ideal transformers. In fact, if $L_1/L_2 \neq L_5/L_6$, the arrangement is inoperative.

Assuming now that windings L_3 and L_4 with the associated circuit be added, then if $L_1=L_2, L_5=L_6$, and $L_3=L_4$, the normal operating condition of the hybrid coil, no current will flow in Z and the

value thereof may be anything from zero to infinity. If $L_1=L_2$ and/or $L_5=L_6$, the flux will be balanced for any arrangement of electromotive force and two or three impedances regardless of whether L_3 and L_4 are equal.

The mesh equation for Fig. 1 arranged in determinant form (determinant being used in the usual mathematical sense as a short form for representing the summation of a number of products of the constants of linear simultaneous equations) are:

i_1	i_2	i_3
L_1+L_2+R $-(L_{25}+L_{15})$ $(L_{13}-L_{24})$	$-(L_{26}+L_{13})$ $+(L_5+L_6+r)$ $+(L_{46}-L_{35})$	$+L_{13}-L_{24}=e$ $+(L_{46}-L_{35})=0$ $+(L_3+L_4+Z)=0$

where $L_{26}=\sqrt{L_2 L_6}$ etc.,).

Solving for

$$i_1 = e \frac{x}{\Delta}$$

the impedance faced by the voltage e is:

$$Z_R = \frac{e}{i_1} = \frac{\Delta}{x} \quad (1)$$

The solution of the determinant is simplified by the fact that in Δ the terms involving the product of three inductances add to zero. If the transformer approaches the ideal (i. e. very high inductance per winding) terms involving one inductance or no inductance generally can be ignored compared to terms involving the product of two inductances. The value of Z_R then is:

$$Z_R = R + Pr + Qz \quad (2)$$

where P and Q are the ratios respectively:

$$P = \frac{(L_1+L_2)(L_3+L_4) - (L_{13}-L_{24})^2}{(L_5+L_6)(L_3+L_4) - (L_{46}-L_{35})^2} \quad (3)$$

$$(P \text{ is zero if } \frac{L_1}{L_2} = \frac{L_3}{L_4})$$

and

$$Q = \frac{(L_1+L_2)(L_5+L_6) - (L_{25}+L_{15})^2}{(L_5+L_6)(L_3+L_4) - (L_{46}-L_{35})^2} \quad (4)$$

$$(Q \text{ is zero if } \frac{L_1}{L_2} = \frac{L_5}{L_6})$$

Similarly it can be shown that sending from r the impedance

$$Z_r = r + MR + Nz \quad (5)$$

where M and N are the ratios respectively:

$$M = \frac{(L_3+L_4)(L_5+L_6) - (L_{46}-L_{35})^2}{(L_1+L_2)(L_3+L_4) - (L_{13}-L_{24})^2} \quad (6)$$

and

$$N = \frac{(L_1+L_2)(L_5+L_6) - (L_{25}+L_{15})^2}{(L_1+L_2)(L_3+L_4) - (L_{13}-L_{24})^2} \quad (7)$$

and sending from z the impedance

$$Z_z = z + JR + Kr \quad (8)$$

where J and K are the ratios respectively:

$$J = \frac{(L_3+L_4)(L_5+L_6) - (L_{46}-L_{35})^2}{(L_1+L_2)(L_5+L_6) - (L_{25}+L_{15})^2} \quad (9)$$

and

$$K = \frac{(L_1+L_2)(L_3+L_4) - (L_{13}-L_{24})^2}{(L_1+L_2)(L_5+L_6) - (L_{25}+L_{15})^2} \quad (10)$$

For disclosure of a practical application of the above outlined theory reference should now be made to Figs. 2 and 3; these figures should be joined left to right respectively. There is sche-

matically illustrated in these figures a portion of a speech transmission system comprising a west terminal repeater section; an intermediate repeater section and an east terminal repeater section. The system illustrated is substantially the same as that illustrated by Figs. 4 and 5 of the patent referred to above except for the fact that resistance hybrids are utilized at the office side of the terminal repeaters instead of repeating coil hybrids and the fact that the circuits of side circuit No. 2 are dropped at the intermediate repeater point (i. e. are on a non-repeated basis), the arrangement of the repeating-coil windings at that point being modified in accordance with features of the present invention.

At the west terminal repeater section, the input path 11 of west-east amplifier 12 and the output path 13 of east-west amplifier 14 are connected in conjugate relationship with each other and in energy transferring relationship with line section 15 of side circuit No. 1 by the resistance hybrid and associated balancing network 16. Output path 17 of amplifier 12 and input path 21 of amplifier 14 are connected in conjugate relationship with each other and in energy transferring relationship with lines 22 and 23 by the repeating coil hybrid 24 and associated balancing network 25.

Voice frequency currents impressed on line section 15 by the voice frequency equipment of the west terminal of side circuit No. 1 divide in the branches of the resistance hybrid, one half passing into output circuit 13 of the east-west amplifier and being lost and the useful half passing into input path 11 of west-east amplifier 12. These currents, after amplification by west-east amplifier 12, are impressed, through windings of repeating coil hybrid 24, on lines 22 and 23. As output path 17 and input path 21 are coupled in conjugate relationship, no part of these amplified currents enters the input path of east-west amplifier 14.

The voice frequency currents pass over lines 22 and 23 to the intermediate repeater point where they again divide among the windings of repeating coil hybrid 26, one half passing into output path 27 of east-west amplifier 41 and being lost and the useful half passing into input path 42 of west-east amplifier 43. These currents, after amplification by west-east amplifier 43, are impressed on lines 44 and 45 for transmission to the east terminal. As the output path of amplifier 43 and the input path of amplifier 41 are coupled in conjugate relationship through repeating coil hybrid 46, no part of the amplified currents enters the input path of east-west amplifier 41.

The amplified voice frequency currents pass over lines 44 and 45 to the east terminal where they divide among the windings of repeating coil hybrid 51, one half of the energy passing into output path 52 of east-west amplifier 53 and being lost and the useful half of the energy passing into input path 54 of west-east amplifier 55. These amplified currents are impressed on line section 56 through the resistance hybrid and pass thereover to the east terminal voice frequency receiving apparatus of side circuit No. 1. Since the output path of amplifier 55 and the input path of amplifier 53 are coupled in conjugate relationship through the resistance hybrid no part of the amplified current enters the input path of amplifier 53.

It will be understood that transmission of voice frequency currents over side circuit No. 1 from

east to west is accomplished in a manner similar to that described above.

It will be observed that the west terminal equipment of side circuit No. 2 is the same as that of side circuit No. 1 and it will be understood that voice frequency currents originated by the west terminal transmitting equipment of side circuit No. 2 will be applied to lines 71 and 72 in a manner generally similar to that described above.

It will be observed further that a phantom circuit is derived at the west terminal for transmission of voice frequency currents produced by the voice frequency transmitting equipment associated with line section 73. This derivation is over lines 74 and 75; line 74 is connected to lines 22 and 23 of side circuit No. 1 between capacitances 76 and 77 while line 75 is connected to lines 71 and 72 of side circuit No. 2 between capacitances 81 and 82.

The voice frequency currents originating in line section 73 are amplified by west-east amplifier 83 before they are impressed on the phantom circuit referred to above. This amplifier and the other equipment units of the phantom terminal are similar to the corresponding units of the west terminal equipment of side circuit No. 1 and operate in a generally similar manner.

Considering now the intermediate repeater section it will be observed that the intermediate section equipment of side circuit No. 2 differs from that of side circuit No. 1, described above, in that the voice frequency circuits of side circuit No. 2 are terminated at the intermediate section. This means, of course, that the two repeated paths that we find in the equipment of side circuit No. 1 are not present in the equipment of side circuit No. 2. The arrangement of the repeating coil equipment of side circuit is modified in accordance with features of the present invention.

Considering first repeating coils 84 and 85 it will be noticed that the general arrangement, i. e. number and location of windings, etc., is the same as that of repeating coil hybrid 26. However the windings of repeating coils 84 and 85 are so interconnected that the two coils function as a single repeating coil of proper impedance and not as a combined repeating coil and hybrid coil as does repeating coil hybrid 26.

It will be noticed that the arrangement of line windings 101, 103, 102 and 104 of coils 84 and 85 is the same as that of the corresponding line windings of repeating coil hybrid 26. As the coils function only as a single repeating coil and not as a combined repeating coil and hybrid coil no balancing network need be provided; in accordance with a feature of the present invention windings 105, 106, 107 and 111, corresponding to the balancing network windings of the repeating coil hybrids, are connected in the form of a short-circuited loop. This in effect electrically merges the two cores and causes the device to function as a single coil. Winding 112 of coil 85, which corresponds to the upper winding of the in-amplifier pair of windings of repeating coil hybrid 26, is left open while coil 113, corresponding to the other winding of the in-amplifier pair of repeating coil hybrid 26, is connected in series with windings 114 and 115 of repeating coil 84; windings 114 and 115 correspond to the out-amplifier pair of windings of repeating coil hybrid 26. Included in this series path may be the usual tip and ring leads of the switchboard drop.

By remembering the fact that the impedance ratio of a transformer is approximately the square of the ratios of the turns of the windings and keeping in mind that the "single" repeating coil comprising coils 84 and 85 is designed to operate at one-half the impedance of the normal repeating coil hybrid we may set down the equation:

$$R^1 = \frac{R}{2} \left(\frac{4}{3} \right)^2 = \frac{8}{9} R$$

Where R is the impedance ratio of a normal repeating coil hybrid (such as hybrid 26) and R^1 is the impedance ratio of the rearranged coils (such as coils 84 and 85). In other words the impedance ratio of the single (in effect) repeating coil associated with side circuit No. 2 at the intermediate repeater point is practically the same as that of repeating coil hybrid 26 of side circuit No. 1 or the corresponding repeating coil hybrid of the intermediate phantom repeater.

The two impedance ratios are so nearly equal that the transmission efficiency of the overall system is not affected unfavorably by the necessary lack of physical symmetry at the intermediate repeater point. Further, it will be readily apparent that should it become desirable to re-establish the circuits of side circuit No. 2 on a repeated, through basis at the intermediate point, it would be a simple matter of changing a relatively few interconnecting leads in order to rearrange coils 84 and 85 to comprise a repeating coil hybrid the exact duplicate of repeating coil hybrid 26. Other advantages of the arrangement, particularly its adaptability to phantom derivation (no special facilities need be provided for maintaining phantom balance) and to the transmission of direct current and low frequency alternating current supervisory signals will be apparent from subsequent portions of the description.

It might be of interest here to refer for the moment to Fig. 1 and portions of the description thereof in order that application of the theory of the circuit of Fig. 1 to the modification of the repeating coil windings of side circuit No. 2 may be established. We have in the circuit of Fig. 1, the windings L_1 and L_2 , the first mentioned corresponding to line windings 101 and 103 of coil 84 (Figs. 2 and 3) and the last mentioned corresponding to line windings 102 and 104 of coil 85; windings 101 and 103 are connected to windings 102 and 104 respectively in series-aiding relationship. Windings 105 and 106 (Figs. 2 and 3) correspond to winding L_3 and windings 107 and 111 correspond to winding L_4 and are connected in a short-circuited loop, i. e. the impedance corresponding to r is zero, windings 105 and 106 being connected to windings 107 and 111 respectively in series-aiding relationship. Windings 114 and 115 correspond to winding L_3 and winding 113 corresponds to winding L_4 , winding 113 being connected to windings 114 and 115 in series opposing relationship. It will be recalled that it was stated above that applicant has discovered that in a circuit of the type illustrated in Fig. 1 (and in Figs. 2 and 3) any of the three impedances can be short circuited (r of Fig. 1; the balancing network impedance of Figs. 2 and 3) and an electromotive force connected in series with one of the remaining impedances (e of Fig. 1; the speech energy present in lines 71 and 72 of Figs. 2 and 3) to supply power to the other impedance (Z of Fig. 1; the impedance of the local switchboard circuits of Figs. 2 and 3).

It will be understood, of course, that the equip-

ment of other circuits of the phantom groups may be modified, as required, in the same manner as that described in connection with the intermediate section of side circuit No. 2.

It is believed that the operation of coils 84 and 85 in reception and transmission of voice frequency currents will be readily apparent. It will be recalled that it was brought out above that voice frequency currents originated by the west terminal transmitting equipment of side circuit No. 2 are applied to lines 71 and 72. These voice frequency currents pass over lines 71 and 72 to the intermediate point where they traverse line windings 101, 102, 103 and 104 of coils 84 and 85. These currents are impressed on the T and R conductors leading to the local switchboard circuits through inductive action between windings 101, 103, 114 and 115 of coil 84 and windings 102, 104 and 113 of coil 85.

There is, of course, no through transmission between the west and east terminals over side circuit No. 2 for voice frequency currents but such currents originating in the circuits associated with the T and R leads of repeating coil 84 may be transmitted over side circuit No. 2 from the intermediate point to the west terminal in a manner similar to that just described above. Similarly voice frequency currents may be transmitted in both directions over side circuit No. 2 between the east terminal and the local switchboard circuits connected through the T and R conductors to windings of repeating coils 131 and 132; the arrangement of coils 131 and 132 is similar to that of coils 84 and 85 described above.

It will be recalled that it was brought out above that a phantom circuit is derived from side circuits Nos. 1 and 2 for transmission of phantom circuit voice frequency currents originated in line section 73, this phantom circuit is derived as was pointed out, over lines 74 and 75.

The phantom circuit voice frequency currents upon reaching the intermediate repeater section are picked off by lines 133 and 134, line 133 being connected to lines 22 and 23 of side circuit No. 1 between capacitances 135 and 136 and line 134 being connected to lines 71 and 72 of side circuit No. 2 between capacitances 137 and 141.

The phantom circuit voice frequency currents are now amplified by west-east amplifier 142 of the phantom circuit intermediate repeater section after which they are again impressed on the two side circuits over lines 143 and 144; line 143 is connected to lines 44 and 45 of side circuit No. 1 between capacitances 145 and 146 and line 144 is connected to lines 147 and 161 of side circuit No. 2 between capacitances 162 and 163.

It will be observed that in spite of the fact that the intermediate repeaters of the two side circuits are physically unsymmetrical in view of the fact that circuits of the side circuit No. 2 are dropped, the novel interconnection of the repeating coils of side circuit No. 2 contemplated by the present invention results in an arrangement whereby the normal derivation of the phantom circuit is not disturbed and whereby the phantom circuit voice frequency currents may be picked off at the intermediate repeater point, amplified and returned to the side circuits with no additional problem whatsoever arising from the fact that circuits of side circuit No. 2 are non-repeated. This is, of course, a valuable feature not only in view of the resulting advantages when the circuits are as described but also in view of the fact that should the intermediate section circuits of side circuit No. 2 subsequently be placed

on a repeated basis, such change can be introduced without necessitating any change in the phantom circuit connections.

Upon reaching the east terminal, the phantom circuit voice frequency currents are again picked off the side circuits by lines 164 and 165 and, after amplification by west-east amplifier 166, are applied by the resistance hybrid to line section 167 and transmitted thereover to the voice frequency equipment associated therewith.

It will be understood that transmission of voice frequency currents over the phantom circuit from east to west is accomplished in a manner similar to that just described.

Direct current signals from source 171, for example dialing impulses or telegraph signals, may be applied to line 22 through composite set retardation coil 172, which is connected in series with the upper pair of line windings of repeating coil hybrid 24, and may be applied from source 173 to line 23 through composite set retardation coil 174 which is connected in series with the lower pair of line windings of repeating coil hybrid 24.

It will be noticed that a continuous straight-through path is provided for the direct current signals at the intermediate repeater section so that these signals continue on without interruption and with no substantial attenuation to the east terminal. Retardation coils 175, 176, 177 and 191 serve to exclude the voice frequency currents from this straight-through direct current path at the intermediate repeater section.

At the east terminal, the direct current signals, after passing through the respective line windings of repeating coil hybrid 51 and respective composite set retardation coils 192 and 193, are impressed on the receiving apparatus associated with the east terminal composite set of side circuit No. 1. Any voice frequency current which may chance to find its way into the direct current circuit will be drained off to ground 194 through capacitances 195 and 196. (Capacitances 197 and 201 and ground 202 fulfill a similar function at the west terminal.)

It will be understood that transmission of direct current and low frequency alternating current signals over side circuit No. 1 from east to west is accomplished in a manner similar to that described above. It will be understood further that transmission of such signals in both directions over side circuit No. 2 is also accomplished in a similar manner and it should be particularly noted that the novel arrangement of the repeating coils of the intermediate section of side circuit No. 2 (where circuits are on a non-repeated basis) is such as to permit the transmission of these signals over side circuit No. 2 in exactly the same manner as over side circuit No. 1; this is a particularly valuable feature not only in view of the resulting advantages when the circuits are as disclosed but also in view of the fact that should the intermediate section circuits of side circuit No. 2 subsequently be placed on a repeated basis, such change can be introduced without necessitating any change in the direct current path.

To briefly sum up some of the outstanding advantages of the novel arrangement contemplated by the present invention and disclosed as applied to the intermediate section of side circuit No. 2; the first advantage to be noted is that, while the electrical characteristics of the combined coil are so closely similar to those of the normal repeating coil hybrid that the modified

structure may be used in a circuit in place of the normal repeating coil hybrid without substantial reduction in the transmission efficiency of the overall system, the physical structure is such that conversion of the modified structure to the normal repeating coil hybrid structure or vice versa involves only a few simple changes in the connecting leads. An additional advantage is the fact that in spite of the unsymmetrical arrangement necessitated by the fact that the circuits of one side circuit are on a non-repeated basis; the method of deriving the phantom circuit and the method of transmitting direct current and low frequency alternating current signals at the "unsymmetrical" intermediate point are exactly the same as those followed at the other points. Obviously this is an advantageous feature as it greatly facilitates changing the circuits of a section from a non-repeated to a repeated basis or vice versa.

Referring now to Fig. 4 there is shown schematically an arrangement of the intermediate repeater section that may be utilized in systems of the type disclosed in Figs. 2 and 3 on occasions when the intermediate circuits of side circuit No. 2, while on a non-repeated basis as in the system described above, are not dropped at the intermediate point but are carried through.

It will be understood that the west and east terminal equipment of the system is the same as that of the system described above and this equipment will not be further described. It will be apparent from the drawings that the intermediate repeater section equipment of side circuit No. 1 and of the phantom circuit is the same as that of the corresponding portions of the system of Figs. 2 and 3. The intermediate section equipment of side circuit No. 2 has been modified however in view of the fact that the voice frequency circuits of this side circuit are carried through on a non-repeated basis.

It will be noticed that the arrangement of the line windings of repeating coils 203, 204, 205 and 206 is the same as that of the line windings of the normal repeating coil hybrids. Windings 221, 222, 223 and 224, corresponding to the balancing network windings of a normal repeating coil hybrid, are left open while windings 225 of coil 203 and windings 226 of coil 205 are connected in a short-circuited loop by path 227 and windings 231 of coil 204 and windings 232 of coil 206 are likewise connected in a short-circuited loop by path 233.

Voice frequency currents received at the intermediate section of side circuit No. 2 over lines 234 and 235 divide among the windings of coils 203 and 204, one half of the energy passing over path 227 to windings 226 of coil 205 and the balance passing over path 233 to windings 232 of coil 206. This energy passes into lines 236 and 237 through induction between windings 226 and the line windings of coil 205 and induction between windings 232 and the line windings of coil 206 respectively; the energy is transmitted over lines 236 and 237 to the east terminal.

It will be observed that the novel arrangement disclosed permits passage of direct current and low frequency alternating current signals through the intermediate repeater section of side circuit No. 2 in the same manner as that followed in the instance of the circuits provided with normal repeating coil hybrids; it will be apparent further that should it be subsequently found desirable to place the intermediate circuits of side circuit No. 2 on a repeater basis, only slight

changes in the interconnecting wiring of the repeating coils will be necessary. The arrangement has been found to so closely simulate the electrical characteristics of a normal repeating coil hybrid that the operating efficiency of the overall system is not appreciably lowered by substitution of a modified repeating coil arrangement for a normal repeating coil hybrid.

It will be apparent that the novel discoveries of applicant in connection with the operation of the general type of circuit illustrated in Fig. 1 are capable of various other practical applications in addition to those specifically disclosed. Innumerable impedance ratios may be obtained as required by utilizing different polings and interconnections of the several windings and various applications are foreseen, among them being use for equalization purposes as the series equalizing impedances can be multiplied by the transformer ratio. It will be also understood, of course, that the type of speech transmission system in connection with which the invention has been described may, and in most cases will, include more than one intermediate repeater section; the modified repeating coil arrangement may, of course, be used at any point where circuits are on a non-repeated basis. In sort it should not be considered that the invention is limited in its application to the specific embodiments disclosed. These embodiments should be looked upon as illustrative and not as restrictive.

What is claimed is:

1. In a speech transmission system, a first side circuit including a terminal section and an intermediate repeater section, a first two-wire line connecting said sections, a second side circuit including a terminal section and an intermediate non-repeated section, a second two-wire line connecting said two last-mentioned sections, a two-way repeater for voice frequency currents at said intermediate repeater section, a repeating coil hybrid connecting said first two-wire line to two sides of said repeater in mutually conjugate relationship, means for deriving a phantom circuit from said two side circuits, an intermediate phantom repeater section, means at said intermediate sections of said two side circuits for picking off phantom currents for application to said intermediate phantom repeater section; and a pair of repeating coils connecting said second two-wire line to equipment of said intermediate non-repeated section; the arrangement and interconnection of said pair of repeating coils being such as to prevent any appreciable unbalance of the intermediate phantom repeater section due to the unsymmetrical relationship of the repeated and non-repeated intermediate sections of the two side circuits.

2. In a speech transmission system of the type including two side circuits and a phantom circuit derived from said side circuits, a phantom group at a point in the system including a repeated side circuit section, a phantom section and a non-repeated side circuit section, a two-way voice frequency repeater for said repeated side circuit section, a repeating coil hybrid connecting the lines of one of said side circuits to two sides of said repeater in mutually conjugate relationship, said repeating coil hybrid comprising a pair of magnetic cores and three pairs of inductive windings on each of said cores, said windings being positioned on the respective cores and interconnected in a predetermined manner, voice frequency terminating equipment associated with said non-repeated side circuit section; a pair of

repeating coils connecting the lines of the other of said side circuits to said voice frequency terminating equipment, each of said repeating coils comprising a magnetic core provided with three pairs of windings thereon, said repeating coils being with respect to the number of windings and arrangement thereof on the respective cores the exact physical duplicate of said repeating coil hybrid, and means for so interconnecting the windings of said repeating coils that the two coils function as the electrical equivalent of a single coil having an impedance ratio substantially the same as that of said repeating coil hybrid.

3. In a speech transmission system, a first side circuit including a terminal section and an intermediate repeater section, a first two-wire line connecting said sections, a second side circuit including a terminal section and an intermediate non-repeated section, a second two-wire line connecting said two last-mentioned sections, a two-way repeater for voice frequency currents at said intermediate repeater section, a first differential transformer connecting said first two-wire line to two sides of said repeater in mutually conjugate relationship, means for deriving a phantom circuit from said two side circuits, an intermediate phantom repeater section, means at said intermediate sections of said two side circuits for picking off phantom currents for application to said intermediate phantom repeater section, a second differential transformer connecting said second two-wire line to equipment of said intermediate non-repeated section, said second differential transformer comprising a first magnetic core and a second magnetic core, a first line winding and a second line winding on said first core, a first line winding and a second line winding on said second core, said first line windings being connected in series with each other and with one side of said second two-wire line, said second line windings being connected in series with each other and with the other side of said second two-wire line, a third winding and a fourth winding on said first core, a third winding and a fourth winding on said second core, and means for connecting said third and fourth windings of each core in the form of a short-circuited loop, said means for picking off said phantom currents including a line connected in parallel to the two line windings on said second core.

4. In a speech transmission system, a first side circuit including a terminal section and an intermediate repeater section, a first two-wire line connecting said sections, a second side circuit including a terminal section and an intermediate non-repeated section, a second two-wire line connecting said two last-mentioned sections, a two-way repeater for voice frequency currents at said intermediate repeater section, a first differential transformer connecting said first two-wire line to two sides of said repeater in mutually conjugate relationship, means for deriving a phantom circuit from said two side circuits, an intermediate phantom repeater section, means at said intermediate sections of said two side circuits for picking off phantom currents for application to said intermediate phantom repeater section, and a second differential transformer connecting said second two-wire line to equipment of said intermediate non-repeated section, said second differential transformer comprising a first magnetic core and a second magnetic core, a first line winding and a second line winding on said first core, a first line winding and a second line winding on said second core, said first line wind-

ings being connected in series with each other and with one side of said second two-wire line, said second line windings being connected in series with each other and with the other side of said second two-wire line, the arrangement of said second differential transformer being such that it is the electrical equivalent of a single core coil with an impedance ratio substantially equal to the impedance ratio of said first differential transformer, said means for picking off said phantom currents including a line connected in parallel to the two line windings on said second core.

5. In a speech transmission system, a first side circuit including a terminal section and an intermediate repeater section, a first two-wire line connecting said sections, a second side circuit including a terminal section and an intermediate non-repeated section, a second two-wire line connecting said two last-mentioned sections, a two-way repeater for voice frequency currents at said intermediate repeater section, a first differential transformer connecting said first two-wire line to two sides of said repeater in mutually conjugate relationship, means for deriving a phantom circuit from said two side circuits, an intermediate phantom repeater section, means at said intermediate sections of said two side circuits for picking off phantom currents for application to said intermediate phantom repeater section, a second differential transformer connecting said second two-wire line to equipment of said intermediate non-repeated section, said second differential transformer comprising a first magnetic core and a second magnetic core, a first line winding and a second line winding on said first core, a first line winding and a second line winding on said second core, said first line windings being connected in series with each other and with one side of said second two-wire line, said second line windings being connected in series with each other and with the other side of said second two-wire line, a plurality of other windings on said first core, a plurality of other windings on said second core and means for so

interconnecting certain of said other windings on each of said cores that said second differential transformer functions as the electrical equivalent of a single core coil with an impedance ratio substantially equal to the impedance ratio of said first differential transformer thereby preventing any appreciable unbalance of the intermediate phantom repeater section due to the unsymmetrical relationship of the repeated and non-repeated intermediate sections of the two side circuits.

6. In a speech transmission system of the type including two side circuits and a phantom circuit derived from said side circuits, a phantom group at a point in the system including a repeated side circuit section, a phantom section and a non-repeated side circuit section, a two-way voice frequency repeater for said repeated side circuit section, a repeating coil hybrid connecting the lines of one of said side circuits to two sides of said repeater in mutually conjugate relationship, said repeating coil hybrid comprising a pair of magnetic cores and three pairs of inductive windings on each of said cores, said windings being positioned on the respective cores and interconnected in a predetermined manner, voice frequency terminating equipment associated with said non-repeated side circuit section; a pair of repeating coils connecting the lines of the other of said side circuits to said voice frequency terminating equipment, each of said repeating coils comprising a magnetic core provided with three pairs of windings thereon, said repeating coils being with respect to the number of windings and arrangement thereof on the respective cores the exact physical duplicate of said repeating coil hybrid, means for connecting certain windings of each of said repeating coils in series aiding relationship with each other and to the lines of said other side circuit, and means for connecting other windings of said repeating coils in series opposing relationship with each other and to said voice frequency terminating equipment.

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