Dec. 8, 1942. M. R. KLEIST 2,304,179

SPEECH TRANSMISSION SYSTEM

Filed Feb. 28, 1942 3 Sheets-Sheet 1

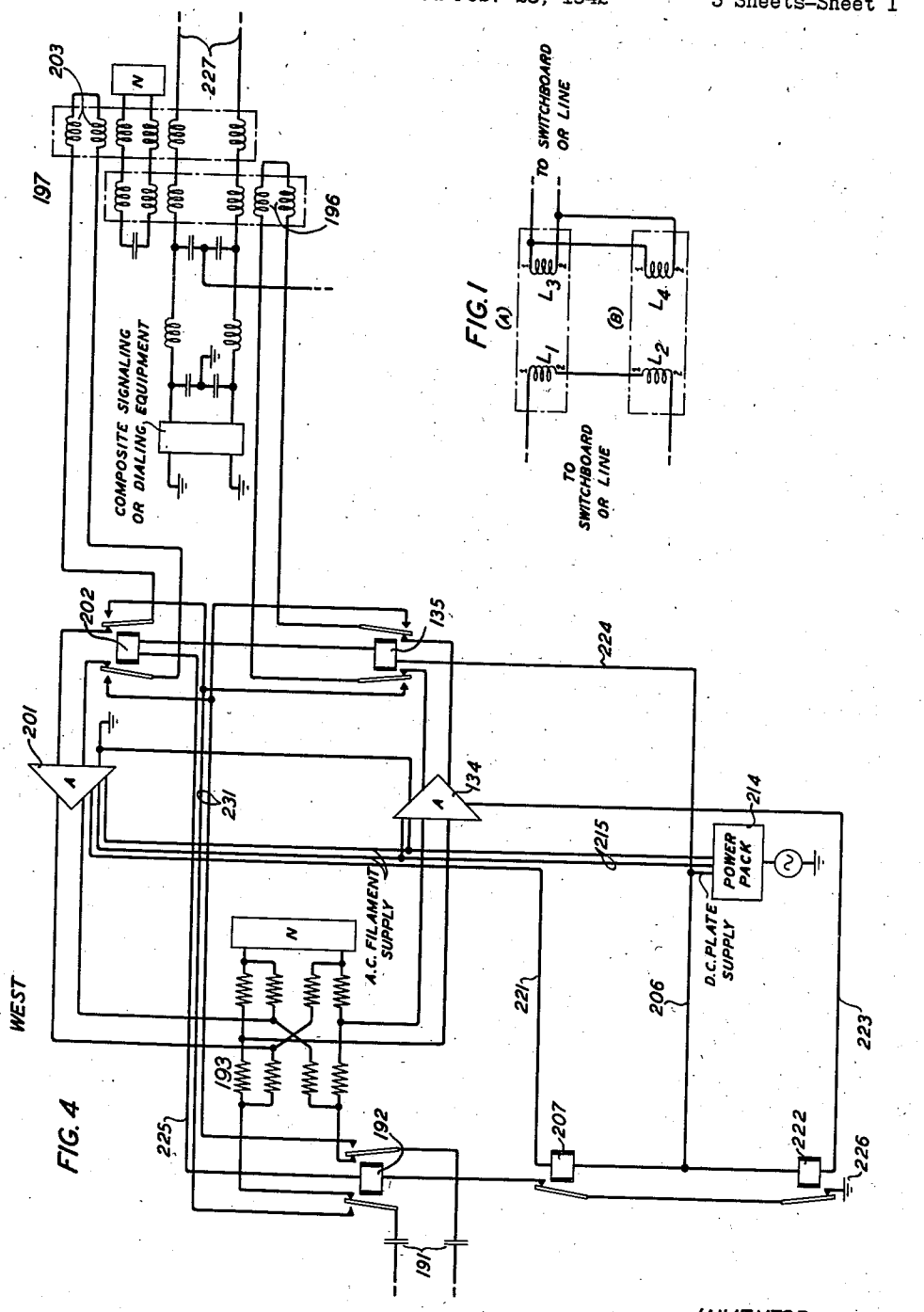

FIG. 4

FIG. 1

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SPEECH TRANSMISSION SYSTEM

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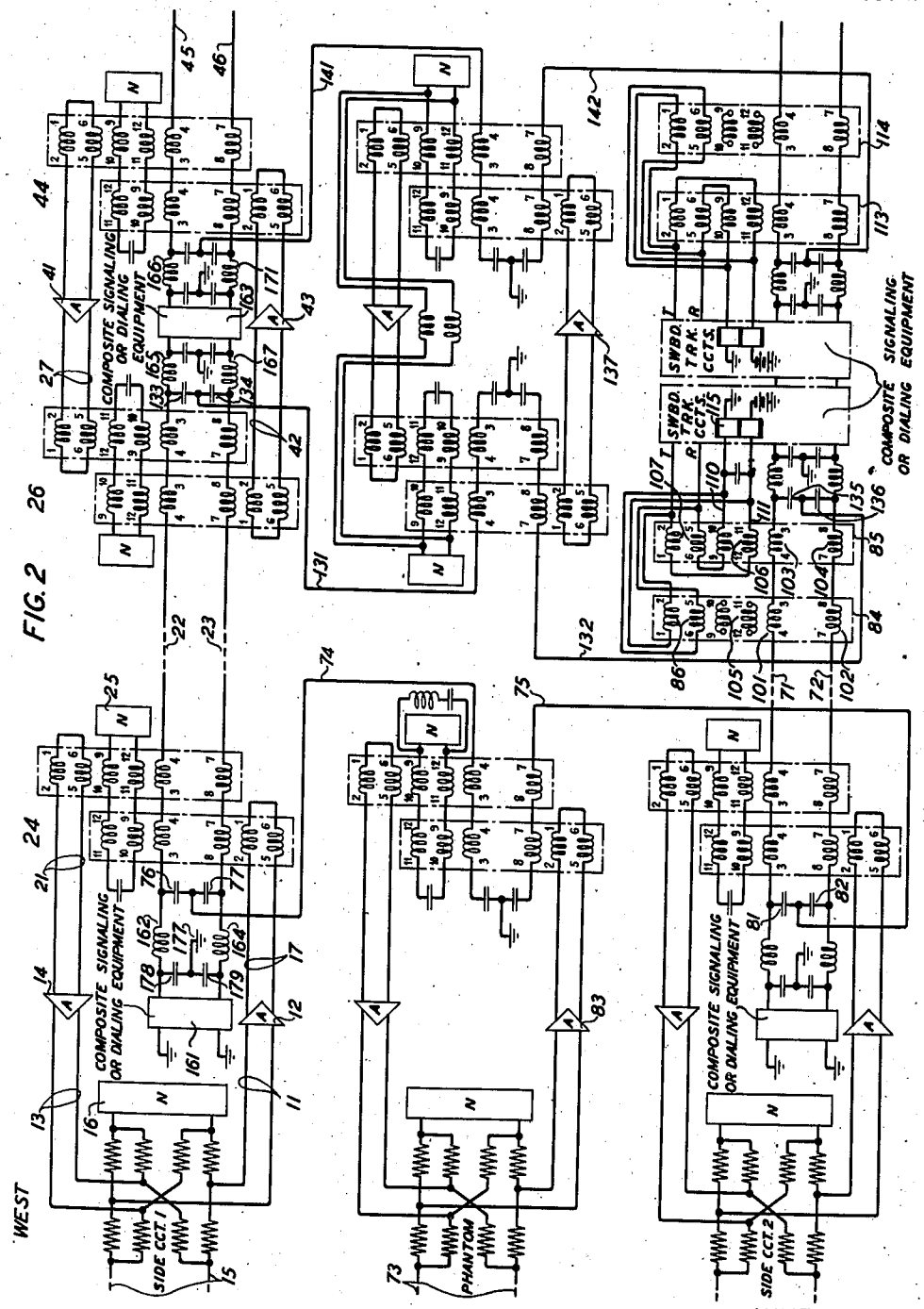

FIG. 2

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SPEECH TRANSMISSION SYSTEM

Filed Feb. 28, 1942 3 Sheets-Sheet 3

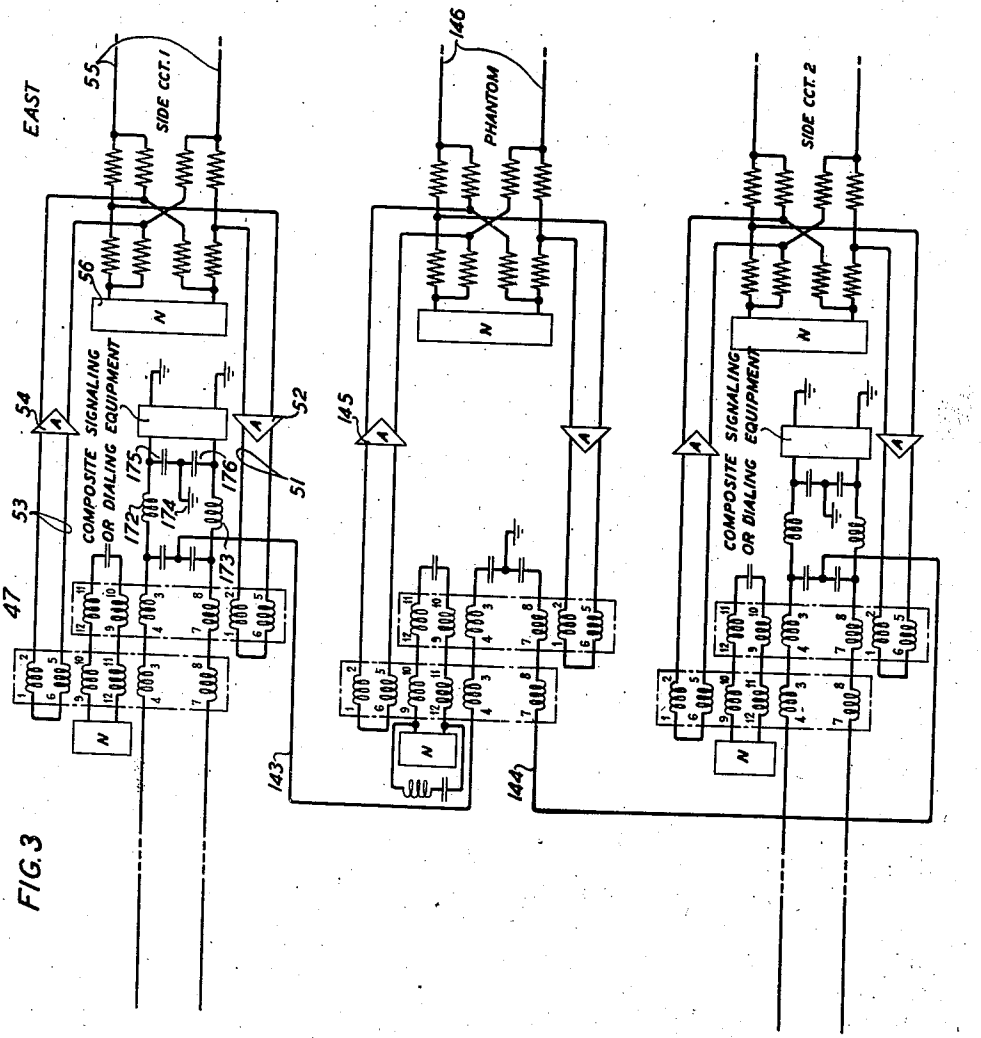

FIG. 3

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Patented Dec. 8, 1942

2,304,179

UNITED STATES PATENT OFFICE

2,304,179

SPEECH TRANSMISSION SYSTEM

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Application February 28, 1942, Serial No. 432,838

5 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 includes 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 equal to but slightly greater than that of the two coils.

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

In Patent 2,282,464 issued May 12, 1942, to Messrs. P. G. Edwards and E. R. Taylor, 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 the 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; the terminals of the respective "upper" and "lower" line winding which are not connected directly to the line are connected as dictated by the particular system. 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" hybrid pair of windings and the other coil of the hybrid is provided with an "in" hybrid 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 carried through on a non-repeatered basis, while the remaining circuit, or circuits, of the group is repeatered in the normal manner. 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. It is particularly desirable, for example, that the drop side of each of the modified repeating coil combinations be reasonably well balanced to ground so that the normal method of applying and controlling composite signaling currents may be followed at the non-repeatered point. 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 repeatered 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-repeatered basis to a repeatered basis, or vice versa, necessitates only a simple change of the conductive strapping of the windings.

A further feature of the invention is an arrangement of repeater coil windings whereby a reasonably good balance to ground is maintained on the drop side of each combination of repeating coils.

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-repeatered 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 repeatered basis.

Still another feature of the invention resides in switching means whereby, upon failure of a particular repeater, the arrangement of certain of the windings of the repeating coil hybrid associated therewith is automatically changed in a manner effective to appreciably reduce transmission loss.

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-repeatered. In the event that a circuit is on a non-repeatered basis, however, certain of the windings of the repeating coils associated therewith are connected in a novel parallel-aiding manner whereby a good balance to ground is main-

tained on the drop side of the coils 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 subsequent explanation of practical applications of the invention;

Figs. 2 and 3 illustrate schematically a speech transmission system utilizing 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 terminal section of one side circuit including switching means for automatically modifying the arrangement of certain of the repeating coil hybrid windings upon repeater failure.

Referring now to Fig. 1, this figure is intended to represent the general arrangement of any two transformers provided with primary windings connected in series aiding and secondary windings connected in parallel aiding. (This, in general, is the arrangement of the modified repeating coil arrangement utilized in non-repeatered circuits in accordance with the novel features of applicant's invention).

The impedance ratio of the coil of Fig. 1 may be written as:

$$\left(\frac{\sqrt{L_1L_4}+\sqrt{L_2L_3}}{\sqrt{L_3L_4}}\right)^2$$

or as the equivalent:

$$\frac{(L_{14}+L_{23})^2}{L_3L_4}$$

By reversing the poling of any one of the windings we obtain the impedance ratio

$$\frac{(L_{14}-L_{23})^2}{L_3L_4}$$

Obviously if winding turns N are used rather than inductance L the above equations can be written:

$$\frac{(N_1N_4+N_2N_3)^2}{N_3^2N_4^2}$$

If the transformers of Fig. 1 be of the type provided with multisection windings (this type of transformer is ordinarily used in the type of system to be described subsequently) numerous impedance ratios can be obtained by utilizing the various sections in different combinations. This may be desirable in a long speech transmission system where different impedance conditions are often encountered at different switchboards.

Referring now to Figs. 2 and 3 which should be joined left to right respectively, there is illustrated schematically 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 voice frequency circuits of side circuit No. 2 are dropped at the intermediate repeater point (i. e. are on a non-repeatered 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; input path 11 of west-east amplifier 12 and 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 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 path 13 of east-west amplifier 14 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 input path 21 of east-west amplifier 14.

The voice frequency currents pass over lines 22 and 23 to the intermediate repeater section where they again divide in 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 through windings of repeating coil hybrid 44 on lines 45 and 46 for transmission to the east terminal repeater section. As the output path of amplifier 43 and the input path of amplifier 41 are connected in conjugate relationship through repeating coil hybrid 44, no part of the amplified currents enters the input path of east-west amplifier 41.

The amplified voice frequency currents pass over lines 45 and 46 to the east terminal where they divide among the windings of repeating coil hybrid 47, one half of the energy passing into output path 51 of east-west amplifier 52 and being lost and the useful half passing into input path 53 of west-east amplifier 54. These amplified currents are impressed on line section 55 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 54 and the input path of amplifier 52 are connected in conjugate relationship by the resistance hybrid and associated balancing network 56, no part of the amplified currents enters the input path of east-west amplifier 52.

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 voice frequency 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 said 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 repeatered paths that we find in the equipment of side circuit No. 1 at the intermediate repeater section are not provided for side circuit No. 2. The arrangement of the repeating coil hybrids is modified in accordance with features of the present invention.

Considering first repeating coils 84 and 85, it will be observed that the general arrangement, i. e. number and location of windings, etc., is the same as that of the normal repeating coil hybrids for example hybrid 26. (For convenience of illustration windings 86 of repeating coil 84, which correspond to the "out" hybrid windings of repeating coil hybrid 26, have been shown on the upper end of the core rather than on the lower end.) However the windings of repeating coils 84 and 85 are so interconnected that they act as a single repeating coil of proper impedance and not as a combined repeating coil and hybrid coil as do the normal repeating coil hybrids such as hybrid 26.

It will be observed that the arrangement of line windings 101, 102, 103 and 104 of repeating coils 84 and 85 is the same as that of the corresponding line windings of repeating coil hybrid 26; these line windings are connected in series aiding relationship with respect to each other. As the coils function as a single repeating coil and not as a combined repeating coil and hybrid, no balancing network need be provided; windings 105, which correspond to one of the pairs of balancing network windings of a normal repeating coil hybrid are left open while windings 106, corresponding to the other pair of balancing network windings of a normal hybrid, are connected in series with windings 107 of the same coil which correspond to the "in" hybrid windings of normal repeating coil hybrid 26. Windings 80 in turn are connected in parallel aiding relationship with respect to windings 106 and 107; joining the two cores by this path in effect electrically merges coils 84 and 85 and causes the combination to function as a single coil. It becomes apparent therefore that we have in the arrangement of coils 84 and 85 the equivalent of that illustrated in Fig. 1 and described above, i. e. a repeating coil having the primary windings (line windings in the instance of coils 84 and 85) connected in series aiding and the secondary windings (windings 86 of coil 84 and the "two-part" secondary comprising windings 106 and 107 of coil 85) connected in parallel aiding.

In practical tests it has been found feasible to use the same basic coils in the modified arrangement invented by applicant as are used in the normal repeating coil hybrids and yet have in the modified device an impedance ratio that while closely approximating that of the normal repeating coil hybrid is at the same time slightly greater so that the transmission efficiency of the overall system not only is not affected unfavorably by the necessary lack of symmetry, at the intermediate repeater point but actually is definitely improved for the non-repeatered circuits of side circuit 2. It will be readily apparent that the arrangement is a particularly valuable one from an economic standpoint as, should it become desirable to establish the intermediate circuits of side circuit No. 2 on a through, repeatered, basis, it would be a simple matter to rearrange coils 84 and 85 to comprise a normal repeating coil hybrid such as hybrid 26. (As pointed out above the reason for establishing certain of the circuits on a non-repeatered basis is often of a temporary nature and it may become desirable after a short time to restore the circuits to a through, repeatered, basis.) 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. Another particularly valuable feature resides in the fact that both secondaries are balanced to ground to facilitate composite signaling.

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 pointed out above that voice frequency currents originating in the voice frequency equipment at the west terminal 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 section where they traverse line windings 101, 102, 103 and 104 of repeating coils 84 and 85. These currents are impressed, in turn, on the T and R leads of the local switchboard circuit through inductive action between the primary (line) windings and secondary windings 106, 107 and 86 of coils 84 and 85.

As pointed out above a feature of the novel arrangement disclosed resides in the fact that the drop side of the coil is well balanced to ground; this balance results from the particular manner in which the secondary windings are arranged. This is a particularly desirable feature as it permits the connection across lines 110 and 111 of composite signaling equipment of the type requiring the two lines to be well balanced to ground if the equipment is to operate satisfactorily; such equipment is ordinarily used for mid-point or local signaling and may comprise, for example, relay 115 which is provided with two parallel operating windings, one winding being in series with line 110 and ground and the other winding being in series with line 111 and battery.

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 local circuits as-

sociated with the T and R leads of repeating coil 85 may control the direct current impressed upon the lines 71 and 72 by the composite signaling or dialing equipment. This direct current is transmitted from the intermediate section over side circuit No. 2 to the west terminal in a manner similar to that described above. Similarly, voice frequency currents and direct current may be transmitted in both directions between the east terminal and the local switchboard circuits associated with the windings of repeating coils 113 and 114; the arrangement of coils 113 and 114 is similar to that of coils 84 and 85.

It will be recalled that it was pointed out above that a phantom circuit for transmission of voice frequency currents originating in line section 73 of the west phantom terminal is derived from side circuits Nos. 1 and 2; 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 131 and 132, line 131 being connected to lines 22 and 23 of side circuit No. 1 between capacitances 133 and 134 and line 132 being connected to lines 71 and 72 of side circuit No. 2 between capacitances 135 and 136. The phantom voice frequency currents are amplified at the intermediate point by west-east amplifier 137 of the phantom circuit intermediate repeater section after which they are again impressed on side circuits Nos. 1 and 2 over lines 141 and 142, respectively.

It will be observed that despite the fact that the intermediate sections of the two side circuits are physically unsymmetrical due to the fact that circuits of 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-repeatered. This is, of course, a particularly valuable feature not only in view of 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 repeatered basis, such change can be introduced without necessitating any change in the phantom connections.

Upon reaching the east terminal the phantom circuit voice frequency currents are again picked off the side circuits by lines 143 and 144 and, after amplification by west-east amplifier 145, are applied by the resistance hybrid to line section 146 and transmitted thereover to the voice frequency equipment of the east phantom terminal.

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.

Composite signaling currents for example dialing signals, may be applied to lines 22 and 23 by composite signaling equipment 161 through composite set retardation coils 162 and 164 which are connected, respectively, in series with the upper pair of line windings of repeating coil hybrid 24 and in series with the lower pair of line windings of the repeating coil hybrid.

The composite of signaling currents are transmitted over lines 22 and 23 to the intermediate repeater point where they are impressed on composite signaling equipment 163. This equipment may incorporate means for repeating the received composite signals into lines 45 and 46.

Retardation coils 165, 166, 167 and 171 serve to exclude voice frequency currents from the path provided for the composite signals at the intermediate repeater point.

At the east terminal composite signals received over lines 45 and 46, after passing through the respective line windings of repeating coil hybrid 47 and respective composite set retardation coils 172 and 173, are impressed on the receiving apparatus of the east terminal composite set associated with side circuit No. 1. Any voice frequency current that may happen to find its way into the direct current path will be drained off through the composite signaling or dialing equipment or to ground 174 through capacitances 175 and 176. Ground 177 and capacitances 178 and 179 and similar grounds and capacitances at the intermediate sections serve also to drain off noise currents from the composite signaling or dialing equipment which otherwise might enter the line circuits of the repeating coil hybrids.

It will be understood that transmission of composite signaling current over side circuit No. 2 is accomplished in a manner similar to that described above 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-repeatered basis) is such that the line equipment of side circuit No. 1 and side circuit No. 2 at the intermediate point is the same; 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 repeatered basis, such change can be introduced without necessitating any change in the composite signaling 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 modified arrangement are such that the equivalent of a single coil having an impedance ratio slightly higher than that of a normal repeating coil hybrid is produced whereby good performance both from a transmission efficiency and a return loss standpoint is achieved, the physical structure of the modified device is such that conversion to a normal repeating coil hybrid involves only a few simple rearrangements of the electrical strappings. An additional advantage of the modified arrangement is that the drop side of the coil is well balanced to ground thereby facilitating mid-point composite signaling. Among other advantages is the fact that despite the necessary unsymmetrical arrangement resulting when the circuits of one of the side circuits are non-repeatered at a particular section, the method of deriving the phantom circuit and the method of transmitting direct current and low frequency alternating current signals at the "unsymmetrical" points are exactly the same as the method followed at "normal" hybrid points. Obviously, this is a particularly advantageous feature as it greatly facilitates changing the circuits of a section from a non-repeatered to a repeatered basis or vice versa.

Referring now to Fig. 4 there is schematically illustrated the west terminal repeater section of one of the side circuits, for example side circuit No. 1, of a system of the general nature illustrated in Figs. 2 and 3. The amplifiers disclosed are of the alternating current energized type and, as will appear from subsequent description, novel switching means are included whereby upon repeater failure due to failure of the energizing current supply, the repeaters and the terminal resistance hybrid are automatically cut out of the system and the "in" hybrid and "out" hybrid windings of the repeating coil hybrid are connected in parallel aiding with each other and directly to the drop leads of the local switchboard circuits. This results in a much lower transmission loss than is encountered in similar emergency systems of the prior art wherein the repeater elements alone are shunted out of the line upon their failure.

Terminal line section 191, under normal operating conditions, is connected through the make contacts of relay 192 to terminal resistance hybrid 193. Under similar normal operating conditions the output path of west-east amplifier 134 is connected through make contacts of relay 135 to "in" hybrid windings 196 of repeating coil hybrid 197 and the input path of east-west amplifier 201 is connected through make contacts of relay 202 to "out" hybrid windings 203 of the repeating coil hybrid.

As schematically indicated the energizing current for the filaments of the amplifying elements is supplied from power pack 214 over lines 215 while the plate potential for amplifier 201 is supplied over line 206, through the operating winding of relay 207 and over line 221 while the plate potential for amplifier 134 is supplied over line 206, through the operating winding of relay 222 and over line 223.

Under normal conditions, i. e., when the proper plate potential is being supplied by power pack 214 to the amplifiers (relays 207 and 222 are held in operated position due to the passage of the plate current through the operating winding thereof. So long as relays 207 and 222 remain in operated position relays 135, 202 and 192 are likewise held operated over a path from the plate potential output of power pack 214, line 224, operating windings of relays 135 and 202, line 225, operating winding of relay 192, make contact of relay 207 to ground 226 at the make contact of relay 222.

So long as power pack 214 is functioning properly therefore and the necessary plate potential is being supplied, circuit conditions will be as illustrated and voice frequency currents originating in line section 191 will be amplified by west-east amplifier 134, applied to "in" hybrid windings 196 of repeating coil hybrid 197 and appear finally in line section 227 for out transmission. Under similar conditions, voice frequency currents coming in over line section 227 will be applied to "out" hybrid windings 203 of the repeating coil hybrid, amplified by east-west amplifier 201 and applied to line section 191.

Let us assume now, however, that the flow of plate potential fails, for example, in the supply path of amplifier 201. Relay 207 will restore to unoperated position due to the cessation of the flow of current therethrough thereby interrupting at its make contact the path over which relays 135, 202 and 192 had been operated; the three last-mentioned relays restore to unoperated position.

Relay 192 now being in unoperated position, terminal line section 191 is disconnected from terminal resistance hybrid 193 and connected instead to line 231. Relays 135 and 202 likewise being in unoperated position, windings 196 and 203 of repeating coil hybrid 197 are disconnected from respective amplifiers 134 and 201 and connected, instead, in parallel aiding relationship with each other and directly through line 231 to line section 191. The resulting structure bears a general similiarity to the modified repeating coil arrangement described above in that connection of windings 196 and 203 of the two cores in parallel aiding relationship results, in effect, in electrically merging the two coils and causing them to function as a single coil.

Voice frequency currents originating at this time in line section 191 will pass directly to windings 196 and 203 of repeating coil hybrid 197 over line 231 and will be impressed through inductive action on line section 227. Similarly, voice frequency currents coming in over line section 227 are repeated through inductive action in windings 196 and 203 and passed therefrom directly to line section 191 over line 231. This novel switching arrangement whereby, upon repeater failure, the terminal resistance hybrid and the amplifiers are shunted out of the circuit and the "in" hybrid and "out" hybrid windings of the repeating coil hybrid connected in parallel aiding relationship with each other and directly to the terminal line section has been found to be effective in appreciably reducing the transmission loss resulting from repeater failure. The switching operations, however, do not interfere with the operation of the over-all system particularly with respect to phantom derivation and direct current and low frequency alternating current signaling.

It will be clear, of course, that the switching operations are initiated in a similar manner upon failure of the flow of plate potential in the supply path of amplifier 134; in the latter event the path over which relays 135, 202 and 192 are held operated would be interrupted at the make contact of relay 222. It will be clear, further, that the arrangement is applicable to direct current energized amplifiers as well as alternating current energized amplifiers.

While the emergency switching arrangement has been disclosed as applied to a terminal section it will be understood that the arrangement may be applied as well to an intermediate repeater section.

While certain specific embodiments of the invention have been selected for detailed disclosure the invention is not, of course, limited in its application to the embodiments disclosed. For example it is contemplated that a speech frequency system of the type disclosed 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-repeatered basis. Also while the modified repeating coil arrangement has been shown applied to one side circuit of a phantom group it will be understood that it may be applied to more than one of the circuits of a phantom group. Further it is contemplated that coils be used of the type having multisection windings and that various polings and interconnections of the sections be followed in order to obtain impedance ratios required by particular situations. (The equations for figuring the impedance ratios for the type of coil

with which the invention is concerned are given above.) In short, the embodiments disclosed should be taken as illustrative of the invention rather than as restrictive thereof.

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-repeatered section, a second two-wire line connecting said two last-mentioned sections, a two-way repeater for voice frequency current 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, a repeating coil set connecting said second two-wire line to equipment of said intermediate non-repeatered section, said repeating coil set comprising a pair of magnetic cores, a first primary winding and a second primary winding on the first of said cores, a first primary winding and a second primary winding on the second of said cores, said first primary windings being connected in series with each other and with one side of said second two-wire line, said second primary windings being connected in series with each other and with the other side of said second two-wire line, a pair of secondary windings on each of said cores, means for connecting said pairs of secondary windings in parallel aiding relationship with each other, and an external circuit connected to said secondary windings.

2. 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-repeatered section, a second two-wire line connecting said two last-mentioned sections, said first and second two-wire lines being balanced to ground, a two-way repeater for voice frequency current 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, a repeating coil set connecting said second two-wire line to equipment of said intermediate non-repeatered section, said repeating coil set comprising a pair of magnetic cores, a first primary winding and a second primary winding on the first of said cores, a first primary winding and a second primary winding on the second of said cores, said first primary windings being connected in series with each other and with one side of said second two-wire line, said second primary windings being connected in series with each other and with the other side of said second two-wire line, a pair of secondary windings on each of said cores, means for so interconnecting said pairs of secondary windings that said repeating coil set is balanced to ground on the secondary winding side, and an external circuit connected to said secondary windings.

3. 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 repeatered side circuit section, a phantom section and a non-repeatered side circuit section, a two-way voice frequency repeater for said repeatered 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 a plurality of windings thereon, voice frequency terminating equipment associated with said non-repeatered 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 a plurality of windings thereon and means for so interconnecting certain of said windings of said repeating coils that the two coils function as the electrical equivalent of a single coil having an impedance ratio substantially equal to but slightly greater than the impedance ratio of said repeating coil hybrid.

4. In a speech transmission system of the type including two side circuits and a phantom circuit derived from said side circuits, the lines of said side circuits being balanced to ground, a phantom group at a point in the system including a repeatered side circuit section, a phantom section and a non-repeatered side circuit section, a two-way voice frequency repeater for said repeatered 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-repeatered 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 each of said repeating coils in parallel aiding relationship with each other and to said voice frequency terminating equipment.

5. In a speech transmission system, a first line section and a second line section, a two-way repeater for voice frequency currents, a resistance hybrid for connecting said first line section to two sides of said repeater in mutually conjugate relationship, a repeating coil hybrid for connecting said second line section to two sides of said repeater in mutually conjugate relationship, said repeating coil comprising two cores, a plurality of windings on each of said cores, a pair of said windings on one of said cores serving under normal operating conditions of said repeater to inductively couple said second line section to said first line section over a path including one directional path of said two-way repeater and said resistance hybrid, a pair of said windings on the

other of said cores serving under normal operating conditions of said repeater to inductively couple said second line section to said first line section over a path including the other directional path of said two-way repeater and said resistance hybrid, and switching means effective upon failure of said repeater to operate normally to connect said two pairs of said windings in parallel aiding relationship with each other and directly to said first line section over a path excluding both directional paths of said repeater and said resistance hybrid.

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