April 28, 1942. E. I. GREEN 2,281,035

REPEATERED TRANSMISSION SYSTEM

Filed May 31, 1941 3 Sheets-Sheet 1

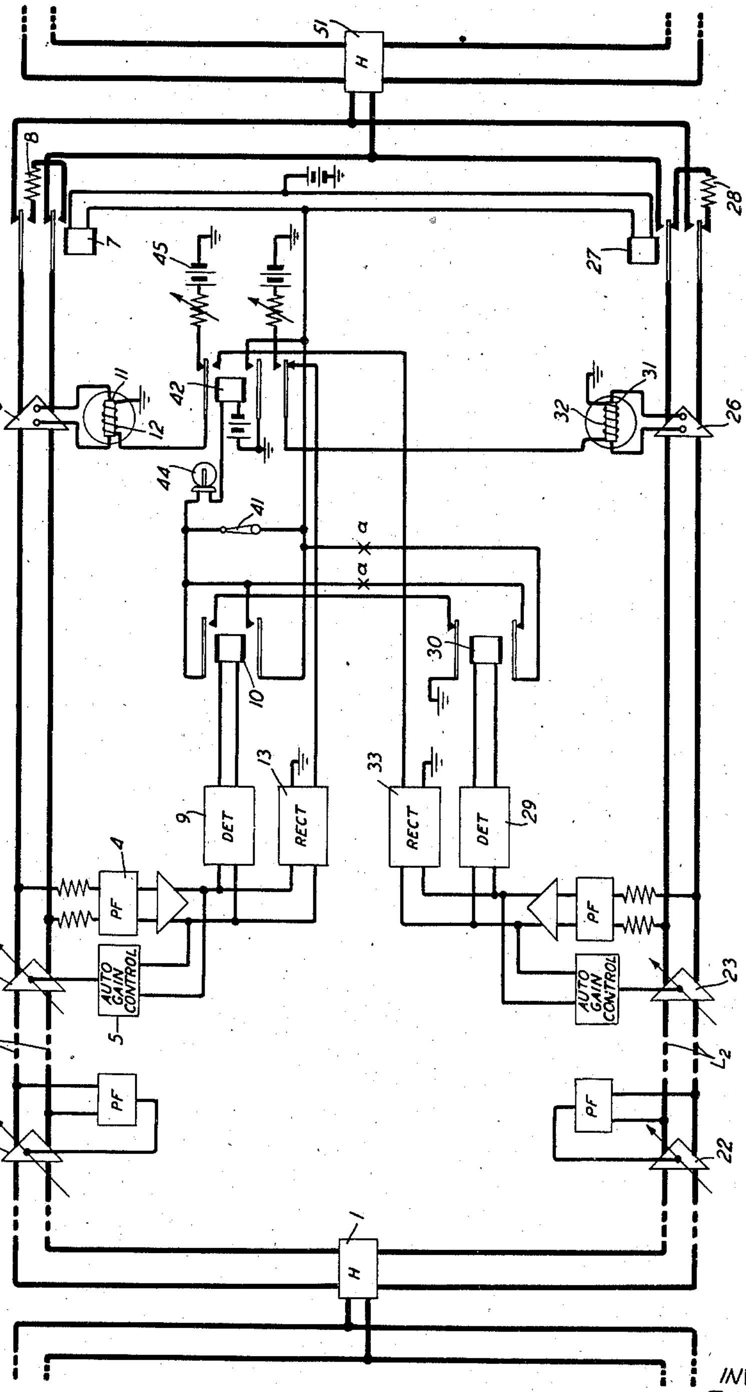

FIG. 1

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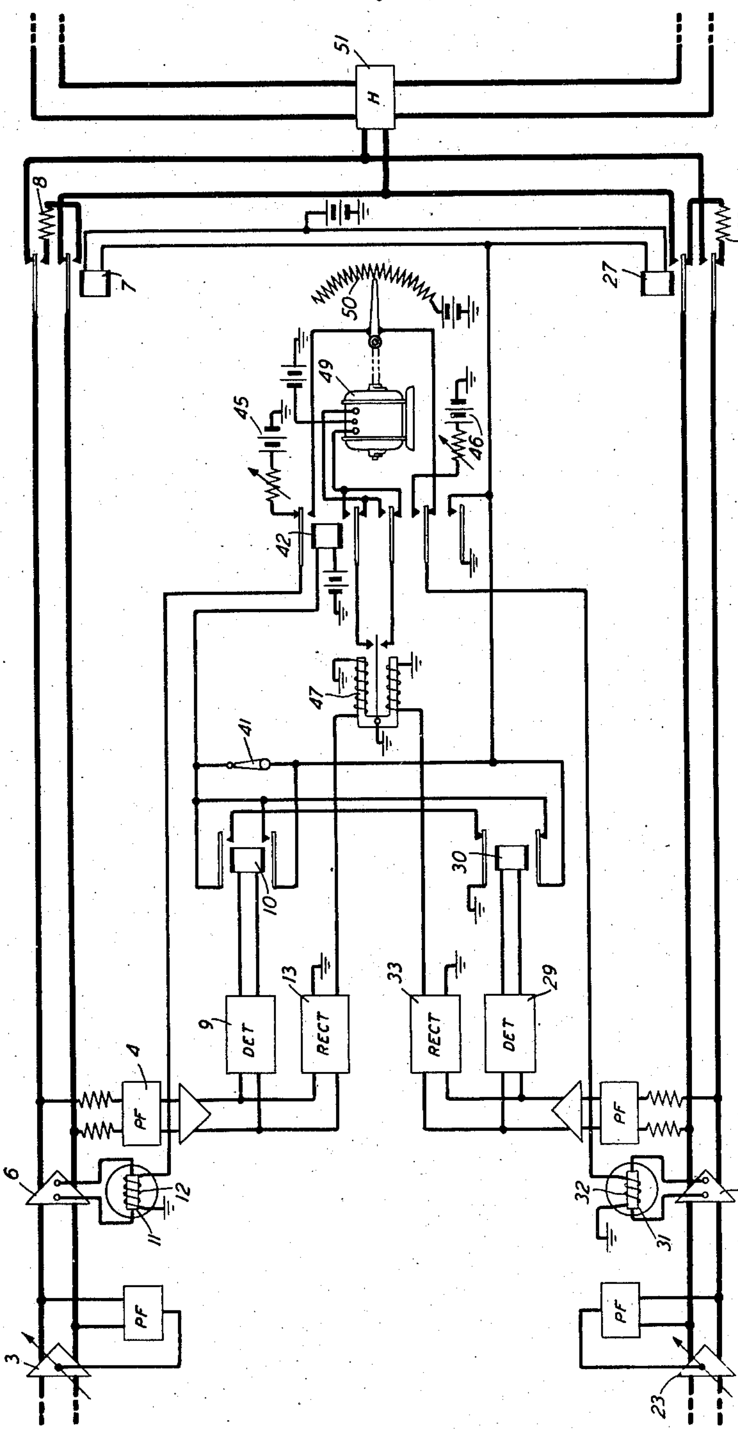

FIG. 2

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REPEATERED TRANSMISSION SYSTEM

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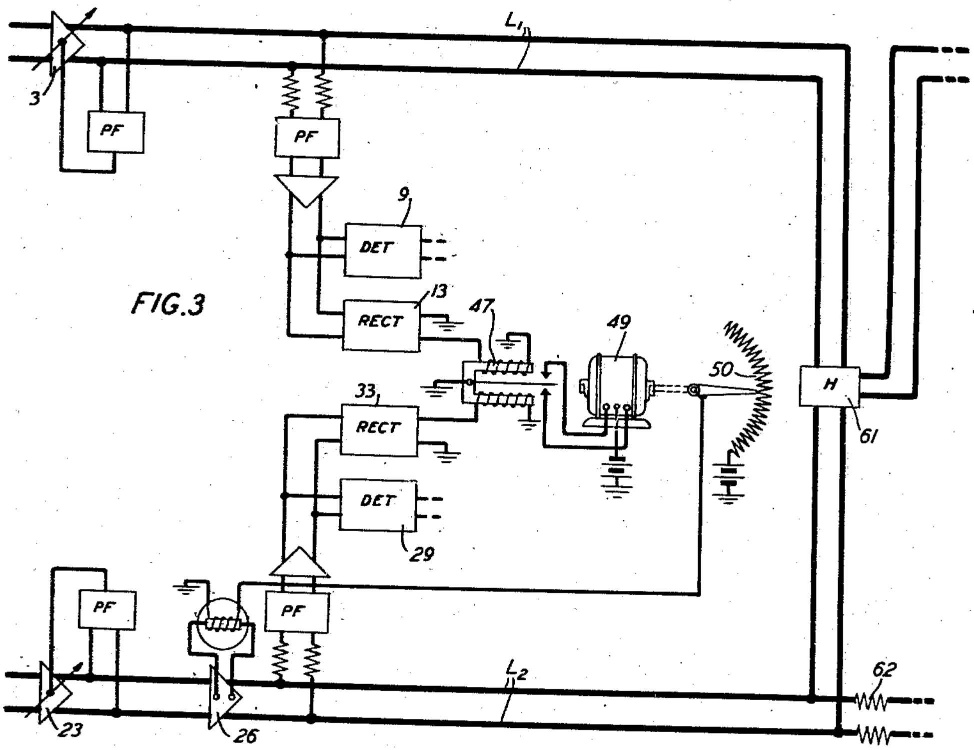
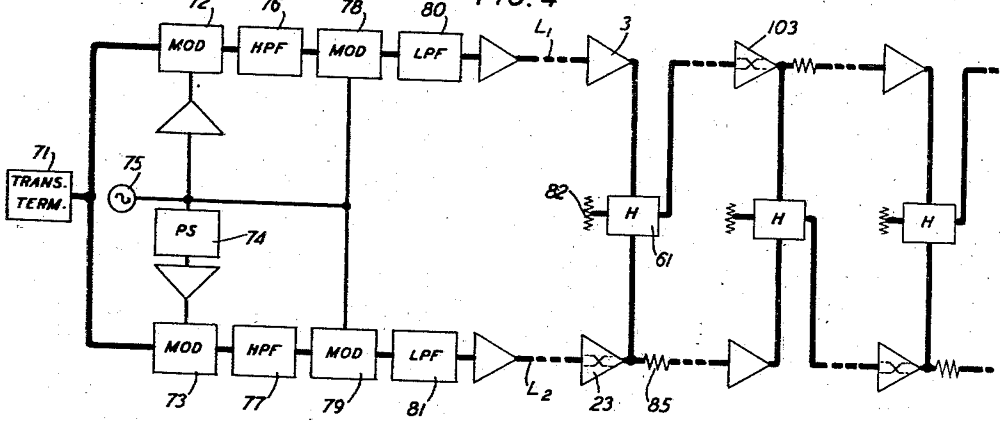


FIG. 3

FIG. 4



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2,281,035

UNITED STATES PATENT OFFICE

2,281,035

REPEATERED TRANSMISSION SYSTEM

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Application May 31, 1941, Serial No. 396,148

10 Claims. (Cl. 178—44)

This invention relates to long distance electric signaling systems in which duplicate transmission facilities are provided to insure continuity of service.

It has been proposed heretofore to separate a long distance signaling system having duplicate transmission facilities into a multiplicity of sections or links so that if in any link the regular or "working" transmission facility becomes impaired, it may be replaced by the spare or "idle" facility in that link. Where provision is made for effecting the substitution automatically under the control of currents transmitted with the signals, as in the wire line system disclosed in I. G. Wilson Patent No. 2,229,158, January 21, 1941, for example, it is found that under some conditions encountered in practice there is a possibility that unless special precautions are taken the occurrence of a necessary substitution in one link may give rise to unnecessary substitutions in other links or that the automatic replacement of an impaired facility in one link may occasion repeated interchange of the two facilities in a distant link.

A principal object of the present invention is to provide an improved system of the kind described and more particularly to eliminate unnecessary or false operation or to reduce substantially the likelihood of its occurrence.

The embodiments of this phase of the present invention that are hereinafter described in detail are specifically adapted for a wire line transmission system of a type such as the coaxial system employing two one-way transmission lines each of which is provided with signal repeaters having automatic gain regulation under the control of a pilot wave transmitted with the signals. The system is divided into a plurality of links for switching purposes and it is so arranged that at the input or sending end of each link both lines receive the signals and pilot waves from whichever of the two lines in the preceding link happens to be the working line. At the output or receiving end of each link automatic switching means are provided which operate in the event that transmission over the regular line is impaired to connect the idle line in that link to the input end of the next link and to disconnect the regular or working line therefrom. Transmission in a given link is deemed to be impaired if the pilot wave received at the output end of the working line fails or if otherwise the intensity of the received pilot departs from a preassigned normal value by more than a certain amount. In response to such failure or abnormal departure of the pilot, the switching mechanism is automatically set into operation.

Gain regulated repeaters at the receiving end of each switching link normally operate in the two lines to maintain the pilot output intensity in each line approximately at a predetermined constant value, which is the same for both the working line and the spare line. If the two intensities are exactly alike and there is then an abrupt failure of the pilot on the working line, quickly followed by substitution of the idle line, the repeaters at all subsequent switching points experience only a momentary effect inasmuch as the pilot received by way of the substituted line is of the same intensity as the pilot previously received by way of the regular line.

Under some conditions, however, the pilot may not fail abruptly at a given switching point but its intensity may gradually drift in one direction or the other beyond prescribed normal limits. Substitution of the idle line will take place in the affected link as before when the prescribed limit is passed but with this this difference. As the pilot drifts from its normal value, to a lower value, for example, the gain regulated repeaters in the following section of working line will continually accommodate themselves to the changing pilot intensity thus maintaining at the next switching station a constant pilot output. When the drifting pilot passes through the prescribed limiting value and the substitution of lines is made in the affected link, there appears at that next switching point a sudden increase in the pilot intensity equal to the difference in the intensities of the two pilots at the receiving end of the affected link. This sudden increase in pilot intensity is communicated almost instantly to all subsequent switching points, inasmuch as the various regulators do not operate instantaneously, and if at any such subsequent point the pilot output intensity happens to be at the moment of the switching somewhat higher than the prescribed normal value although within the prescribed limits, the increase in pilot intensity incidental to switching will raise the total pilot intensity at that point above the upper normal limit and cause a switch to occur. This switch is obviously unnecessary for in a few moments the regulators would have reduced the pilot intensity to a value within the normal range and transmission would have been quite normal.

So also if the pilot output intensity in the idle line of the affected link happened to be below its normal value at the moment of switching, the comparatively large change in pilot intensity communicated to the next link incidental to the switching operation would of itself be sufficient to cause a false switch at many subsequent switching points.

If the circuit is so arranged that a manual adjustment is required after a switch occurs before the switching mechanism is in condition to make another switch, only one false switch can take place at any one point. The circuit, however, may be fully automatic so that it will switch back and forth between regular and spare lines whenever the pilot level on the working line departs from its normal range. In such a fully automatic system it is theoretically possible to have as many successive false switches at a distant switching point as there are switching points between it and the initial switching point.

In general, false switching may occur under either of two circumstances, (1) when there is a drift of the pilot level on the working line beyond the normal limits while the pilot level on the idle line remains within the normal range, and (2) when there has been a drift of the pilot level on the idle line in one link, the level on the working line in a following link having varied from normal in the same direction, and the working line of the first-mentioned link, being normal, becoming subject to a sudden failure.

In accordance with this phase of the present invention as embodied in two systems illustrated in the drawings, the objective of reducing or eliminating false switching is attained by automatically adjusting the relative pilot levels on the two lines at each switching point so that so long as they remain within the prescribed normal limits they are approximately or exactly alike. In the event then that the pilot on the working line fails at any switching point or otherwise necessitates a switch, there will be little or no change in pilot level experienced at subsequent switching points and therefore no occasion for false switching.

Another phase of the present invention has to do with a long distance signaling system having duplicate facilities that normally are used concurrently and that are so arranged that if one is disabled, the other serves alone. As set forth in the I. G. Wilson patent supra, such a system may provide for a phase displacement of 120 degrees between the currents transmitted through the two facilities and a vector addition of the two currents at a receiving point. If the two vectors so combined are of equal amplitude, the vector resultant at the receiving point will be of the same amplitude as either component alone, hence if one facility is suddenly disabled there will be little or no change in the amplitude of the received current and service can continue substantially unimpaired.

Another object of the present invention is to obviate the false operation of marginally operative devices in a system of the kind last described that might occur if the two current vectors were not exactly equal. Even though the two facilities be provided with automatic transmission regulators these would ordinarily permit a limited range of relative amplitude variation such that the vector resultant at a given point might be sensibly different than either vector alone. More particularly the difference, in respect of the amplitude of pilot or control currents transmitted through the system, might be sufficient that in the event of sudden failure of one facility, various marginally operative devices responsive to the control current would be subject to false operation. These devices may be for example alarm circuits and switching devices adapted to disconnect impaired facilities.

In accordance with a feature of the present invention provision is made for accurate equalization of the transmission levels in the two facilities at points where vector combination of the respective transmitted currents is effected. In accordance with another feature, the duplicate facilities are divided into a multiplicity of links with vector combination of the currents at the junctions thereof and preservation of the 120-degree relation at the input end of each link.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the following description of the embodiments illustrated in the accompanying drawings. In the drawings:

Fig. 1 illustrates an embodiment of the invention comprising duplicate, alternatively operative transmission lines in which the pilot output of the working line varies the pilot output on the idle line in the same direction and degree;

Fig. 2 illustrates a modification of Fig. 1 in which the pilot outputs of the two lines are at each switching point continuously and automatically adjusted to equality;

Fig. 3 illustrates an embodiment of the invention comprising duplicate, simultaneously operative transmission lines in which the transmission levels on the two lines are accurately equalized in the manner of Fig. 2; and

Fig. 4 further illustrates the Fig. 3 system.

Referring more particularly now to Fig. 1, there is illustrated a system of the kind described comprising two transmission lines, L1 and L2, arranged for transmission in the same direction between a pair of terminal stations not shown. For switching purposes the line system is divided into a multiplicity of tandem links with a hybrid coil at each junction adapted to receive signals from one or the other of the lines in the preceding link and to apply them to the transmit ends of both of the lines in the following link. At the output or receiving end of each link there are provided switching means which operate under the control of pilot currents transmitted through the system along with the signals to connect one or the other of the lines through the hybrid coil to the input end of the next link. Thus in each link both lines are normally continuously energized with signal and pilot throughout their lengths but only one is effectively connected at its output end for through transmission.

Repeaters 2 are interposed at intervals in each line and there may be a plurality of them in each link in addition to those at the junction or switching points, viz., repeater 3 in line L1 and repeater 23 in line L2. All of these repeaters are of a type adapted for automatic gain regulation under the control of pilot current transmitted with the signal, and they normally operate to maintain the transmission levels at their respective outputs within fixed limits despite fluctuations in the attenuation of the transmission line and other effects tending to change the transmission equivalent of the system. The pilot currents that control the switching means may serve also for the repeater gain regulating system. The regulating equipment associated with each repeater may comprise a pilot filter 4 for selectively diverting a small part of the pilot current from the output of the repeater through a resistance pad, an amplifier for the diverted pilot current and a repeater gain control mechanism 5 that is automatically set in accordance with the intensity of the diverted pilot current to maintain the pilot output intensity within the predetermined normal range. In one illustrative case in practice, the limits of the normal regulating range are plus or minus three decibels from a mean value of pilot output intensity, and the gain control mechanism comprises a silver sulphide element or other thermistor connected in gain-controlling relation in the repeater-amplifier circuit.

The switching mechanism includes a relay 7 that is associated with the output end of line L1 and a corresponding relay 27 associated similarly with line L2. These relays may, if desired, be of a type consisting of two magnetic reeds surrounded by a glass envelope containing a suitable gas such as helium, the contact between the reeds being actuated by an external magnetic field, all as disclosed in the pending application of L. R. Schreiner, Serial No. 342,635, filed June 27, 1940. This construction permits the outer conductor of a coaxial circuit to be carried continuously through the relay. In one condition of the system, neither of the relays 7 and 27 is operated, in which case line L1 is connected by relay 7 to the input terminal of the hybrid coil 51 in the next section and line L2 is connected by relay 27 to a terminating resistor 28. In an alternative condition of the system both of these relays are operated and in this case line L1 is disconnected from hybrid coil 51 and terminated by resistor 8 while line L2 is disconnected from terminating resistor 28 and connected to the input terminals of hybrid coil 51.

As previously intimated, the system may be arranged for semiautomatic operation, that is, for a single automatic transfer from the regular line, say L1, to the other or spare line L2 after which the switching circuit must be manually reset. Alternatively the system may be arranged for fully automatic operation so that the idle line, whichever it may be at a given time, is automatically substituted for the working line if the latter becomes impaired, and, without the intervention of an attendant, a switch may be made in the reverse direction if the substituted line then becomes impaired and the other line has in the meantime been restored to normal. First to be described is the semiautomatic arrangement. This requires that the resetting or restore key 41 be closed and that a circuit shunting the key be broken at the point *a—a*.

Treating line L1 as the regular line and line L2 as the spare, and assuming that the circuit is arranged for semiautomatic operation, relays 7 and 27 are then normally in the unoperated condition and line L1 is connected for through transmission. To effect a switch to line L2 in the event of impairment of line L1, means are provided, responsive to an abnormal change in the pilot level at the output of repeater 3, to operate relays 7 and 27. The operating means comprises a detector 9 that is connected to receive the diverted pilot from the output of repeater 3 and that is so constructed, as by incorporating a pair of differently biased relays, that if the intensity of the pilot applied to it departs from a preassigned range a relay 10 in its output circuit is immediately operated. If as suggested the pilot intensity at the output of repeater 3 is normally held by the gain regulating system to a range of plus or minus three decibels, the operating margin of detector 5 can be arranged to coincide, or it may be otherwise so arranged as to operate when predetermined limits are exceeded.

Associated with the output of repeater 23 and controlled by pilot current diverted therefrom is a detector 29 and a relay 30 which respectively correspond with detector 9 and relay 10. As long as the pilot intensity at the output of repeater 23 is within the normal range, or in other words as long as line L2 is unimpaired and in condition to be used for replacing line L1, relay 30 is unoperated and its upper break contact is closed. Then on operation of relay 10 in response to a fault on line L1, an operating battery circuit for relays 7 and 27 is closed through the upper and lower make contacts of relay 10 in series and the upper break contact of relay 30. Thereupon relays 7 and 27 operate and line L2 is thereby substituted for line L1 for through transmission. At the same time an operating battery circuit for a lock-up relay 42 is closed through the upper make contact of relay 10 and the upper break contact of relay 30. The consequent operation of relay 42 closes a holding circuit through one of its make contacts and key 41. With relay 42 in its locked position, a holding circuit for relays 7 and 27 is completed through one of its make contacts. A lamp 44 in series with the operating winding of relay 42 lights whenever this relay is in its operated condition, or in other words as long as the spare line is in use.

It will be noted that on manually opening restore key 41, the operating circuit of lock-up relay 42 will be broken, and if line L1 is unimpaired at the time so that relay 10 is in its unoperated condition, relays 7 and 27 will be deenergized, thereby released, and cause line L1 to be substituted for line L2.

For fully automatic operation of the switching system key 41 is held open, or removed, and the shunting circuit is completed through *a—a*. The lower break contact of relay 30 now serves in lieu of the key 41. In normal operation over line L1, the last-mentioned break contact is closed, so that when occasion arises a switch can be made to line L2. If on that occasion line L2 is impaired, and relay 30 is therefore in its operated condition, both contacts of that relay are open and a switch is precluded.

After a switch is made to line L2, lock-up relay 42 holds switching relays 7 and 27 in their operated condition even though line L1 is restored to normal and relay 10 is thereby released. If now line L2 becomes impaired and relay 30 therefore operates, the opening of the lower contact of relay 30 breaks the operating circuit of lock-up relay 42 thereby releasing relays 7 and 27 and restoring the system to its original condition, that is, with line L1 in service. The last-described switch is precluded, however, if line L1 is still impaired and relay 10 is therefore still operated.

The Fig. 1 switching arrangement as above described, whether conditioned for semiautomatic or fully automatic operation, is such that a normal or necessary interchange of lines in one link may give rise to false switching in other links under certain conditions hereinbefore described in detail. These conditions, it will be recalled, involve the fact that whereas the various pilot levels in both lines at all switching points may lie within the normal range just prior to the occurrence of a fault, these levels may have drifted from the center or mean value of their respective ranges in such relative directions that the sudden change in level ordinarily to be expected on substituting one line for another may be enough that the normal range is momentarily exceeded at various switching points. In accordance with a feature of the invention provision is made in Fig. 1 to reduce the likelihood of such false switches occurring.

More particularly, provision is made in Fig. 1 for varying the transmission equivalent of the idle line in synchronism with the variations in the pilot output level on the working line so that at the instant before switching the pilot output levels on both idle and working lines are at least approximately equalized. For this purpose an auxiliary amplifier **6** of adjustable gain is interposed in line L**1** following repeater **3** and a similar auxiliary amplifier **26** is likewise disposed at the output of repeater **23**. The gain adjusting mechanism of each auxiliary amplifier is illustrated as comprising an indirectly heated thermistor, viz., thermistor element **11** and heater **12** for amplifier **6** and thermistor element **31** and heater **32** for amplifier **26**.

Heating current for each of the thermistors is derived from a constant current source when the line with which it is associated is the working line, and from the pilot current on the other line when the line with which it is associated is the idle line. Thus a rectifier **13** connected in parallel with the input of detector **9** supplies amplified, rectified pilot current for heater **32** through a break contact on relay **42** that is closed as long as line L**1** is the working line, while heater **12** is supplied through another break contact on relay **42** with constant current from a source **45**. When relay **42** is operated, incidental to substitution of line L2 for line L**1**, heater **32** is supplied with current from a constant current source through a make contact of relay **42** and heater **12** is supplied with current through another make contact on the same relay from the output of a rectifier **33**, the latter being connected to receive amplified pilot current diverted from the output of repeater **23**. The constant current circuits are so adjusted that when they are operating on the thermistor heaters **12** and **32**, the respective gains of the two auxiliary amplifiers are accurately held at a predetermined reference value. For simplicity of exposition, this reference value may be assumed to be zero decibels. Likewise the circuit parameters are so proportioned that when heating current is derived from the rectifiers **13** and **33**, the gain of each auxiliary amplifier is of the reference value, zero decibels, when the intensity of the pilot in the opposite line is exactly at its mean value, that is at the center of its normal operating range. The circuit parameters can be and are further so selected that any change in the intensity of the heating current derived from the pilot in one line gives rise to an equal change in the same sense in the gain of the auxiliary amplifier in the other line.

If for example, then, line L**1** is the working line and the pilot intensities at the output of repeaters **3** and **23** are at their respective mean values, the gain of auxiliary amplifier **6** is held at zero value by the heating current supplied from source **45** and the auxiliary amplifier **26** is likewise maintained at zero gain under the control of the pilot current derived from line L**1**. Now if the pilot level on line L**1** begins to change, the gain of auxiliary amplifier **26** in line L2 changes in direct proportion so that the pilot level on line L2 at the output of amplifier **26** is maintained exactly equal to that on line L**1**. It will be apparent that if there should be a sudden failure of line L**1** under these conditions, there would be only a momentary change of pilot level experienced at subsequent switching points and false switching would not occur.

In general it may be said that the Fig. 1 arrangement operates at each switching point to restrict the differential between the pilot level on the two lines to a value not exceeding half the normal range of either pilot. In the embodiment of the invention illustrated in Fig. 2, on the other hand, the differential may be further reduced and in fact eliminated so that a switching operation at any given switching point gives rise to no sensible change in pilot intensity at subsequent switching points.

In Fig. 2 the switching mechanism is essentially the same as that shown in Fig. 1 and corresponding elements are assigned the same reference characters. A principal difference that will be noted is the shifting of the auxiliary amplifiers **6** and **26** to a position preceding the point at which pilot currents are diverted for control of the switching mechanism and the provision of separate pilot filters for the automatic gain regulators of repeaters **3** and **23**. As in Fig. 1 the pilot intensity at the respective outputs of repeaters **3** and **23** is maintained within predetermined limits of plus or minus 3 decibels for example; the gain of the auxiliary amplifier in the working line is maintained at a constant reference value of zero decibels, for example; and the gain of the auxiliary amplifier in the idle line is continuously adjusted in accordance with the pilot intensity on the working line. In Fig. 2, however, the adjustment of the gain of the auxiliary amplifier in the idle line proceeds automatically until the pilot level at its output is equal to the pilot level at the output of the other auxiliary amplifier.

The pilot equalizing equipment in Fig. 2 comprises a differential relay **47**, the opposing windings of which are supplied with operating current from the rectifiers **13** and **33**. Relay **47** is connected through contacts on relay **42** to control the operation of reversible motor **49** which drives a rheostat **50**. The adjustment of the latter controls the amount of battery current that is supplied to thermistor heater **32** through a break contact on relay **42** when line L**1** is in use, and it also controls the amount of battery current supplied to the heater **12** through a make contact on the same relay when line L2 is in use. The circuit elements are so proportioned that when the outputs of rectifiers **13** and **33** are equal, the armature of differential relay **47** stands in its neutral position.

Assume that line L**1** is the working line and that the pilot intensity at the output of auxiliary amplifier **6**, initially equal to that at the output of auxiliary amplifier **26**, begins to drift, for example, to decrease. Thereupon the armature of differential relay **47** is moved to its lower contact and motor **49** together with the wiper arm of rheostat **50** are thereby caused to rotate. This changes the heating current to heater **32** and in such sense as to decrease the gain of auxiliary amplifier **26**. Operations continue until the gain is so reduced that the intensities of the two pilots are equal, whereupon the armature of differential relay **47** assumes its neutral position and stops the motor **49**. Similarly if the pilot intensity on working line L**1** relatively increases, the armature of differential relay **47** is moved to its upper contact and motor **49** is driven in the opposite direction to raise the gain of amplifier **26**. When line L2 is the working line, the gain of auxiliary amplifier 6 in line L1 is controlled in the same manner. It will be noted, however, that in this case movement of the armature of differential relay 47 to either of its contacts requires that motor 49 be driven in a direction opposite to that required when line L1 is the working line. This requirement is met by interposing in the motor control circuit a reversing circuit controlled by contacts of relay 42, whereby on transfer of through transmission to line L2 and consequent operation of relay 42 the motor control circuit is reversed. Limit stops may be associated with motor 49 and rheostat 50 so that under all conditions the wiper arm of rheostat 50 is precluded from leaving its associated resistor.

In Fig. 3 the invention is shown embodied in another form in a system comprising duplicate transmission facilities that normally are both connected for concurrent through transmission. In this case it is assumed that the two lines are energized with the same signal and pilot currents but displaced in phase relative to each other by 120 degrees throughout the frequency range of interest. At the end of each link the currents in one of the lines, say L2, are reversed in phase and the currents from the two lines are then applied to respective terminals of a hybrid coil 61. These terminals are in conjugate relation with each other but are in transfer relation with the output terminals of the hybrid coil, the latter being connected to transmit the vector sum of the applied currents to the outgoing line L1. The other line L2 of the next link receives the current of reversed phase from line L2 in the preceding link through a level adjusting pad 62. Further details of the over-all system will be described with reference to Fig. 4.

As previously indicated the regulated amplifiers 3 and 23 at the end of the transmission link shown in Fig. 3 operate to maintain the intensity of the currents in the two lines approximately equal, whereas for optimum performance of the system and freedom from false operation of various elements therein, the two intensities should be held to a higher degree of equality. In accordance with the present invention, the relative level equalizing means of Fig. 2 is utilized with certain simplifications for this purpose. As shown in Fig. 3, only one auxiliary amplifier of adjustable gain need be used, just as only one auxiliary amplifier is variably controlled in Fig. 2 while the other line is in service. If auxiliary amplifier 26 is the one retained as indicated in Fig. 3, its gain is continually adjusted by means of reversible motor 49 and rheostat 50 as before so that the gain adjustment proceeds until the current level at the output of amplifier 26 is the same as that at the output of repeater amplifier 3. For the equalizing function detectors 9 and 29 need not be used and rectifiers 13 and 33 may be connected directly to the control windings of relay 47. The two detectors, however, may be used for other purposes as for example for sounding an alarm or for disconnecting one of the lines if it becomes impaired. As in Fig. 2, the gain control for auxiliary amplifier 26 may be so adjusted that the gain is zero when the control pilot level on line L1 is at its mean value.

The transmitting terminal station for the Fig. 3 system and the combining circuits at successive link junctions are shown in Fig. 4 with the level equalizing means of Fig. 3 deleted for simplicity of illustration. Referring to Fig. 4, signals and pilot currents are transmitted in the W-E direction from a terminal station at the left through the duplicate transmission lines L1 and L2 which are subject to the same changes in attenuation and which for specific example may be coaxial conductor pairs within the same cable. The signals to be transmitted may comprise a multiplex of telephone channels or television signals, ranging in either case from 64 to 2064 kilocycles per second for specific example. Whatever their character, the signals from the signal source 71 are applied to the two lines L1 and L2 with equal amplitudes in the two lines but displaced in phase relative to each other by 120 degrees throughout the signal frequency range.

The phase displacement is effected by applying the signals from source 71 to the respective modulators 72 and 73 which are supplied with carrier current from a source 75. The frequency of the latter may be, for example, 8 megacycles per second. A phase shifter 74 is interposed in the lead from carrier source 75 to one of the modulators 73 and it is designed to introduce a carrier phase shift of 120 degrees. Of the two principal second order side-bands produced by modulators 72 and 73, either the two upper side-bands or the two lower side-bands are to be suppressed, and it may be supposed, for example, that high-pass filters 76 and 77 are adapted to pass only the upper side-bands. The latter are then applied to the respective modulators 78 and 79 which are respectively supplied with carrier currents in like phase from source 75. The two lower side-bands resulting from this operation are selected by respective low-pass filters 80 and 81, individually amplified and applied to the respective lines L1 and L2. It can readily be demonstrated that the two side-bands thus applied to the line are identical with the original signals from source 71 but displaced in phase from each other by 120 degrees. Pilot currents to be transmitted through the system may be derived from the transmitting terminal 71 concurrently with the signals and in any event are also to be applied to the two lines with 120-degree relative phase displacement and equal amplitudes.

Assuming the two transmission lines have equal phase characteristics, it will be appreciated that at any point such as a repeater station the signals and pilots in the two lines can be combined and the vector resultant will be equal in magnitude to either of the component vectors alone. Thus, if the two vectors are maintained exactly equal in amplitude, as by means of the Fig. 3 level equalizer, and one line should fail, transmission would continue through the other without any abrupt change in amplitude or other effect except a phase shift of 60 degrees. The latter phase shift is small enough that carrier telegraph signals which might be present on the line would be transmitted satisfactorily.

Once the currents from the two lines are combined, some such means as that provided at the transmitting terminal station would ordinarily be required to produce another set of phase-displaced currents for transmission through the next link of the system. In Fig. 4, however, this necessity is avoided and other advantages secured by providing, at the output end of each link, means for reversing the phase of the signals in one of the two lines and means for applying to the outgoing section of the other line the vector resultant of the incoming signals in that line and the phase-reversed signals from the other line.

More specifically, as shown in Fig. 4, the repeater station at the end of the first link comprises amplifier 3 which receives the currents from line L1 and applies them to hybrid coil 61. Currents from line L2 are passed through amplifier 23 where they are reversed in phase, relative to the currents from line L1, and then applied to hybrid coil 61 in conjugate relation to the output of amplifier 3. In the hybrid coil, which is balanced by a network 82, the two sets of currents are effectively combined in adding phase relation and applied to the outgoing section of line L1. The output of amplifier 23 is applied directly to the next section of line L2 through a pad 85 which compensates for the loss occurring in hybrid coil 61. Brief consideration will disclose that the two sets of currents thus delivered to the next section of the transmission system are again in 120-degree phase relation with respect to each other. The repeater station at the end of the next link is the same as the first except that the phase-reversing amplifier 103 is disposed in line L1 and the resultant of the vectorial addition of the two signals in the hybrid coil is applied to line L2. Alternate junctions in the system are alike in the respects described.

Although the present invention has been described largely in terms of illustrative embodiments, it will be understood that the invention is susceptible of embodiment in various other forms within the spirit and scope of the appended claims.

What is claimed is:

1. A long distance signaling system with duplicate transmission facilities comprising two repeatered transmission lines interconnecting the same points, a plurality of switching stations separating said system into a multiplicity of tandem links each having an input and an output end, means for applying pilot waves and signals concurrently to both of said lines at the input end of each of said links, switching means at the output end of each of said links for connecting said lines alternatively to the input end of the next link, said switching means being controlled by the intensity of pilot waves received from the line that is so connected to the next link and operative to effect the alternative connection when said intensity departs from a normal limited range, automatic transmission regulating means normally maintaining the pilot intensities in both of said lines at the output end of each link within said limited range, and means constricting the differential between said last-mentioned intensities to a value substantially less than said limited range.

2. A long distance signaling system comprising regular and spare facilities in a multiplicity of successive transmission links, means for transmitting control currents through each link of both facilities, switching means respective to each of said links and marginally operative in response to an abnormal change in the intensity of said control current in the regular facility of the respective links for automatically substituting the spare facility in the respective links, regulating means for normally maintaining the respective intensities of the control currents in the two facilities at each of said switching means within the operating margin thereof, and means associated with each of said switching means for reducing the intensity differential between the control currents in the two facilities.

3. In a signaling system comprising duplicate transmission facilities separated into a multiplicity of long distance transmission links each having an input end and an output end, means for maintaining pilot current on both of said facilities in each of said links, transmission regulating means respective to the two facilities normally maintaining the intensities of said pilot currents within a predetermined range at the output end of each of said links, means at each of said links responsive to a departure of the regulated pilot intensities from said predetermined range for disconnecting the affected facility, and means at each of said links for normally restricting the differential between said regulated pilot intensities.

4. A long distance transmission system comprising duplicate transmission facilities separated into a multiplicity of links for the concurrent transmission of the same signals, means for maintaining a 120-degree vector relationship between the respective signals applied to the two facilities, means at each junction of said links for reversing the phase of the signals received from one of the facilities of the preceding link relative to the phase of the signals received from the other, means for applying the signals of reversed phase to one of the facilities of the next link, means for vectorially combining said signals of reversed phase with said signals from said other facility and means for applying the vectorially combined signals to the other facility in the said next link.

5. A combination in accordance with claim 4 in which alternate links of the one facility receive said vectorially combined signals and in which the intermediate links of said one facility receive said signals of reversed phase.

6. A signaling system comprising duplicate transmission facilities separated into a multiplicity of long distance transmission links, means for applying signals and pilot waves to the two transmission facilities in each of said links, means for maintaining a 120-degree vector relationship between the signal and pilot waves in the one facility and the signal and pilot waves in the other facility, automatic transmission regulating means normally maintaining the transmission equivalent of each of said facilities approximately constant, and means at the junction of said links operative under the control of said pilot waves for equalizing the transmission levels in the two facilities irrespective of variations in relative level permitted by said regulating means.

7. A system comprising two long distance transmission lines each including repeaters interposed in tandem therein, means for transmitting control currents through both of said lines in the same direction of transmission, automatic transmission regulating means for each of said lines, said regulating means being adapted to maintain the intensity of the said control currents approximately constant at said repeaters, at least one of said repeaters comprising means responsive to the said approximately constant control currents for reducing changes in the relative intensity of the said control currents in the two lines.

8. A combination in accordance with claim 7 comprising means at said one repeater substantially equalizing said intensities independently of said regulating means.

9. In combination, two long distance transmission lines extending over the same route, means for transmitting control current through each of said lines, transmission regulating means normally maintaining said control current within a limited range at a plurality of points along

said lines, means at one of said points for automatically replacing the control current in one of said lines with the control current from the other of said lines for transmission to another of said points, means at said other point marginally operative by the control current in one of said lines, and means at said one point continually restricting the intensity differential of said control current at said one point to a value substantially less than the operating margin of said device.

10. A system comprising a pair of duplicate long distance signal transmission facilities separated into a multiplicity of links, each with a plurality of amplifying repeaters therein, interlink coupling means supplying signal and control currents from the output end of each link to the input ends of both facilities of the next following link, transmission regulating means normally maintaining the said control current in both of said facilities within a limited intensity range at the output end of each of said links, means marginally operable by said regulated control current transmitted through said system, said coupling means being adapted to supply signal and control currents as aforesaid from the output end of either facility alone in a given link in the event of failure of the other facility in that link, and means inhibiting false operation of said marginally operable means incidental to failure of one facility in a preceding link, comprising means substantially equalizing the intensity of the regulated control current in the two facilities at the output end of each of said links.

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