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SWITCHING OF SPARE REPEATER SECTIONS

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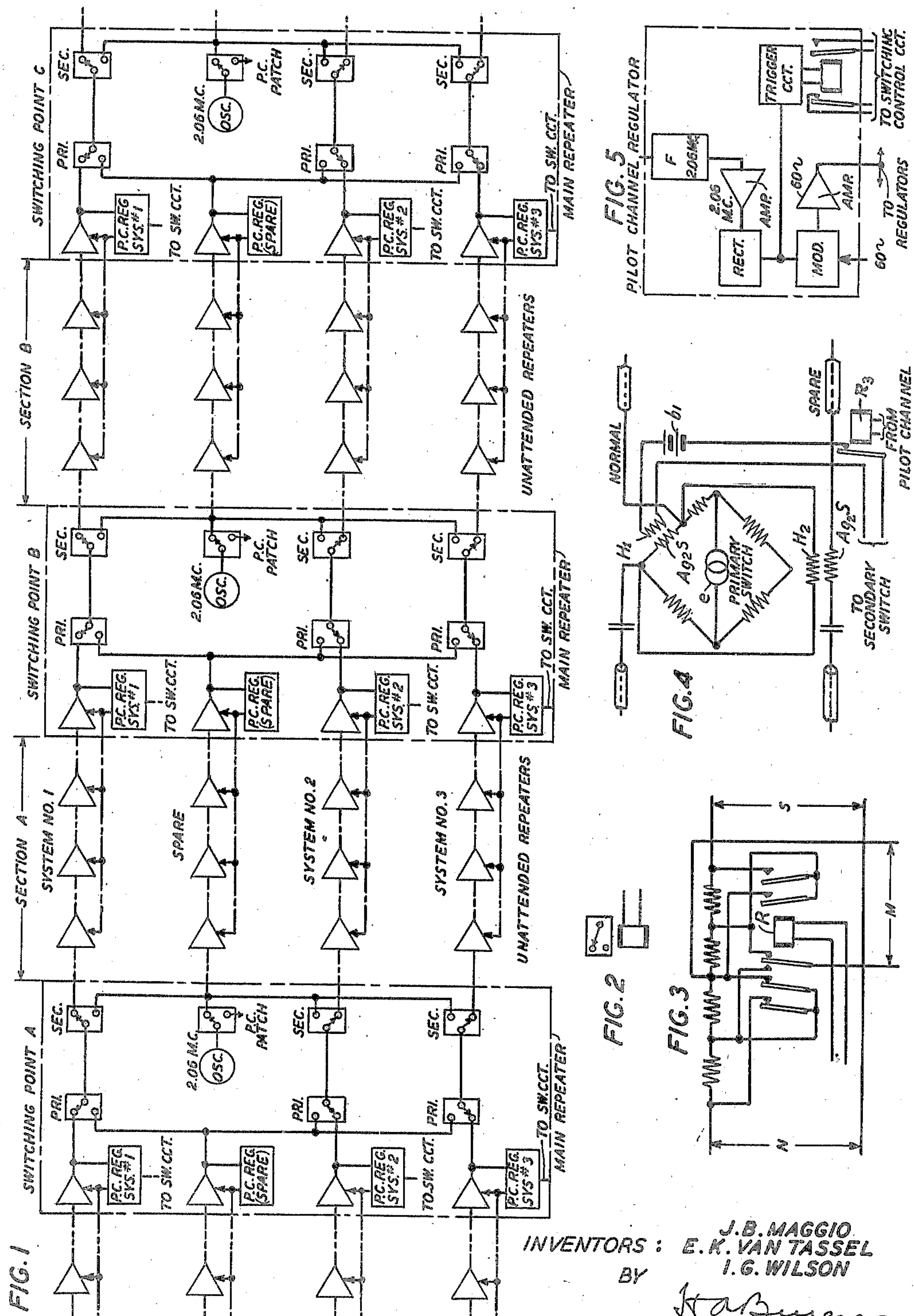

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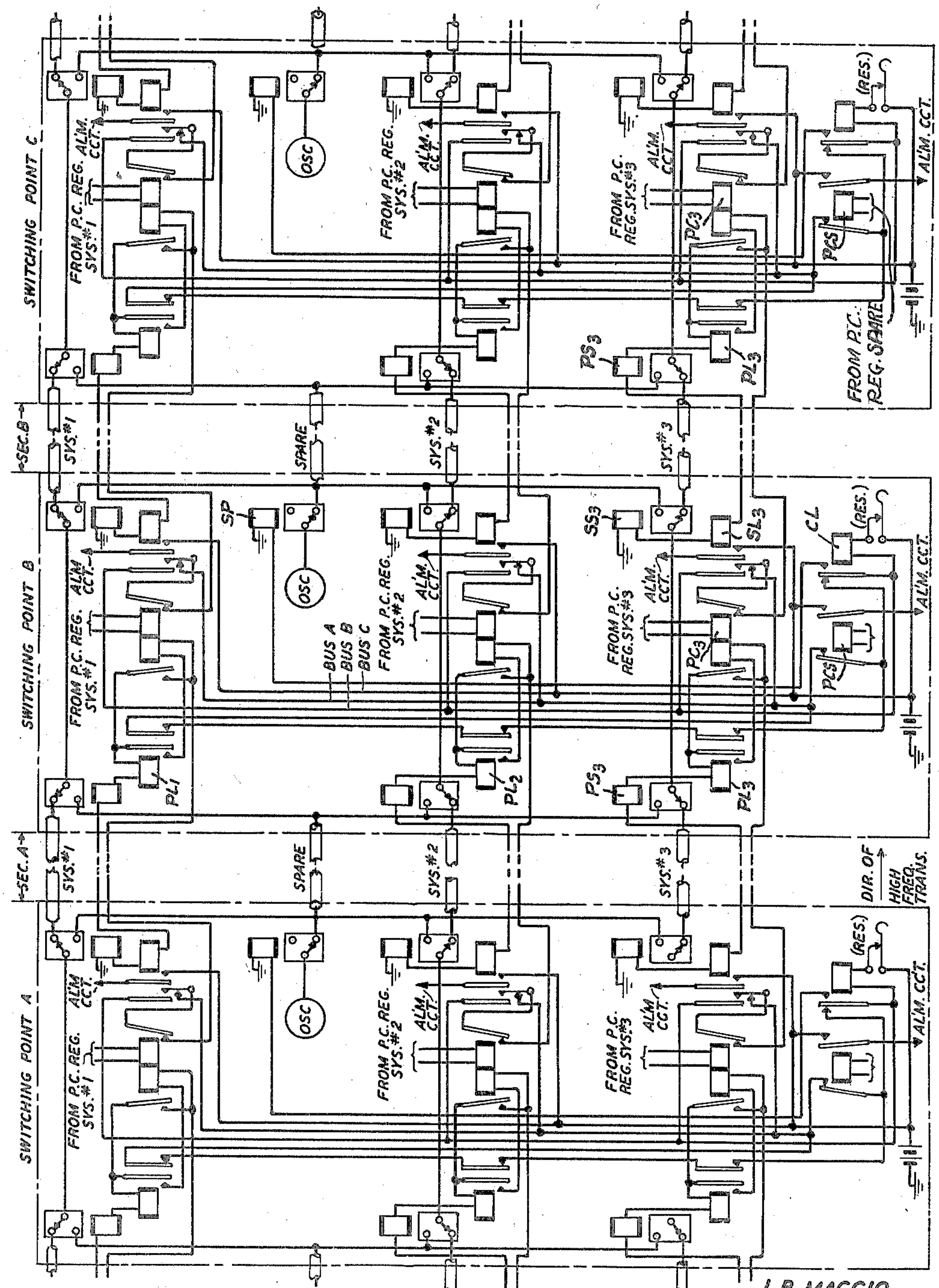

FIG. 6

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SWITCHING OF SPARE REPEATER SECTIONS

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15 Claims. (Cl. 178—44)

This invention relates to broad band transmission systems such as multichannel carrier current signaling systems.

Although the invention is applicable to open wire circuits, wire cable and coaxial cable circuits, it relates to problems which become especially significant in circuits carrying a large number of signal channels, such as a coaxial cable. In such circuits it is customary to use a large number of line repeaters in tandem spaced at intervals which may be as short as five miles or even less, with several unattended repeaters between attended repeater points, a section between such attended points being perhaps fifty or one hundred miles long. If a failure or a degradation in the operation of any element or elements in the circuit occurs, such as a tube failure, it usually means that the whole circuit fails or is degraded and thus may involve several hundred signal channels in the circuit. While with great precautions the likelihood of failures or degradations may be very small, the number of channels involved renders it of the greatest importance to make suitable provision in the event that they do occur.

In a system to which our invention relates there will be a plurality of signal circuits, such as a plurality of coaxial circuits, either running parallel in close juxtaposition or by routes which differ substantially. One of these circuits we set aside as a reserve or spare circuit, portions of which may be switched in to replace any corresponding portion of one of the normal circuits on which there is failure.

One object of this invention is to make such substitution of a defective circuit by the reserve or spare circuit in as short an interval of time as possible. Another object is to provide interlock means such that if a reserve or spare circuit is in use, no other circuit can take it over. Still a further object is to provide means whereby when the circuit which has been replaced is restored to normal operating condition, the spare circuit will be automatically switched out. Other objects will appear in connection with the description of our invention.

The invention will be better understood by reference to the following specification and the accompanying drawings in which:

Fig. 1 shows the transmission paths for a plurality of circuits, the showing being in a highly simplified and schematic form;

Figs. 2 to 5 are more detailed drawings of certain parts of the circuit of Fig. 1; and

Fig. 6 is a more complete showing of the circuit of Fig. 1 with special reference to the control circuits.

Referring more specifically to Fig. 1 there are shown the transmission paths involved when there are three regular coaxial systems and one spare system in one direction of transmission. While in this figure, as well as the subsequent ones, the invention will be described in terms of coaxial conductors, it is to be understood that this is for illustrative purposes only and that the invention applies equally well to other transmission circuits, such as the ordinary cable circuits, and is of particular use in any circuit transmitting a broad band of signals, such as is required in television or multichannel signaling.

In such circuits, especially in coaxial systems, it is necessary to have repeaters at frequent intervals along the transmission line and it is expedient that certain of these repeaters shall be unattended, the general control of these repeaters being from certain attended repeater points. In this description it will be convenient to refer to a portion of the line extending from one attended point to the next attended point as a section. In Fig. 1 there are shown two such sections, A and B, and portions of the adjoining sections. Between and connecting the sections there is an attended repeater point which in accordance with this invention is also a switching point. Between two points such as switching point A and switching point B there is shown a section of circuits 1, 2 and 3 and also a section of spare circuit. In the event of failure or degradation of any one section, that section is replaced by the section of spare circuit and, as pointed out later, the switching is accomplished automatically without interruption of service. With a plurality of normal circuits in each section, any one of which is to be replaced by the spare, it is evident that switching at both ends of the impaired section is necessary and provision, therefore, is made as hereinafter described. The length of section which may be switched in a given time interval is inherently limited by the propagation time of the switching impulse as well as the time of operation of the relays involved. If one assumes, for example, that the maximum allowable time for switching is three milliseconds, then the length of the section will depend on the nature of the circuit but we find that in the case of such coaxial conductors as now contemplated, the section is limited to some fifty or a hundred miles.

In Fig. 1 it will be observed that each regular system terminates at one side of a high frequency transfer switch. The transfer switch at the output of the section is hereafter referred to as the primary switch and that at the input of the section as the secondary switch. With this arrangement of transfers a section of any system may be replaced with the spare section by operating the transfers at both ends of the section.

At each switching point there is a short section of high frequency conductor (between the primary and secondary switch) which always carries the transmission of the system with which it is associated regardless of preceding or subsequent switching. At these points it is evident that signal channels may be dropped off or added to the system, as may be desired.

In such transmission systems as are here contemplated it will in general be desirable to control or regulate the gain of the repeaters, both the attended and unattended ones. One method for regulation consists in transmitting over the circuit continuously a pilot signal which may conveniently have a frequency in or near the band of frequencies being transmitted for signal purposes. Thus, if the signaling band is to extend up to 2 megacyles, the pilot frequency may be placed at 2.06 megacyles. Such control of repeaters in a transmission line is now well understood in the art and is assumed to be present in the systems described herein. It will be noted in Fig. 1 that the input to the pilot channel regulator associated with each system is connected at the output of the receiving amplifier of the switching section.

In addition to the above an independent source of pilot signal, OSC, is located at each switching point. This is normally connected, as shown, to the input of the spare section and serves to maintain the gains of the amplifiers of the spare section at the proper value as the temperature or other conditions affecting the cable vary. Usually it would be convenient to make the frequency of this local pilot channel oscillator the same or substantially the same as the pilot frequency for the normal or regular circuits.

Fig. 1 shows the system in the normal condition. All transmission paths are carried straight through. Let us assume a transmission failure of system **3** in cable section B. Failure of the pilot channel at the output of section B operates the primary switch at station C and the secondary switch at station B associated with system **3**, all in a manner which will be more fully described hereinafter. By a direct current interlock relay system the spare pilot channel oscillator at station B is removed from the input of the spare section at the same time. The transmission of system **3** is now carried on the spare system in cable section B.

With the failure of the pilot channel in section B of system **3**, the regulator protection circuit will set all of the amplifier gains in the failed section to a nominal value, that is, if the nature of the failure is not such that the regulating system itself is inoperative.

After the trouble in the displaced section B of system **3** has been cleared up, the pilot channel oscillator at station B is connected to the input of that section for adjusting purposes. This operates the pilot channel regulator of that section of system **3** and restores the amplifier gains in that section to the proper value for the prevailing cable conditions. When the displaced cable section B is restored to normal operation the spare pilot channel oscillator is automatically removed from the input of that section and restored to the input of the spare by the operation of the spare pilot transfer switch.

The plurality of primary and secondary switches of Fig. 1 are shown in slightly greater functional detail in Fig. 2, it being understood that the relay for operating the switch is under control of the pilot signals. While such switches may take on a large variety of forms, we find that for such high frequencies as 3 or 5 megacycles or even higher, switches which involve the making and breaking of contacts, if these are included in the main transmission path, do not constitute a sufficient opening of the circuit. The small capacity between the adjacent contacts, even though amounting to a few micro-microfarads only, does not introduce sufficient loss. For this reason one particular form of high frequency switch which we find particularly effective is shown in detail in Fig. 3. This switch is based on a form of high frequency switch disclosed in patent application of I. G. Wilson, Serial No. 296,893, filed of even date herewith. The switch of Fig. 3 comprises essentially two of the switches of the Wilson disclosure. In this switch the "opening" of a circuit consists in introducing a series resistance and a shunt short circuit across the line and the "closing" of a circuit consists in short-circuiting the series resistance and opening the shunt short circuit. The circuit of Fig. 3 may be considered as being, for the moment, a primary switch. Pilot signal coming over the normal section N activates the relay R which short circuits a series resistance in the N circuit and removes a short circuit. At the same time it opens a short circuit across the series resistance of the spare section S and closes a short circuit across the spare. Transmission then takes place from the N circuit to the circuit connecting to the next section indicated in Fig. 3 by M. This is a normal condition for this switch. If, now, pilot signal fails then release of the relay R will reverse the situation and the normal circuit N will be disabled or "switched out," while the spare will be "switched in." If the switch is serving as a secondary switch then it transfers an incoming signal at M, which is normally connected to N, to the spare S.

A modified form of high frequency switch is shown in Fig. 4. In each of the transmission circuits there is included an element of Ag_2S which has the property of a very rapid decrease in resistance with rise in temperature. Such an element is sometimes given the name of "thermistor." This element in series in a regular circuit is made a part of one arm of a Wheatstone bridge. The temperature of the element is maintained at an appropriately high value by means of a heater H_1 supplied from battery b_1 when the relay from the pilot channel is energized. This heater circuit also includes a corresponding heater for an Ag_2S element at the other end of the normal section. Under these conditions the loss introduced in the transmission circuit is of small value. The bridge is supplied at two of its opposite corners with any suitable source of power such as a 60-cycle source e. Across one of the arms of the bridge is a second heater element H_2. Under normal conditions, the bridge being balanced, no alternating current power flows through the second heater and the Ag_2S element in the spare circuit is cool and therefore introduces a large loss to transmission in the spare circuit.

In case of failure of the pilot signal the relay R_3 opens and the heater H_1 cools off, whereupon the

Ag_2S element in the normal circuit introduces excessive loss. Such change unbalances the bridge and heating current now flows through H_2 and reduces the loss due to the Ag_2S element in the spare circuit to a very low value. It is apparent by this description that the circuit of Fig. 4 is essentially a switch.

In each of Figs. 3 and 4 it will be observed that the switch performs the function of opening one circuit and closing another and the manner of introduction of either of these switches in the circuit will be obvious from the drawings.

A somewhat further detailed showing is given in Fig. 5 of the pilot channel regulators of Fig. 1 which are there shown as derived from the last repeater of a section. Each regulator is supplied with pilot channel signal (here shown as 2.06 megacycles) through a filter, an amplifier and a rectifier. The output of this rectifier controls the regulators. Also, from the output of the rectifier there is derived a trigger circuit which in turn operates the switching control circuit.

Complete control circuits for an installation comprising the three regular systems and a spare in one direction of transmission are shown in Fig. 6, as an elaboration of Fig. 1. In this Fig. 6 all switches are shown in normal position. The oscillator output, which again may be assumed as 2.06 megacycles, is interlocked with all secondary switches.

Again assuming a transmission failure in section B of system **3** the operation is as follows: At the beginning of the switching process the common lock-up relay CL at station B is not operated. Since section A is operating normally, the back contacts on the PL_1, PL_2 and PL_3 relays are closed and switching battery is supplied to bus A, whether or not the spare pilot channel PCS relay is operated. The system **3** pilot channel PC_3 relays at stations B and C are held operated by the presence of pilot channel. If the pilot channel fails at station C and not at station B, the PC_3 relay at station C releases while that at station B does not.

The release of the back contact of the PC_3 relay at station C completes the circuit from bus A at station B through the primary lock-up PL_3 and primary switch PS_3 at station C, and the secondary lock-up SL_3 and the secondary switch SS_3 at B, to ground. In the event of simultaneous failures of the pilot channels at stations B and C, this circuit is not completed, since the forward contact on the PC_3 relay at station B operated. An auxiliary pair of small wires is used for this circuit. (This pair may also be used as the order wire.) These relays operate and the high frequency transfer switches SS_3 and PS_3 transfer the transmission of the spare system in the section B.

At station B the secondary lock-up SL_3 transfers and locks the operating switching circuit to battery bus B and registers a switching alarm. At the same time the common lock-up CL operates and removes switching battery from bus A, preventing any operation of any of the other switching circuits controlled from station B. Thus, in the event of failure of another system in the same section the switching circuit is prevented from again operating. This last operation also operates the SP relay and removes the spare pilot channel from the input of the spare section.

At station C the operation of the primary lock-up PL_3 relay locks associated PC_3 relay. The opening of the back contact of the PL_3 relay removes the shunt across the forward acting contacts of the PCS relay at station C. In the event of pilot channel failure at the output of the spare section (which is now a part of system **3**), switching battery is removed from bus A. In the event of simultaneous failure of the pilot channel at both ends of a switching section the PC_3 relay at each station releases and no switch is made in that section.

Having switched one section the next section of that circuit cannot switch on to its spare. However, the spare in this next section is available for any of the other circuits. Subsequent sections are all in normal condition and failures will be handled as described for section B. In the event of failure of the spare when it is not in the transmission path an alarm is registered by the release of the PCS relay, the latter simultaneously disabling the switching circuit and precluding substitution of the spare for any of the regular sections.

When the displaced section has been repaired it is restored to normal operation by operation of the restore key RES. This removes battery from all switching circuits and the system as a whole is again in normal operating condition.

While the invention has been described in terms of a specific circuit arrangement, it is to be understood that this is for illustrative purposes only and that numerous changes may be made without departing from the spirit of our invention.

What is claimed is:

1. A plurality of conductor pairs extending between two geographically separated points for the transmission of signals, a similar pair acting as a reserve pair, each pair normally carrying a pilot signal for maintenance of correct operating conditions, and means subject to failure of pilot signal on any pair to replace the said pair by the reserve pair.

2. A plurality of conductor pairs extending between two points, a similar pair acting as a reserve pair, each normally carrying a pilot signal for maintenance of correct operating conditions, and a separate switching circuit subject to failure of pilot signal on another pair to replace the said pair by the reserve pair.

3. A plurality of conductor pairs extending between two points, at least one of them being a reserve pair, each normally carrying a pilot signal for maintenance of correct operating conditions, a separate switching circuit subject to failure of pilot signal on another pair to replace the said pair by the reserve pair, and an interlock system in the switching circuit whereby when the reserve pair is in use all other pairs are locked out from use of the reserve pair.

4. A plurality of conductor pairs extending between two geographically separated points, at least one of them being a reserve pair, each normally carrying a pilot signal for maintenance of correct operating conditions, and a separate switching circuit which operates on failure of pilot signal on another pair to replace the said pair by the reserve pair, the switching circuit being so arranged that if pilot signal fails at both ends of a pair, no switching occurs for that pair.

5. In a transmission system, a plurality of substantially equivalent parallel and independent long distance signal transmission circuits, one of which is set aside as a spare, each circuit being divided into sections, each regular circuit normally carrying a pilot signal, and means subject to the pilot signal for switching in a section of the spare for any corresponding section of a regular circuit which has failed.

6. In a transmission system, a plurality of substantially equivalent parallel and independent circuits, one of which is set aside as a spare, each

circuit being divided into sections, each regular circuit normally carrying a pilot signal, a separate pilot signal source for each section of the spare for maintaining the transmission equivalent of said each section substantially constant, and means subject to the pilot signal of the regular pairs for switching in a section of the spare for any corresponding section of the regular circuits which has failed.

7. In a transmission system, a plurality of substantially equivalent parallel and independent long distance signal transmission circuits, one of which is set aside as a spare, each circuit being divided into sections, each regular circuit normally carrying a pilot signal, and a separate switching circuit in one section which operates on failure of the pilot signal on another circuit of that section to replace the said section by the spare of that section.

8. In a transmission system, a plurality of substantially equivalent parallel and independent circuits, one of which is set aside as a spare, each circuit being divided into sections, each regular circuit normally carrying a pilot signal, a separate switching circuit in one section subject to failure of the pilot signal on another circuit of that section to replace the said section by the spare of that section, and an interlock system in the switching circuit whereby when the spare of that section is in use all other circuits in that section are locked out from use of the spare.

9. The combination of claim 7 characterized by the fact that there is a similar switching circuit for each section.

10. The combination of claim 7 characterized by the fact that there is a similar switching circuit for each section, the switching circuits being so arranged that if pilot signal fails on both ends of a regular section, no switching for that regular circuit occurs in that section.

11. The combination of claim 7 characterized by the fact that there is a similar switching circuit for each section and further characterized by the fact that there is a separate pilot signal source for each section of the spare circuit and that there are means whereby on the switching in of a spare section its pilot source is disconnected and regular pilot signal for the circuit on which replacement has been made is introduced on the inserted spare section.

12. In a transmission system, a plurality of substantially equivalent parallel and independent long distance signal transmission circuits, one of which is set aside as a spare, each circuit being divided into sections, each regular circuit normally carrying a pilot signal, a separate switching circuit in one section subject to failure of the pilot signal on another circuit of that section to replace the said section by the spare of that section, an interlock system in the switching circuit whereby when the spare is in use all other circuits in that section are locked out from use of the spare, and a restoring key which reintroduces the regular section and restores the switching circuit to normal condition.

13. In a transmission system, a plurality of substantially equivalent independent circuits, one of which is set aside as a spare, each circuit being divided into sections, each regular circuit normally carrying a pilot signal, a separate switching circuit in one section which operates on failure of the pilot signal on one of the regular circuits of that section to replace the said section by the spare of that section, and means in said switching circuit whereby if the spare section has failed the operation of the switching circuit for that section is prevented.

14. In a wide band signal transmission system, a plurality of long distance signaling circuits, each divided into sections comprising one or more signal repeaters, said circuits extending between and connecting a pair of geographically separated terminal stations, means at one of said terminal stations for transmitting individual pilot currents through said several circuits, means responsive to said pilot currents for controlling the transmission equivalents of said repeaters, a spare signaling circuit extending between said terminal stations and likewise divided into sections, and means responsive to an abnormal change in the said pilot current at the output end of any given section for substituting the corresponding section of said spare circuit, said responsive means being conditioned to be unresponsive in the presence of normal pilot current at the input end of said given section.

15. A combination in accordance with claim 14, comprising individual pilot current sources associated with the several sections of said spare circuit for controlling the respective transmission equivalents thereof, and means for dissociating the said individual pilot current source from a given section of said spare circuit when said given section is substituted, whereby control of the transmission equivalent of the substituted spare section is thereupon transferred to the pilot current transmitted through the circuit into which the spare section is substituted.

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