

April 21, 1942.

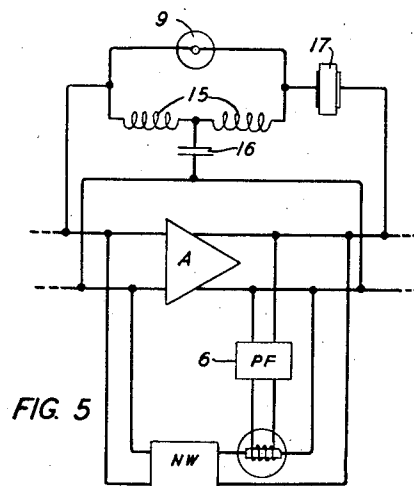
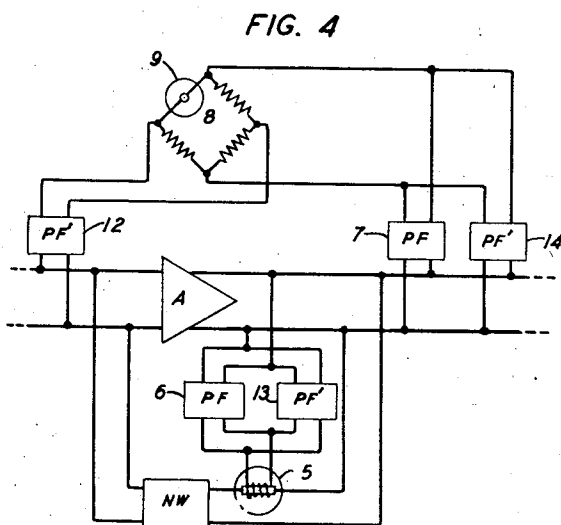
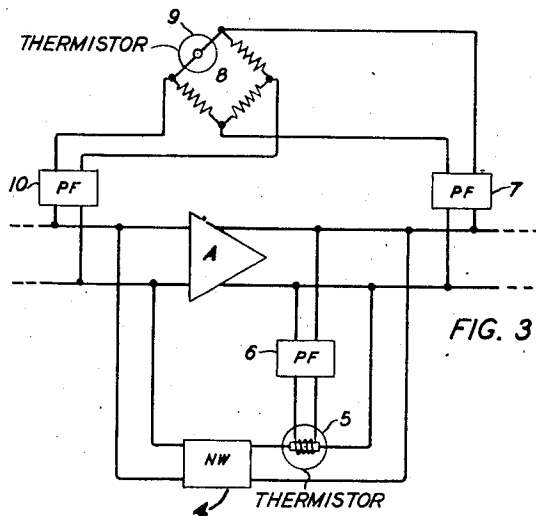
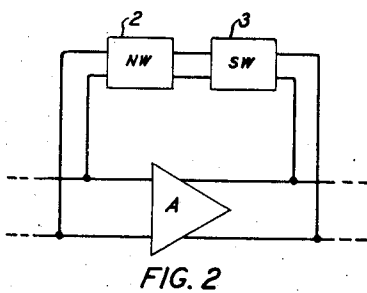
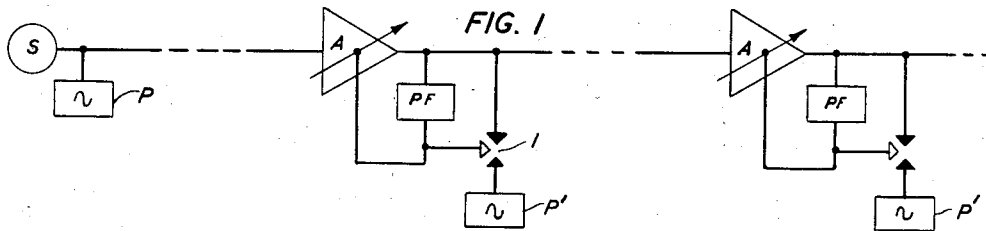
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2,280,293

REPEATER CONTROL

Filed Feb. 25, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 6

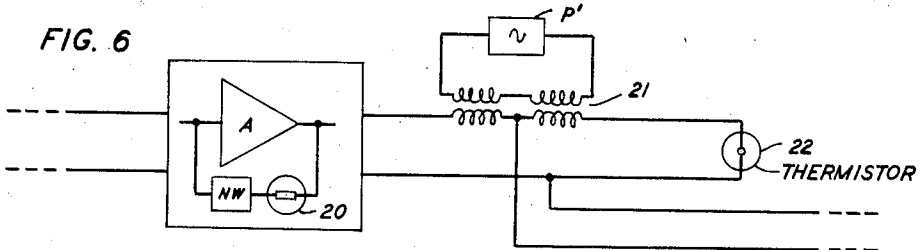


FIG. 7

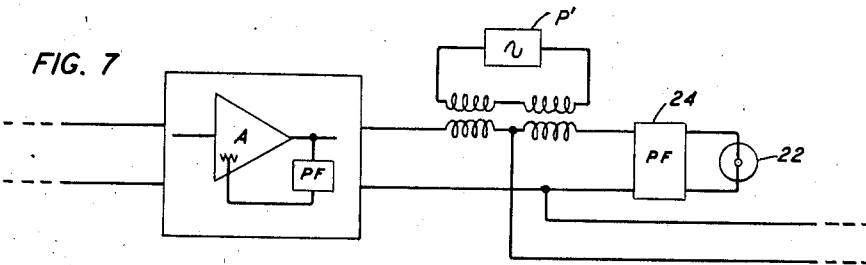


FIG. 8

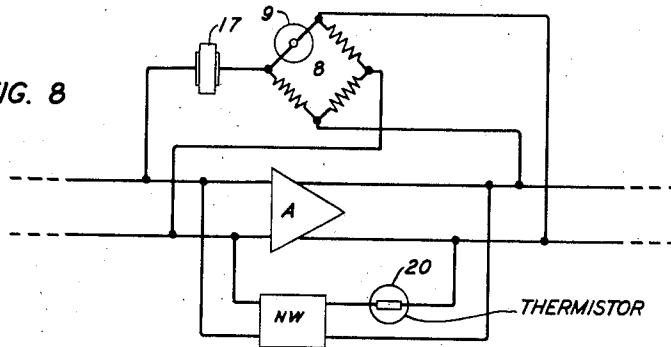
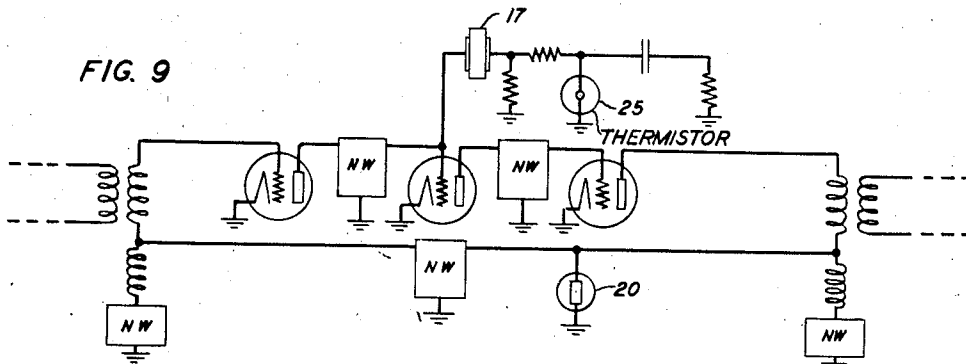


FIG. 9



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REPEATER CONTROL

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Application February 25, 1941, Serial No. 330,444

11 Claims. (Cl. 178—44)

This invention relates to electric wave transmission systems comprising repeaters individually controlled by waves transmitted through the system, and more particularly to signaling systems employing pilot waves transmitted concurrently with the signal for controlling, or for contributing to the control of, a transmission characteristic of the repeaters, such as the amplification or gain thereof.

In wire line transmission systems employing pilot currents for the control of repeater gain, changes in the intensity of the pilot currents appearing at each repeater are taken as a measure of the changes in transmission equivalent or attenuation of the next preceding repeater section, and they are translated into a compensating change in the gain of the repeater. Thus if the pilot intensity falls from a predetermined normal value, the gain of the repeater is automatically increased so that the pilot and signal currents are restored to their normal level. In the event that a fault occurs in the system such that the pilot disappears or is reduced to an ineffective low value at the repeaters following the point of fault, such repeaters would ordinarily respond by automatically adjusting themselves to produce maximum gain. This response of itself tends to disrupt service by introducing signal distortion and noise. Although the fault may be of only a few moments' duration, nevertheless when service is resumed the system may be found noisy for a short time because of the maximum gain adjustment of the repeaters and the interval required for the control circuits to readjust the gain. The fault, moreover, may be such that only the pilot channel is disabled, in which case service could continue substantially unimpaired for an appreciable period except for the resulting improper adjustment of the repeater gain.

In accordance with the present invention the effect of pilot failure is largely localized or confined to the particular section of the system where the fault occurs and the remainder of the system is provided immediately and automatically with pilot currents enabling the repeaters to continue functioning with automatic gain control in normal manner. This desirable result is brought about by providing for the generation of pilot current oscillations at the several repeaters of the system and for the application of such oscillations to the transmission line under the control of, or responsive to the failure of, the normal pilot current. Thus if the normal pilot reaches a point near the middle of the system,

for example, and fails to appear thereafter, oscillations of suitable pilot frequency are generated at the repeater next following that point and applied to the line for transmission to, and gain control of all succeeding repeaters.

Certain embodiments of the invention hereinafter to be described in detail are especially advantageous in respect of economy of apparatus, simplicity of construction and adjustment, reliability of operation and in other respects that will appear. They provide for use of the repeater amplifier as an active part of an oscillator that is adapted to generate "substitute" oscillations of suitable pilot frequency and amplitude but which is normally disabled or inhibited from oscillating. Means are provided for removing the disability and causing oscillations to be generated in response to failure of pilot currents to appear at the repeater. Whereas every regulated repeater in the system may be thus arranged to serve as an emergency pilot source, only the regulated repeater next following the fault is brought into action in the event of failure of the normal pilot, for in all succeeding repeaters the oscillator portion is disabled or maintained disabled by the arrival of the emergency pilot current.

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 diagrammatically a system in accordance with the invention;

Fig. 2 illustrates diagrammatically a repeater amplifier adapted for oscillation under the control of transmitted current;

Figs. 3 to 5 show repeaters conforming with Fig. 2 and adapted for operation with unmodulated pilot currents; and

Figs. 6 to 9 show other repeaters in accordance with the invention, some of which are particularly adapted for use with modulated pilot current.

Referring more particularly now to Fig. 1 there is shown a system in accordance with the invention in which signals from a source S and pilot current from a source P are transmitted together through a wire line having repeater amplifiers A interposed at intervals therein. The source S may be, for example, the transmitting terminal circuit of a multiplex carrier telephone system, and the source P may be an oscillator adapted to produce oscillations of constant am-

plitude and of a fixed frequency within or adjoining the frequency range occupied by the telephone channels. Assuming that the pilot currents are to be used for repeater gain regulation, means are provided at each of the repeater amplifiers A to pick off or partially divert the pilot currents at or near the outputs of the repeater and for applying them to a gain regulating element within the amplifier. The pick-off means may comprise a pilot filter PF arranged in the manner disclosed in U. S. Patent 2,154,888, issued April 18, 1939, to H. S. Black, and the gain-controlling element may comprise a thermistor disposed in gain-controlling relation in a negative feedback path within the amplifier. Under normal operating conditions, the intensity of the pilot currents appearing at each amplifier varies with the changes in the transmission equivalent or attenuation of the preceding line section and between extreme values that are more or less fixed. Between these extremes, the pilot currents operate to maintain the transmission equivalent of each repeater section substantially constant, thereby maintaining the pilot intensity at the output of each repeater substantially constant also.

As noted hereinbefore, any failure of the pilot currents to arrive at a given repeater or any abnormally great reduction in the intensity of the pilot currents reaching that repeater, is interpreted by the gain control element as calling for an abnormally great increase in the gain of the repeater. Accordingly in such event the gain of the repeater is automatically adjusted to a high value beyond the normal operating range. The same action takes place at each succeeding repeater where the pilot fails to appear or is abnormally reduced in intensity. In this condition of the system, cross-talk, static and other disturbing effects induced into the message channels as well as disturbances originating within the system are all amplified in high degree and may of themselves be sufficient to impair or practically interrupt service on some or all of the telephone channels. Thus if there should develop at the terminal station a fault of such nature that the supply of pilot currents to the line was interrupted without affecting the supply of message currents, the entire system might be practically disabled by the consequent unnecessary extreme response of the repeater gain-control devices. Again the fault might be of momentary character but long enough for the gain-control devices to complete the extreme adjustment of the repeater gain, whereupon the message channels would remain noisy after removal of the fault while the gain-control devices proceeded to reduce the repeater gain to normal value. This same multiplication of the effective duration of a temporary fault would obtain also if the message channels as well as the pilot channel were disabled by the fault.

In accordance with the present invention as illustrated in highly schematic form in Fig. 1, means are provided at the several repeaters for applying to the outgoing line for transmission to succeeding repeaters, oscillations of suitable frequency and amplitude to replace the normal pilot currents in the event that such currents fail to reach the respective repeaters at normal intensity. As illustrated, an auxiliary oscillator P' may be provided at the several repeaters and arranged to be connected to the outgoing transmission line by a switch 1 that is normally open, but which is closed in response to an abnormal reduction in

the pilot current appearing at the output of the pick-off filter PF. If now, for example, a fault develops in the pilot supply at some point preceding the first of the amplifiers shown, switch 1 at the repeater closes and pilot currents are transmitted through the line to all following repeaters. The latter are thereby held within their normal gain range, they are continuously regulated to compensate for changing line attenuation and the like, and they are held in instant readiness for the resumption of normal transmission immediately upon clearance of the fault. In the situation assumed, it is evident that the first of the repeaters following the fault may receive neither the normal pilot current nor control current from the local substituted pilot source. This condition is not necessarily obtained as will appear from the disclosures hereinafter made, but even if it does in a given case, it should be appreciated that abnormally high gain might well be tolerated in one repeater where it would not be in the several hundred repeaters that might be involved in a given system. It should be understood too that if a fault developed between repeaters, all repeaters preceding the fault would receive normal pilot current and all repeaters following the fault excepting possibly for the first of these, would receive the substitute pilot current.

In considering further details of the invention as illustrated in Figs. 2 to 9, it may be well to bear in mind that not all of the repeaters in a given system need be arranged to provide substitute pilot currents, that some of the repeaters in the system may be of a non-regulating type, and that the substitute pilot source may be associated with the unregulated repeaters as well as, or instead of, with the repeaters having gain regulation.

It should be borne in mind also that the substitute pilot currents may in a given system have a frequency differing from that of the normal pilot currents, where, for example, the pilot pick-off filters PF are not sharply selective or have multiple pass-bands or in other cases such as those to be described with reference to Figs. 6 to 9. Where, however, the pilot currents are used in conjunction with other pilot currents for slope or twist regulation, it will ordinarily be necessary or desirable that the normal and substitute pilot frequencies be the same.

Whereas from the diagrammatic showing in Fig. 1, it might be supposed that a separate oscillator is essential for the production of the substitute pilot current, such is not the case. That an amplifier can be adapted to generate oscillations without interfering with its functioning as a signal amplifier, is well known, and I have found that such an amplifier-oscillator is adaptable to the purposes of the present invention. In Fig. 2, for example, there is shown in highly diagrammatic form a repeater amplifier A all or some active portion of which is embraced by a positive feed-back circuit. The latter comprises means represented by network 2 for fixing the frequency of the oscillations generated in the positive feedback loop and means represented by switch 3 for conditioning the loop for oscillation or non-oscillation in response to the disappearance or appearance of normal gain-control currents at the repeater. Either of the elements 2 and 3 may be arranged also to fix the amplitude of the locally generated oscillations. Other special functions may be incorporated also in the positive feedback circuit.

Network 2 in Fig. 2 may be designed to have

minimum attenuation at the frequency of the substitute pilot to be provided, thereby fixing the frequency of the local oscillations. Transmission through the positive feedback loop may be made dependent upon the pilot power at the output of the amplifier. More particularly when the output pilot power is within its normal range, the transmission loss in the positive feedback circuit is maintained at a higher value than the amplifier gain effective in the positive feedback loop, hence precluding oscillation, but if the pilot output power falls below its normal range the feedback loss is decreased rapidly to a value equal to the effective amplifier gain in the loop and oscillations thereupon are generated in the loop. The output intensity of these oscillations may be limited to a value slightly below the normal pilot output intensity to preclude restoration of the feedback loop to its non-oscillating condition.

The specific embodiment of the invention illustrated schematically in Fig. 3 is consistent with the foregoing description of Figs. 1 and 2 and comprises a repeater amplifier of the stabilized feedback type with automatic gain control. The gain stabilizing feedback circuit is illustrated as comprising a network 4, which provides the desired over-all feedback characteristic, and a thermistor 5 that is variably heated by pilot currents diverted through pilot filter 6 from a point at or near the output of the amplifier. These elements may be so proportioned and adjusted as described fully in the patent to H. S. Black noted hereinbefore as to maintain the normal pilot output intensity within a very narrow range despite substantial changes in the transmission equivalent of the preceding repeater section. A second path, adapted for positive feedback, is connected around the amplifier. At the input end of this feedback path is a filter 7 that admits only currents of the normal pilot frequency. Currents passed by the filter 7 are applied to opposite or input terminals of a resistance bridge 8, one arm of which comprises a directly heated thermistor 9. The other or output terminals of the bridge are connected through a filter 10, that is similar to filter 7, to the amplifier proper.

The positive feedback circuit in Fig. 3 is so adjusted that the pilot currents admitted through filter 7 normally maintain directly heated thermistor 9 at such temperature and resistance that bridge 8 is balanced and there is infinite loss between the input and output terminals thereof. This condition can readily be maintained during normal operation of the system inasmuch as the gain regulator normally maintains the pilot output intensity at an approximately constant value. In the event that a fault occurs and normal pilot no longer appears at the output of the amplifier, thermistor 9 cools, changes in resistance, unbalances the bridge 8 and thereby reduces the loss interposed by the bridge. As the bridge loss is thus reduced a point is reached where the net loss through the positive feedback circuit equals the amplifier gain in the feedback loop, that is, at the pilot frequency, and oscillations are generated. These oscillations maintain a constant amplitude for they control, and are controlled by, the temperature and resistance of thermistor 9. That is, if the oscillations should tend to increase in amplitude thermistor 9 is thereby heated and the bridge unbalance changed in such sense as to increase the bridge loss and reduce the oscillation amplitude. To provide a safe margin for the switching function of bridge 8 and thermistor

9, the locally generated oscillations may be stabilized at a value a few decibels below the output intensity of the normal pilot output current, or more precisely, the intensity of the locally generated oscillations at the normal pilot pick-off point (filter 6) should be somewhat less than the pilot intensity obtaining at that point during normal operation.

From the foregoing description of Fig. 3, it will be evident that upon failure of the normal pilot or abnormal reduction of the intensity thereof, oscillations of this same pilot frequency are generated locally and applied at a predetermined constant level to the outgoing transmission line section. It will be evident too that upon restoration of the normal pilot, the pilot output of the amplifier is momentarily enhanced, or tends to be enhanced, but the additional heat thereby supplied to thermistor 9 changes the temperature thereof and restores bridge 8 to balance whereupon the local oscillations cease.

In one aspect of the Fig. 3 circuit, and in accordance with an important feature of the present invention, the presence or absence of oscillations in a circuit adapted for the generation of currents from an external source, and more particularly by the application of such currents to a gain control or loss control element in an amplifier-oscillator. Bearing in mind further that the normal pilot input intensity to the amplifier may be minute as compared with the pilot output power, it will be seen that the invention provides for turning on and off strong oscillations under the control of weak ones.

Another important feature of the Fig. 3 circuit that is especially worthy of note has to do with the restraint it imposes on the amplifier gain control device in the event of failure of normal pilot. It has been noted hereinbefore that on pilot failure the gain of the amplifier next following the fault may tend to rise to an extremely high value and thereby tend to introduce distortion and noise. In Fig. 3, however, it will be observed that the oscillations locally generated in such event are applied also through filter 6 to the gain-controlling thermistor 5 of the same amplifier. Although the heat so supplied to the thermistor 5 may be slightly less than that normally supplied, because of the margin provided for bridge 8, the heating effect is substantial and enough to prevent the amplifier gain from going to the extremely high value that would obtain if no heating effect were provided at all. In accordance with this phase of the invention then, means are provided for locking the gain of the repeater at a tolerable value in the event of pilot failure. More specifically stated, the repeater amplifier is adapted to generate local oscillations in the event of pilot failure and to apply such oscillations in lieu of normal pilot current to a thermistor or other gain-controlling element of the same amplifier.

Although Fig. 3 is adapted to illustrate the principles underlying the invention, it may be noted that in practice, filter 10 may be found unnecessary in most cases, the functions of filters 6 and 7 may be performed by either one of the filters alone, and other simplifying changes could be made.

Fig. 4 illustrates a modification of Fig. 3 that is adapted for the generation within the repeater of substitute pilot oscillations having a frequency other than that of the normal pilot currents. As compared with Fig. 3, the changes consist in re-

placing filter 10 with a filter 12 that is arranged to pass the desired new pilot frequency, and by paralleling filters 6 and 7 with filters 13 and 14, respectively, also tuned to the new pilot frequency. Normal pilot current is admitted through filter 7, as in Fig. 3, to maintain bridge 8 in its high loss condition and to unbalance the bridge on failure of normal pilot, and for this purpose the currents may optionally be applied directly to a heater element associated with thermistor 9. Filters 12 and 14 define the frequency at which the positive feedback circuit will oscillate and the intensity of the oscillations so developed are controlled by thermistor 9 as described with reference to Fig. 3. Filter 13 permits a control of the gain of the amplifier by the substituted pilot currents whenever the latter appear.

Fig. 5 illustrates another modification of the Fig. 3 circuit that differs therefrom principally in respect of the switching and frequency determining portions thereof. In lieu of resistance bridge 8, two inductances 15 are connected in series in the positive feedback circuit and the condenser 16 shunted across the circuit from their junction. The reactive elements are so proportioned as to provide series resonance if thermistor 9, which is shunted across the pair of coils, is short-circuited. Under normal operating conditions thermistor 9 is maintained at such resistance that oscillation-suppressing loss is interposed in the positive feedback circuit. Upon abnormal reduction of the normal pilot currents admitted to the positive feedback circuit through piezo-electric crystal 17, the loss so interposed is reduced and the circuit begins to oscillate.

In my copending application Serial No. 280,285 and in that of J. H. Bollman Serial No. 280,269, both filed June 21, 1939, (which issued February 11, 1941, as United States Patents Nos. 2,231,538 and 2,231,553, respectively,) there are disclosed repeater gain-regulating systems in which the initial intensity of the pilot wave is varied oppositely to the normal changes in the average intensity of the aggregate message current so that the average intensity of pilot and signal combined is maintained substantially constant. At the repeaters in such a system the gain-controlling devices are supplied not with pilot currents alone but with both pilot and signal currents, and they are controlled in such manner that the average intensity of signal and pilot combined is maintained constant at the output of the amplifier. Repeater gain-regulating systems of this character are subject to the same disadvantages in the event of pilot failure as the gain-regulating system hereinbefore described and they are subject also to other deleterious effects when only the pilot supply is affected by the fault.

To supply substitute pilot current in the event of pilot failure in a system of the kind last described, an arrangement in accordance with the invention as illustrated in Fig. 6, may be employed. In this figure, amplifier A represents one of the gain-regulating repeater amplifiers of such a system, and as previously indicated it is provided with repeater gain-control means such as a beta circuit thermistor 20 that is heated by pilot and signal currents to maintain the power content of pilot and signal combined substantially constant at the output of the amplifier. The amplifier output is connected in continuous power transfer relation with the outgoing transmission line through a bridge circuit comprising hybrid coil 21. Connected to one pair of the

bridge terminals is a thermistor 22 of the directly heated type which is at all times supplied with the current from the amplifier output. It is so proportioned that when the amplifier output is of normal constant intensity, it is heated to a temperature and resistance such as to maintain the bridge in balance and to render the terminals to which the substitute pilot source P' is connected, conjugate to the outgoing transmission line. Source P' may be an oscillator and is adapted to supply current of constant intensity and of a frequency suitable for use as a substitute pilot. In normal operation then, the bridge is balanced and the substitute pilot currents are confined to the repeater. If now through some fault the output of amplifier A drops to zero or some ineffective low value, thermistor 22 is reduced in temperature and the consequent resistance change unbalances the hybrid coil bridge circuit and allows current from source P' to reach the outgoing transmission line. Thermistor 22 may be assigned such characteristics that the intensity of the outgoing substitute pilot current is maintained at a constant value slightly below the intensity of the current normally supplied to that outgoing line. It will be evident that when the fault is cleared and the output of amplifier A returns to normal, thermistor 22 will thereby be heated, restore the bridge to balance and virtually switch off the source P'.

Consider now the consequences of a failure of only the normal pilot current in the system of Fig. 6. In the first place the gain of amplifier A will increase, unnecessarily, to maintain constant power output in the absence of the power contribution of the normal pilot. Thermistor 20, however, may be so sluggish in its operation as to be non-responsive to the fluctuation in power occurring at say syllabic frequencies. Hence, even with only a single telephone channel in use, intelligible signals can be transmitted through the amplifier. Thermistor 20 may in fact advantageously be proportioned to respond only to such intensity changes as are maintained for ten or twenty seconds, for example. Thermistor 22 on the other hand may be a fast-acting or sensitive thermistor that will respond to intensity changes occurring as rapidly as syllabic frequencies. Hence, it variably unbalances the bridge at a rapid rate and modulates the substitute pilot current from source P' in substantially the same manner as the normal pilot currents were modulated, prior to the fault, at the transmitting terminal station. Inasmuch as the average intensity of signals and substitute pilot combined is then maintained constant at the proximate end of the outgoing transmission line, none of the following repeaters are aware of the substitution and gain regulation at those repeaters takes place in the usual manner.

The bridge balancing and switching features of Fig. 6 may be applied also to a repeater gain regulating system in which an unmodulated pilot is employed as in Figs. 3 to 5. A suitable example is illustrated in Fig. 7 where the only changes involved are the substitution of a repeater amplifier A adapted for pilot channel control and the interposition of a pilot filter 24 in the leads to thermistor 22. In this case the pilot output of the amplifier is normally maintained constant and pilot current of constant intensity is applied through filter 24 to thermistor 22 to maintain the bridge in balance. In the event of pilot failure, the consequent change in resistance of thermistor 22 unbalances the hybrid coil

bridge circuit and allows substitute pilot current from source P' to be admitted to the outgoing line at a predetermined constant level.

Fig. 8 illustrates a modification of the Fig. 3 circuit that is adapted for use in a repeater gain-control system employing a modulated pilot as described with reference to Fig. 6. Whereas in Fig. 3 the gain-controlling thermistor is heated only by pilot current, in Fig. 8 the gain-controlling thermistor 20 is indicated schematically as being heated by both the signal currents and the normal or substitute pilot currents as the case may be. Likewise thermistor 9 in bridge circuit 8 is heated by signal currents as well as by the pilot currents. A piezoelectric crystal 17 interposed between the output of bridge 8 and the input of the amplifier fixes the frequency of oscillation through the positive feedback circuit. In normal operation thermistor 9 is maintained at a constant temperature such that the bridge 8 is balanced, and no local oscillations are generated. In the event of pilot failure the heating current supplied to thermistor 9 is thereby reduced, the bridge becomes unbalanced and oscillations of the frequency fixed by crystal 17 are developed in the positive feedback loop. Thermistor 9, which corresponds to thermistor 22 of Fig. 6, is comparatively fast-acting and therefore variably unbalances the bridge 8 to effect the desired amplitude modulation of the locally generated oscillations.

Fig. 9 shows in comparative detail a multistage repeater amplifier of the stabilized feedback type arranged in accordance with the invention to generate signal modulated pilot oscillations in the event of pilot failure. The positive feedback circuit comprises a piezoelectric crystal 17 for fixing the frequency of the locally generated oscillations and a thermistor 25 which is heated by the output currents of the amplifier. The arrangement here disclosed is substantially identical with that described in the application of C. O. Mallinckrodt application Serial No. 280,272, filed June 21, 1939, (which issued February 11, 1941, as United States Patent No. 2,231,542) for the production of normal pilot current at the transmitting terminal station, with slight changes better adapting the combination to the purposes now in view. To provide some margin in the operation of the circuit as a substitute pilot generator, the positive feedback circuit is designed to have somewhat greater loss during normal operation of the system than the loss value which would permit oscillation to begin. In other words, with normal output from the amplifier and thermistor 25 thereby held at a predetermined constant resistance, the net loss of the positive feedback circuit at the substitute pilot frequency is made somewhat greater than the gain in the mu portion of the positive feedback loop. Another change involves the addition of a thermistor 20 in the normal beta circuit for those cases in which the repeater is to have gain regulation.

What is claimed is:

1. A system including a plurality of repeaters for the concurrent through transmission of signal waves and auxiliary waves, at least one of said repeaters comprising means for regulating a transmission characteristic thereof under the control of waves transmitted through said system, at least one other of said repeaters anterior to said one repeater comprising means adapted to generate auxiliary waves, and means to supply said generated auxiliary waves to said system for

transmission to said one repeater in response to an abnormal change at said other repeater in the said controlling waves.

2. A long distance transmission system including repeaters spaced apart therein, means for supplying pilot and signal waves to said system for concurrent through transmission, each of a plurality of said repeaters including means responsive to substantial failure of the said pilot waves normally received thereat for supplying substitute pilot waves to said system for transmission concurrently with said signal waves, means rendering each of said last-mentioned means inoperative whenever substitute pilot waves are received with normal intensity at the respectively corresponding repeater, a plurality of said repeaters being positioned to receive either said first-mentioned pilot wave or said substitute pilot wave and each comprising a repeater gain regulator controlled at least in part by the intensity of the pilot wave received thereat.

3. In a repeated transmission system, the method of regulating a transmission characteristic of the repeaters to compensate for adventitious changes in said system which comprises normally transmitting through said system and all of said repeaters successively control waves that change in accordance with the extent of and in response to said adventitious changes, so regulating said transmission characteristic of the several repeaters in response to changes in said control waves appearing at the respective repeaters as to compensate for said changes so appearing, and, in response to failure of said control waves to appear at one of said repeaters, generating substitute control waves and transmitting said substitute control waves from said one repeater through said system to subsequent repeaters, whereby the effect of said failure on the regulation of said repeaters is substantially localized.

4. A repeated transmission system for the concurrent long distance through transmission of signals and normal pilot waves, means at the respective repeaters of said system for regulating the gain thereof in response to changes in the intensity of said pilot waves reaching successively the respective repeaters, said regulating means being adapted to maintain within a predetermined normal range the intensity of the pilot waves leaving the repeater, and means at one or more of the repeaters of said system for applying substitute pilot waves to said system for transmission therethrough, said last-mentioned means being responsive to an abnormal reduction in the intensity of the pilot waves at said last-mentioned repeater or repeaters.

5. A repeated transmission system for the concurrent through transmission of signal and pilot waves comprising means for varying the intensity of said pilot waves to maintain the average intensity of said signal and pilot waves combined at a substantially constant initial value, means at one or more of said respective repeaters in said system for regulating the gain thereof under the control of the said signals and pilot waves combined appearing successively at the respective repeaters, said gain-regulating means being adapted to maintain the average intensity of said signals and pilot waves combined substantially constant at the output of each of said repeaters, means at one or more of the repeaters of said system for generating substitute pilot waves the intensity of which varies as afore-said and for applying said substitute pilot waves

to said system for transmission therethrough, said last-mentioned means being responsive to an abnormal reduction in the average combined intensity of signal and pilot waves appearing at said last-mentioned repeater or repeaters.

6. In a long distance signal transmission system comprising a multiplicity of repeater amplifiers, means for regulating the gain of the several repeaters under the control of pilot waves that are transmitted through said repeaters successively and concurrently with the signals, at least one of said repeaters comprising means for generating substitute pilot waves, said generating means comprising means adapting the repeater amplifier to oscillate at the substitute pilot frequency, means normally inhibiting said amplifier from so oscillating, and means responsive to an abnormal reduction in the intensity of the pilot waves ordinarily appearing at said repeater for enabling said amplifier to oscillate.

7. A combination in accordance with claim 6 comprising a positive feedback loop including at least a part of the repeater amplifier, means in the said loop normally interposing therein greater loss than gain at the substitute pilot frequency, and switching means responsive to effective pilot failure for equalizing said loss and gain, whereby said substitute pilot waves are generated.

8. A combination in accordance with claim 6 in which the regular and substitute pilot waves are of the same frequency.

9. A combination in accordance with claim 6 in which the regular and substitute pilot waves are of different frequencies.

10. A long distance transmission system comprising a plurality of spaced repeaters, means for

normally transmitting control current through said system and the repeaters therein, each of said repeaters comprising a transmission regulator responsive to the said transmitted control current and normally operative to maintain the said control current at a substantially constant level at the output of the respective repeaters, each of said repeaters comprising means for supplying substitute control current of constant level to said system in response to failure of the normal control current at the output of the respective repeaters, the level of the substitute control current so supplied being at least approximately the same as the normal level of the normal control current.

11. A combination in accordance with claim 10 in which said means for supplying substitute control current includes a repeater amplifier having an oscillation generating feedback loop, an oscillation stabilizing impedance element connected in loss controlling relation in said loop, the loss introduced by said element being varied by the current traversing it as a function of the amplitude thereof, said element being so connected as to be traversed by current proportional in amplitude to the normal control current at the output of the repeater and as so traversed introducing sufficient loss in said loop as to preclude oscillations, said feedback loop and impedance element being so proportioned that on failure of the normal control current at the output of said repeater the said loss introduced by said impedance element is thereby reduced enough to permit the generation of oscillations.

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