

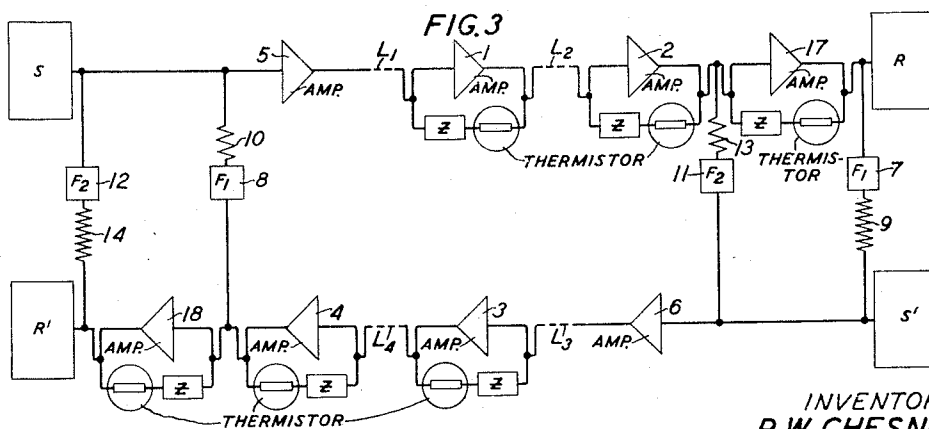
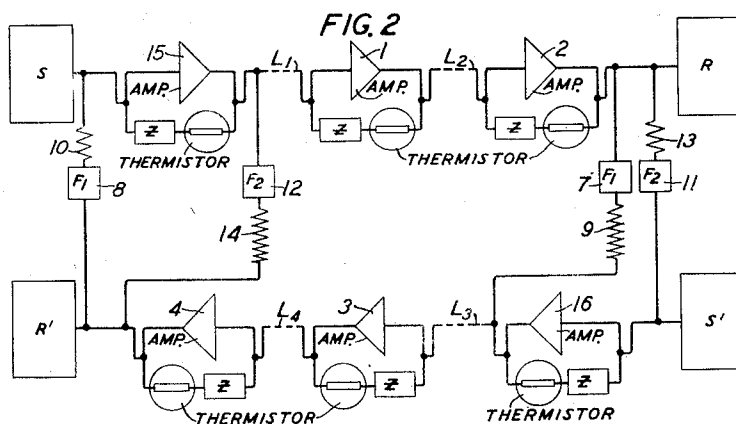
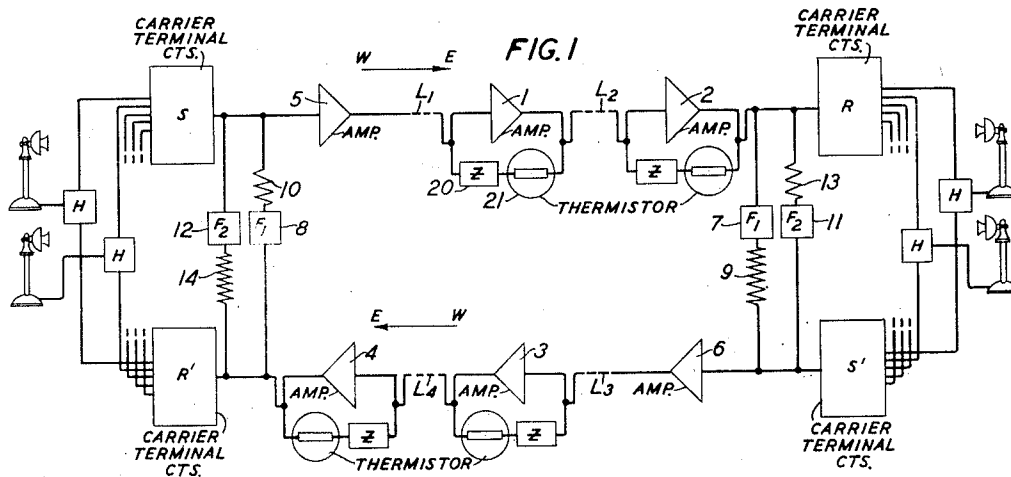
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TRANSMISSION REGULATION

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TRANSMISSION REGULATION

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This invention relates to electrical signaling systems and more particularly to methods and means for controlling the transmission characteristics of such systems.

5 An object of the invention is to provide new and improved methods and means for controlling the amplification characteristics of an electrical wave amplifier. Another object is to effect automatic, continuous and precise control of the amplification characteristics of signal repeaters in an electrical signaling system. Still another object is to facilitate the generation of a pilot or control wave, the intensity of which fluctuates in such relation to the fluctuations of a signal wave that the average intensity of the two waves combined remains substantially constant or follows some predetermined law of variation. A more particular object of the invention is to provide new and improved methods and means for automatically controlling the gain of repeater amplifiers in a wire line carrier current signaling system to compensate for variations in the attenuation of the line.

15 A feature of the invention is that the gain-controlling wave is generated by or within the signaling circuit or system to be controlled. Another feature is that the signaling circuit serves to modulate the control wave.

20 The present invention is especially adapted for automatic control of the amplification afforded by repeaters in a wire line carrier telephone system and it is principally in terms of its embodiment in such a system that the invention is hereinafter described. It will be appreciated by those skilled in the art, however, that the invention and its underlying novel principles are capable of embodiment in other systems and for the performance of other functions. These broader aspects of the invention are indicated in the appended claims.

25 Heretofore it has been proposed that to effect automatic control of the gain of signal repeaters in a wire line transmission system, a pilot wave be applied to the line along with the signals and caused to vary in intensity in such manner that the average intensity of signals and pilot wave combined is maintained substantially constant. Each repeater is then made so self-adjusting under the control of its output currents that the average intensity of the amplified signal and pilot wave combined is maintained at its initial or some other predetermined level, whereby a change in the transmission equivalent of the line automatically produces a compensating change in the gain of the repeater.

30 In accordance with the present invention as embodied in preferred form in a system of the kind

last described, oscillations of the desired pilot wave frequency are established in a circuit comprising signal amplifiers each of which has self-adjusting means for maintaining constant the total power output of signals and pilot wave combined. The aforesaid amplifiers may be the signal amplifiers at repeater stations along the line, in which case the oscillatory circuit may comprise a closed loop including these amplifiers in tandem relation and frequency selective means for inhibiting oscillations around the loop except at the desired pilot frequency. Inasmuch as the power output from each amplifier is made constant, the difference between the power output of one amplifier and the power output of the succeeding amplifier remains invariable, at zero, for example, and wholly independent of changes in the attenuation of the interposed section of transmission line. In other words, the transmission equivalent of the repeater section is independent of line attenuation. At the same time the signal level at each amplifier is permitted to follow in normal manner the variations in the level of signals applied to the system, despite the constant output power control of the amplifier, for as the level of applied signals changes, the level of the pilot frequency oscillations automatically changes an equal amount in the opposite sense, so that the repeater gain control is not aware of any change in signal level, per se.

35 In one aspect, the invention involves a principle of operation of an oscillatory system having an amplitude-limiting or gain-changing control element responsive to the currents flowing in the system, viz., that when signals or other waves are applied to the control element the amplitude of oscillations automatically readjusts itself to such a value that the applied wave and the oscillations of new amplitude have a combined effect upon the control element that is the same as the oscillations alone had before the application of the other waves. In another aspect, the invention may be said to provide a pilot wave the intensity of which varies in such manner in relation to the variations in the intensity of the signal waves that the average intensity of pilot wave and signals combined is substantially constant.

40 The nature of the present invention and its various objects, features and advantages will appear more fully in the following detailed description of typical embodiments illustrated in the accompanying drawing:

45 Fig. 1 of the drawing illustrates a four-wire transmission system utilizing an embodiment of

50
55 embodied in preferred form in a system of the kind

the invention for automatic transmission regulation; and

Figs. 2 and 3 illustrate modifications thereof.

Referring more particularly now to Fig. 1, there is shown a four-wire transmission system in which signals are transmitted over one pair of conductors in the W—E direction from source S to receiver R, and in the E—W direction over another pair of conductors from source S' to receiver R'. The signals to be transmitted may be voice frequency telephone signals, television signals or of any other desired character, but for purposes of further exposition of the invention it will be assumed that the system is a multiplex carrier telephone system and that the two sources are terminal circuits of the system providing, for specific example, twelve carrier telephone channels spaced apart in the frequency range from 12 to 60 kilocycles per second. The two receivers are then the corresponding receiving terminal circuits of the system, and each may be connected in the usual manner through hybrid coils H with its associated transmitting terminal to provide twelve two-way voice frequency circuits. The total wave output of the source, S or S', will be referred to as constituting "the signal."

The wire lines constituting the transmission medium may be of any suitable form, such as open-wire lines, coaxial conductor pairs or shielded pairs in the same or different multipair lead sheathed cables. In any case the lines are subject to one or more influences, such as temperature changes, which cause the line attenuation to fluctuate. An object of the invention, as indicated hereinbefore, is to minimize the effect of such fluctuations on the signal intensity and to maintain the transmission equivalent substantially constant for both directions of transmission.

One or more repeater stations is or may be included in the four-wire system, and in Fig. 1 there is indicated one such station comprising a signal amplifier 1 in the W—E line and a signal amplifier 3 in the E—W line. Similar amplifiers 2 and 4 are provided at the receiving terminals for amplifying the signals received from the respective last sections of the two lines. Each of these four amplifiers is of the stabilized negative feedback type, in which the amplification-frequency characteristic is essentially determined by the attenuation-frequency characteristic of its beta or feedback circuit. Each, further, comprises the usual beta circuit network 20 which compensates for the normal attenuation-frequency characteristic of the preceding section of transmission line, and a thermistor 21, also in the beta circuit, which is so proportioned and arranged in the circuit in known manner that the wave power output of the amplifier remains substantially constant despite a fairly wide range of variation of power applied to the input terminals of the amplifier. An amplifier of this general description is disclosed in, and described with reference to Fig. 7 of an application for Letters Patent, Serial No. 114,390, filed by H. S. Black, December 5, 1936 (U. S. Patent No. 2,209,955, issued August 6, 1940), and in an application of J. H. Bollman, Serial No. 280,269, filed of even date herewith. It will be understood that should the wave power output of such an amplifier tend to increase, for example, the current traversing the thermistor and therefore its temperature likewise tend to increase, with the result that the beta circuit attenuation and the overall gain of the amplifier tend to decrease, thereby reducing the wave power output to its

original value. The beta circuit, and more particularly the thermistor 21, can be so proportioned that the response to changes in wave power input is fairly rapid, rapid enough, for example, that input power fluctuations of syllabic frequency do not cause corresponding fluctuations of output power.

In the W—E direction of transmission, the signal from the source S is first amplified in the transmitting terminal amplifier 5, the gain of which may be comparable with that of the repeater amplifiers, transmitted over the first line section L₁ to repeater 1, thence over line section L₂ to the receiving terminal amplifier 2 and the receiving terminal circuits R. In the E—W direction of transmission, the signal from source S' passes through the transmitting terminal amplifier 6, line section L₃, repeater 3, line section L₄ and receiving terminal amplifier 4 to the receiving terminal circuits R'.

Connected in series between the output circuit of receiving terminal amplifier 2 and the input circuit of the transmitting terminal amplifier 6 in the oppositely-directed line, is a narrow-band filter 7 and a resistor 9. Another narrow-band filter 8 and a resistor 10 are similarly connected in series between the input terminals of amplifier 5 and the output terminals of amplifier 4. The resistors may be considered as representative of resistance pads or other attenuating means. The two filters are tuned alike to pass a substantially single frequency f_1 lying in a portion of the frequency range not occupied by the signaling channels. This frequency may lie between the channels or above or below the 12 to 60-kilocycle range specified, but it is preferably such that the attenuation at the frequency selected varies in substantially the same manner as the average attenuation over the signaling range. There can now be identified a transmission loop comprising in tandem relation the two filters and their associated resistors, the six amplifiers of the system and the interconnecting line sections. Sustained oscillations at the "pilot" frequency f_1 to which the filters 7 and 8 are tuned will appear in this loop if there is a net transmission gain around it, that is, if the amplification afforded by the six amplifiers exceeds the attenuation offered by the transmission lines and the resistors 9 and 10, and if the total phase shift around the loop is zero or an integral multiple of 2π .

Supposing that there are no signals being transmitted over the system, the pilot frequency oscillations will tend to increase indefinitely in amplitude. Opposing this tendency, however, is the fact that each of the amplifiers 1, 2, 3 and 4 is designed to have a constant, predetermined power output and any tendency of the power output to exceed the predetermined value results in such automatic reduction in the gain of the amplifier that the power output is restored to or maintained at that predetermined value. The intensity of oscillation increases, therefore, to the point where the concurrently reduced gain of the four self-regulating amplifiers is equal to the losses in the transmission loop, that is, to the point where the net loop gain is zero at the pilot frequency f_1 . Resistors 9 and 10 can be designed or adjusted to fix the intensity of the oscillations at any predetermined level under the conditions assumed.

Consider next what takes place when a signal of given intensity from say source S is applied to the system. This signal, appearing at each of amplifiers 1 and 2, tends to increase the total

power output of each amplifier, inasmuch as its power is added to that of the pilot frequency oscillations. This tends in turn to effect automatically a reduction in the gain of the amplifier and a reduction in the intensity of the pilot frequency oscillations. An equilibrium condition is finally reached in which at each of the self-regulating amplifiers 1 and 2 the total power output of signal and pilot wave combined is just equal to the power output obtaining before the signal appeared in the system, and the net gain around the transmission loop at the pilot frequency f_1 is again zero.

It has been implicitly assumed in the foregoing description that the gain of amplifiers 3 and 4 does not change with changes in the intensity of the pilot frequency oscillations. The assumed condition can be practically realized, however, by making resistor 9 of high resistance and resistor 10 of low resistance so that the pilot frequency oscillations applied to amplifier 6 are of such small intensity as to have substantially no gain-controlling effect at amplifiers 3 and 4.

The intensity of the signal varies continually, for it depends on the number of carrier channels in use at any given time and on the varying speech level of each talker's voice, and there is also a variation in intensity from syllable to syllable. Superimposed on these normal, initial intensity variations are the variations due to the slowly changing attenuation of the transmission line carrying the signal. Regardless of the cause of a given change in signal intensity, however, there is an equal and opposite change in the intensity of the pilot frequency oscillations so that the intensity of signal and pilot wave combined at the output of each of the self-regulating amplifiers is maintained substantially constant. Although it is important that the combined intensity remain constant, it is equally important that the signal arrive at the receiving terminal intact in so far as its initial, normal intensity variations are concerned, or, in other words, that the intensity of the signal bear the same ratio to the intensity of the pilot wave at the receiver end of the transmission line as obtains at the transmitter end of the line. To satisfy this latter condition it can be shown that it is necessary only that the transmission equivalent of the portion of the pilot wave loop extending from the output circuit of the amplifier 2 to the input circuit of the amplifier 5 be maintained substantially constant. That it does remain substantially constant is insured by automatic gain regulation provided for the E-W transmission line as described hereinafter.

It may be observed that the intensity of the pilot wave at the input of amplifier 5 where it is introduced into the W-E line, fluctuates only as the initial intensity of the signal fluctuates and that the pilot wave fluctuations are of such sense and magnitude that the intensity of pilot wave and signal combined is substantially constant at this point. It may be noted too that the system embodies the general principle stated hereinbefore inasmuch as in the oscillatory loop circuit the sum of the introduced signal currents and the self-oscillations of pilot frequency has the same effect on the gain-controlling thermistors as the self-oscillations alone had before the introduction of the signal currents.

To effect automatic regulation of the gain of amplifiers 3 and 4 in the E-W transmission line another loop transmission path tuned to a different pilot frequency f_2 is provided. This second path

comprises the six amplifiers and their interconnecting line sections, a filter 11 and resistor 13 in series with each other and in parallel with the series combination of filter 7 and resistor 9, and a filter 12 and resistor 14 similarly connected in parallel with filter 8 and resistor 10. The filters 11 and 12 are narrow-band filters tuned to pass a frequency f_2 suitable for the second pilot wave. Oscillations established in this second path operate on the thermistors in amplifiers 3 and 4 to control the gain thereof in precisely the same manner as the oscillations in the first-described loop path control the gain of amplifiers 1 and 2. Resistor 14 is made of high resistance and resistor 13 of low resistance so as substantially to eliminate the effect of the second pilot wave on the gain of amplifiers 1 and 2.

To reduce interaction between the two gain control systems embodied in Fig. 1, the circuit may be modified as shown in Fig. 2. As compared with Fig. 1, the modification consists in replacing amplifiers 5 and 6 with self-regulating amplifiers 15 and 16, respectively, of the same type indicated for the repeaters; in excluding amplifier 16 from the first transmission loop; and in excluding amplifier 15 from the second transmission loop. The changes in the transmission loops consist in connecting filter 7 and resistor 9 to the output circuit rather than to the input circuit of amplifier 16, and in connecting filter 12 and resistor 14 to the output circuit rather than to the input circuit of amplifier 15. In the circuit as thus modified, changes in the intensity of either of the pilot waves have less effect on the gain of the amplifiers intended to be controlled by the other pilot wave. Thus, in the transmission loop comprising filters 7 and 8 the loop gain is controlled primarily by the three thermistors in amplifiers 15, 1 and 2, whereas only two of these thermistors, viz., those in amplifiers 1 and 2, have any effect on the gain of the other transmission loop which comprises filters 11 and 12. Similarly in the latter transmission loop the loop gain is controlled primarily by the self-regulating amplifiers 16, 3 and 4, and the pilot wave in that loop operates on only two of the self-regulating amplifiers, viz., 1 and 2, in the other loop.

Fig. 3 shows another modification of the system shown in Fig. 1, which, like that of Fig. 2, is designed to reduce interaction between the gain control circuit for E-W transmission and the gain control circuit for W-E transmission. As compared with Fig. 1 the modification consists in the provision of self-regulating amplifiers 17 and 18, of the kind specified for the repeaters, which in circuit sequence immediately follow the receiving terminal amplifiers 2 and 4, respectively, and in reconstructing the two transmission loops so that each embraces the one amplifier, 17 or 18, that is included in the signaling circuit that loop is designed to regulate. Thus, amplifier 17 in the W-E circuit is included in the transmission loop comprising filters 7 and 8 but amplifier 18 is excluded, and amplifier 18 is included in the transmission loop comprising filters 11 and 12 but amplifier 17 is excluded. The net result, as in Fig. 2, is that each of the pilot waves controls the gain of a greater number of the amplifiers in its respective transmission loop than are controlled by the pilot wave in the other loop.

Whereas in the foregoing illustrative examples of practice in accordance with the invention the gain-controlling elements are responsive to the total power applied to them, it should be apparent

that other types of gain-controlling elements responding to peak values of current or voltage or in general utilizing some measure of wave intensity other than power can be used in the same way to perform the desired regulating functions. The invention is not limited to such details as these and it embraces any modifications that come within the spirit and scope of the appended claims.

What is claimed is:

1. A loop transmission circuit comprising means for maintaining sustained oscillations therein, means in said circuit for controlling the transmission equivalent thereof, a signal source, and means for applying both the signals from said source and said oscillations to said controlling means, whereby the said transmission equivalent is subject to joint control by said signals and said oscillations.

2. A combination in accordance with claim 1 in which said controlling means operates to maintain the intensity of said signals and said oscillations combined substantially constant.

3. A transmission system comprising a signal source, a plurality of amplifiers geographically spaced apart for successively amplifying the signals from said source, a transmission loop comprising all of said amplifiers, said transmission loop being oscillatory at a frequency not occupied by said signals, and means at each of a plurality of said amplifiers for controlling the gain thereof, said controlling means being responsive to said signals and oscillations of said frequency combined.

4. In combination, an oscillatory transmission loop, an amplifier included therein, a thermistor traversed by oscillations in said loop for controlling the gain of said amplifier, means for applying signals to said amplifier for amplification therein, and means for applying the amplified signals in fixed proportion to said thermistor for concurrent control of the gain of said amplifier.

5. In combination, a negative feedback amplifier including a gain-controlling directly-heated thermistor in the beta circuit thereof, said thermistor being so proportioned and arranged as to maintain the total wave power output of said amplifier substantially constant, means for applying signals to said amplifier for amplification therein, and a circuit including said amplifier in tandem relation therein for generating oscillations, whereby said oscillations are modulated by said signals.

6. In combination, a signal source, a signal receiver and means for impressing the signals from said source on a transmission medium that variably attenuates said signals in their passage from said source to said receiver, a transmission loop comprising said medium and said receiver and means for establishing oscillations therein, and means at said receiver for maintaining the intensity of said signals and oscillations combined substantially constant.

7. In a signaling system, a signal source, a device for amplifying the signals from said source, said device having an input circuit and an output circuit, a first loop circuit connecting said input and output circuits and constituting a negative feedback circuit for the frequency range occupied by said signals, a second loop circuit connecting said input and output circuits and constituting a positive feedback circuit for the generation of oscillations, and means responsive to currents flowing in both of said circuits for controlling the gain of said amplifying device.

8. A combination in accordance with claim 7

in which said responsive means comprises a thermistor.

9. In combination, an amplifier, means for applying signals to be amplified thereto, transmission means connecting the input and output circuits of said amplifier to form a self-oscillatory loop tuned to pass at least one substantially single frequency, and means responsive to the total wave output of said amplifier including oscillations generated in said loop for controlling the gain of said amplifier.

10. A combination in accordance with claim 9 in which said gain-controlling means operates to maintain the total wave power output of said amplifier substantially constant.

11. In a signaling system, a signal source, a transmission line subject to variations in attenuation for transmitting the signal from said source, an amplifier in said transmission line, and means completing a transmission loop comprising said amplifier and said line, the attenuation-frequency characteristic of said loop being such that oscillations of substantially single frequency occur therein, and said amplifier being so self-adjusting as to maintain the total wave intensity of said signals and oscillations combined substantially constant at its output terminals.

12. In combination, a signal source, means for amplifying the signals from said source, and a long transmission line for conveying the amplified signals from said means, and an oscillatory transmission loop comprising said amplifying means, a substantial portion of said line subject to variations in attenuation and filtering means adapted to pass a substantially single frequency comparable with the frequency of said signals, said amplifying means being so self-adjusting under the control of its total wave output as to maintain said total wave output at a substantially constant intensity level.

13. In a signaling system, a long transmission line subject to variations in attenuation, a signal source connected to one end thereof, one or more signal amplifiers disposed in said line and geographically distant from said source, at least one of said amplifiers being so self-adjusting that the total wave power output therefrom is substantially constant despite wide variations in the wave power input thereto, a circuit extending from the output circuit of one of said self-adjusting amplifiers to a point of said line in the vicinity of said source so that a loop transmission path is formed comprising said line and said last-mentioned amplifier, the transmission characteristics of said loop path being such that oscillations tend to occur at a substantially single frequency.

14. A system for the transmission of signals between geographically separated points comprising two transmission lines connecting said points and individual to the two directions of signal transmission therebetween, a signal amplifier in each of said lines at the receiving point thereof, means at each of said points connecting the output circuit of one of said amplifiers to the other line, said means having a substantially fixed attenuation-frequency characteristic such that two loop transmission channels tuned to different and substantially single frequencies are provided, each of said loops including said transmission lines and amplifiers, and each of said amplifiers being so self-regulating as to gain that the total wave power output therefrom is maintained substantially constant.

15. A four-wire signal transmission system comprising a pair of lines for transmission in the re-

spective signaling directions, each of said lines being subject to variations in attenuation due to changes in temperature and the like, at least one signal repeater intermediate the terminals of each of said lines and a signal amplifier at the receiving terminal of each of said lines, each of said repeaters and said amplifiers being so self-regulating as to gain that the total wave power output thereof remains substantially constant for a wide range of wave power input thereto, frequency selective means connecting each pair of adjacent terminals of said lines and comprising two transmission loops each including both of said lines, said repeaters and said amplifiers, said loops being tuned to pass and to oscillate continuously at mutually different substantially single frequencies, whereby the gain of each of said repeaters and amplifiers is subject to the joint control of the signals and oscillations traversing it and the transmission equivalent of each of said lines is maintained substantially constant.

16. A system in accordance with claim 15 comprising means for substantially attenuating both of said oscillations at respectively different terminals of said system, whereby in each of said lines the intensity of a respective one of said oscillations is so reduced as to have small effect on the transmission equivalent of that line.

17. A system in accordance with claim 15 comprising at the sending terminal of each of said lines a signal amplifier adapted for substantially constant wave power output, each of said amplifiers being included in only one of said loops.

18. A system in accordance with claim 15 comprising at each of said receiving terminals a second signal amplifier adapted for substantially constant wave power output, each of said second signal amplifiers being included in only one of said loops.

19. A system in accordance with claim 15 in which each of said loops includes a greater number of the signal-amplifying, constant power output elements in one of said lines than are included in the other of said loops.

20. In a signaling system, a transmission link subject to random variations in transmission equivalent, a closed oscillating loop system including said transmission link so that the intensity of the oscillations in said loop system tends to vary with said variations in transmission equivalent, and means controlled by said oscillations for varying the transmission equivalent of said link in opposite sense to said random variations.

21. In a signaling system, a transmission link subject to random variations in a transmission characteristic thereof that tends to produce corresponding variations in a parameter of signals

transmitted through said link, a closed oscillatory loop system including said transmission link in such manner that said parameter of the oscillations in said loop system tends to vary with said random variations, and means controlled by said oscillations for varying the said transmission characteristic of said link equally and oppositely to said random variations.

22. In combination, an electric wave amplifier, means for applying signals of variable average intensity to the input of said amplifier, means for applying concurrently to the input of said amplifier substantially single-frequency oscillations, and amplifier gain controlling means responsive to the joint control of said signals and said oscillations for maintaining the average wave power output of oscillations and signals combined substantially constant.

23. In combination, a signal amplifier and gain-controlling means therefor, said means comprising a loop circuit including said amplifier for the generation of oscillations, an impedance element variable under the joint control of said oscillations and signals to maintain constant the total average intensity of said oscillations and signals combined, and means external of said amplifier for varying the attenuation in said loop circuit and thereby controlling the gain of said amplifier.

24. In combination, a source of signals of normally varying average intensity, an amplifier for amplifying the signals from said source, a wave transmission loop including at least a portion of said amplifier for the generation and loop transmission of oscillations lying outside the frequency range occupied by said signals, and means for varying the intensity of said oscillations in equal and opposite relation to the variations in the said average intensity of said signals.

25. In combination, a source of signals having normal initial variations in average intensity, a device for amplifying the signals from said source, said amplifier having a feedback path for the gain-reducing feedback of said signals, a loop transmission circuit including at least a part of said amplifier for the generation of substantially single-frequency oscillations, and an impedance under the joint control of said signals and oscillations for maintaining the total output of said amplifier, comprising said oscillations and signals, substantially constant.

26. A combination in accordance with claim 25 in which said impedance comprises a thermistor heated by said oscillations and signals in substantially constant proportion.

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