

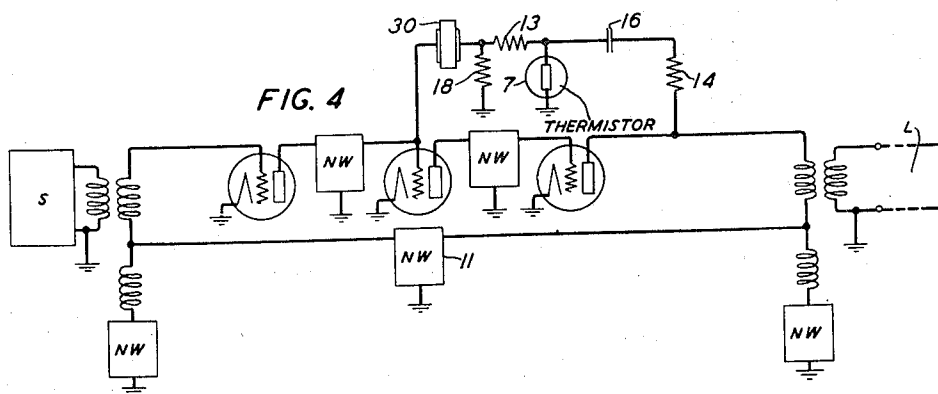
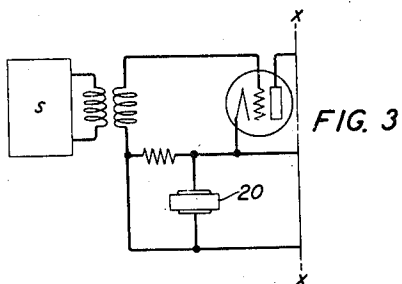
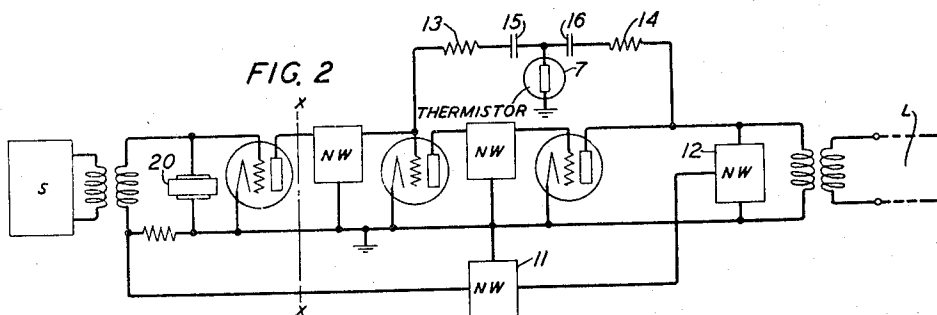
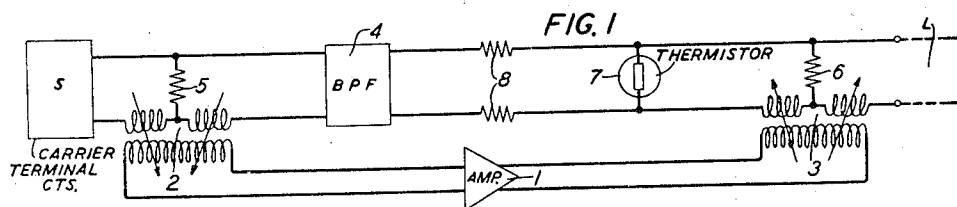
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TRANSMISSION CONTROL CIRCUIT

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TRANSMISSION CONTROL CIRCUIT

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This invention relates to electrical signaling systems and more particularly to the control of amplification in long distance transmission systems.

5 In a principal aspect the present invention represents an improvement on a system for so controlling the gain of repeater and receiving amplifiers in a long distance wire line transmission system as to compensate for the attenuation variations of the line due to temperature changes and the like, as disclosed and claimed in an application for Letters Patent, Serial No. 280,269, filed by J. H. Bollman of even date herewith. In that system there is transmitted along with the signal a pilot wave the amplitude of which is so modulated with respect to the initial normal intensity variations of the signal that the total power of signal and pilot waves combined remains substantially constant at the sending end of the line. The signal repeater amplifiers and the signal receiving amplifier are made so self-adjusting as to gain, under the joint control of the transmitted signal and pilot waves as to maintain the total combined power substantially constant at their respective output terminals, thus automatically compensating for any changes in the attenuation of the respective preceding sections of line. The means for generating and modulating the pilot wave is disclosed as comprising a signal amplifier of the stabilized negative feedback type which has a narrow band positive feedback path for generating the pilot oscillations and which has also a thermistor in the negative feedback path for maintaining the total wave power output of the amplifier substantially constant whereby any change in signal intensity automatically produces an equal and opposite change in the intensity of the pilot oscillations.

One object of the present invention is to provide improved means for producing a pilot wave, the power of which fluctuates in complementary relation to the power fluctuations of a signal wave. A more specific object is to provide a thermistor controlled self-oscillating signal amplifier in which the gain of the amplifier is substantially independent of variations in the resistance of the thermistor or of surges in the intensity of the signals, in which the terminal impedances of the amplifier are substantially independent of such variations, and in which signal distortion or modulation arising in the thermistor is substantially suppressed.

In accordance with preferred embodiments of the invention the foregoing objects are attained in a self-oscillating negative feedback signal

amplifier in which the gain-controlling thermistor is disposed elsewhere than in the negative feedback path, as for example, in the mu circuit of the amplifier or in the positive feedback path comprising the self-oscillatory circuit. Where the thermistor is in the mu circuit any signal distortion products arising in the thermistor are substantially reduced by negative feedback; and where the thermistor is in the positive feedback path any signal distortion products are reduced by the attenuation of that path. In either case the gain of the amplifier is substantially unaffected by variations in the resistance of the thermistor or by signal surges.

The nature of the present invention and its various features, objects and advantages will appear more fully in the detailed description of illustrative embodiments that is to follow. Reference will be made to the accompanying drawing in which:

Fig. 1 illustrates an embodiment of the invention in which an oscillation-controlling thermistor is disposed in a positive feedback path of a signal amplifier;

Figs. 2, 3 and 4 show other embodiments utilizing negative feedback amplifiers and alternative circuit positions for the means fixing the frequency at which self-oscillation of the amplifier occurs.

Referring more particularly now to Fig. 1, there is represented a portion of a signaling system comprising at S a source of signals that are to be applied to a wire line L for transmission thereover to a distant signal receiver. It will be assumed for specific example that the signaling system is a multiplex carrier telephone system providing twelve one-way message channels spaced apart in the frequency range between 12 and 60 kilocycles per second and that "the signal" is the total wave output of the transmitting terminal apparatus indicated at S. The wire line, which may have one or more signal repeaters spaced at intervals therein, is subject to variations in attenuation, and it is an object of the invention as indicated hereinbefore to effect such automatic adjustment of the gain of the repeaters and of the receiver as to offset the effect of the variations in line attenuation. This general object, as well as others, is achieved by transmitting along with the signal a pilot wave that is so varied in amplitude that as applied to the line the total power of signal and pilot wave combined is maintained substantially constant despite the normal fluctuations in signal intensity. The signal receiver and the repeaters that

are to be regulated are made so self-adjusting as to gain, under the joint control of the signal and pilot wave, that the total wave power output of each is held constant, thereby compensating for variations in line attenuation. Suitable receivers and repeaters are disclosed in the application of J. H. Bollman, *supra*, and elsewhere. The present invention is concerned primarily with means for producing the fluctuating pilot wave.

The signal from source S in Fig. 1 reaches the transmission line L through an amplifier 1, which may be of any suitable type affording preferably uniform gain over the frequency range occupied by the signal and which is coupled to source S and line L by hybrid coils 2 and 3, respectively. Between the hybrid coils there is connected also a circuit comprising bandpass filter 4. The connections to the hybrid coil are so made in known manner that the latter circuit is conjugate to both source S and line L but in energy transfer relation at both ends with amplifier 1. The circuit comprising filter 4 thus constitutes a feedback path or beta circuit for the amplifier, the latter comprising the associated mu circuit, and under the proper conditions self-sustaining oscillations can be established in the mu-beta loop thus formed. Resistors 5 and 6 associated with hybrid coils 2 and 3, respectively, aid in matching the terminal impedances of the amplifier with the impedances of the source and line.

If the power fed back from hybrid coil 3 to the input circuit of amplifier 1 is at least equal to the signal power impressed on the amplifier from source S and it is in aiding phase relation, or, in other words, if there is positive feedback of at least unity magnitude, oscillations will appear in the mu-beta loop at the frequency or frequencies for which the conditions specified obtained. Filter 4 has a narrow or substantially single-frequency transmission characteristic such that the attenuation of the beta circuit is high, and preferably uniform, at all signal frequencies, but low enough at the desired pilot wave frequency that oscillations of the desired frequency appear. The pilot frequency chosen may be between the message channels or above or below them, and it may be, for specific example, 61 kilocycles per second.

At the input end of the beta circuit, that is, immediately following hybrid coil 3 in circuit sequence, is a shunt thermistor 7 followed by a pair of series resistors 8. The thermistor is of the self-heating type, that is, its temperature is controlled by the currents flowing through it; its shunt connection is predicated on the assumption that its temperature coefficient of resistance, like that of silver sulphide, for example, is negative. The thermistor is heated not only by the oscillations generated in the mu-beta loop but also by a fixed fractional portion of the signal power that is diverted to it by hybrid coil 3. The heating effect due to the signal power fluctuates since the intensity of the signal normally fluctuates with a variety of factors such as the number of message channels in use at any particular time and the varying intensity of the several talkers' voices, and the temperature and resistance of the thermistor tend to fluctuate correspondingly. If, however, the signal intensity, say increases, thereby lowering the resistance of the thermistor, the attenuation of the beta circuit is thereby increased and the intensity of the local oscillations thereby reduced. By suitable proportioning of the various circuit elements, any given change in the intensity of the signal may be caused to effect an equal and opposite change

in the intensity of the pilot frequency oscillations, so that the sum of the two combined remains substantially constant, not only at the thermistor but also at the input terminals of the transmission line. This, of course, is the condition desired.

Because of the non-ohmic character of the thermistor it tends to distort the currents impressed upon it and thereby to produce what are known in the art as modulation products. It is desirable that such modulation products be suppressed or otherwise prevented from reaching the transmission line L and mingling with the signal. In Fig. 1 it is to be noted that in one direction from the thermistor such modulation products are highly attenuated by the resistors 8 and by the filter 4 and that in the other direction they are precluded from entering the line by the conjugacy afforded by the hybrid coil 3. Thus, any modulation products reaching the line L may be kept at a negligibly low level.

It is to be noted also that in Fig. 1 the gain of the amplifier 1, and the amplification afforded the signal in its passage from source to line, is invariable and quite independent of any changes in the resistance of thermistor 7. The signal intensity may therefore change abruptly without giving rise to a disturbing change in signal amplification. For the same reason, and having in mind that the intensity of the local oscillations does not change instantly from one stable value to another with an abrupt change in the attenuation of the mu-beta loop, the signal amplification is not affected by the inherent sluggishness of the oscillation system with respect to the growth and decay of self-oscillations therein. It may be observed also that the output impedance of the amplifier is independent of fluctuations in the thermistor resistance because of the conjugacy afforded by the output circuit hybrid coil, and that the input impedance is protected from such fluctuations by both the conjugacy afforded by the input circuit hybrid coil and the high attenuation interposed between the input circuit and the thermistor.

Fig. 2 illustrates a modified form of the invention in which there is connected between the source S and line L a stabilized negative feedback amplifier having means for the generation and appropriate modulation of pilot frequency oscillations. The amplifier, as such, is of well-known type comprising input and output transformers, three stages of amplification with suitable coupling networks between stages, and a negative feedback circuit, comprising network 11, connected at one end across a series resistor in the grid circuit of the first amplifying stage and connected at the other end across the bridging points of a bridge network 12 which shunts the primary winding of the output transformer and which renders the transmission line L and the negative feedback circuit conjugate. The amplifier as above described may be supposed to have a gain-frequency characteristic that is substantially flat and that is substantially determined by the attenuation-frequency characteristic of the feedback circuit.

One or more stages of the amplifier in Fig. 2 may be embraced by a positive feedback circuit, as, for example, by a connection from the anode of the vacuum tube in the last amplifying stage to the grid of the tube in the intermediate stage as illustrated. This connection is represented as comprising specifically two series resistors, 13 and 14, separated by a pair of blocking condensers, 15

and 16, and a self-heating thermistor 7, as described with reference to Fig. 1, connected between the junction of the two condensers and ground, ground being the potential also of the cathodes of the several amplifier tubes. There is thus provided what may be called a positive mu-beta circuit comprising the last two stages of the amplifier and the positive feedback circuit as above described. Oscillations will appear in this loop under the conditions outlined in the discussion of Fig. 1, viz., when and if the gain of the mu portion of the loop at least equals the loss in the beta portion. The gain of this mu portion depends on the amount of negative feedback provided. Whatever the net gain of the last two stages, with negative feedback, may be at the signaling frequencies, resistors 13 and 14 are made large enough to insure that the attenuation of the positive feedback loop is so great as to preclude the generation of oscillations at such signaling frequencies.

To permit the generation of oscillations in the positive feedback loop at the desired pilot wave frequency, of 61 kilocycles, for example, the amount of negative feedback reaching the grid of the second stage amplifier is reduced at that frequency, thereby increasing the gain, at that frequency, of the last two stages of the amplifier. In Fig. 2 the desired reduction in negative feedback is obtained by shunting between grid and cathode of the first stage amplifier tube a piezoelectric crystal 20 or other equivalent device or circuit having a high impedance at all signaling frequencies and a relatively low or negligible impedance only at the desired pilot frequency or over a narrowly restricted range of frequencies that includes the desired pilot frequency. By thus short-circuiting (with respect to the desired frequency) that portion of the negative mu-beta loop that is not common to the positive mu-beta loop, the gain of the mu portion of the latter loop can be raised to the point where oscillations appear at the desired frequency. The oscillations increase in intensity, simultaneously increasing the temperature of thermistor 7, until the concurrent reduction in thermistor resistance raises the attenuation of the positive feedback circuit to a value such that it is equal to the gain of the last two amplifier stages. At that point the oscillations are stabilized, except as changes in signal intensity occur.

Whereas the thermistor 7 in Fig. 2 has been described as being in the positive feedback path, it may equally well be said to be in the mu portion of both feedback loops, for it is shunted across the cathode and anode of the last stage amplifier tube in series with condenser 16 and resistor 14. Regardless of the point of view, however, it is evident that a fixed fractional portion of the signal power is applied to it and that its resistance tends to change accordingly. As its resistance tends to change on application of signal power, however, it tends to change the total attenuation in the positive mu-beta loop in such sense as to reduce the local oscillations. By proper proportioning of the circuit elements the one tendency can be made to neutralize the other, so that any change in signal power occasions an equal and opposite change in the power of the local oscillations, and the total power content of the two combined is maintained substantially constant.

With respect to modulation products arising in the thermistor it is to be noted that they are reduced substantially by negative feedback before they reach the transmission line L. It may be

noted too that the circuit shown is immune, in the same manner and for the reasons obtaining in the case of Fig. 1, to changes in the resistance of the thermistor and to sluggishness of the oscillatory circuit in response to changes in thermistor resistance.

Whereas the piezoelectric crystal 20 is shown in Fig. 2 as shunting the mu portion of the negative feedback loop, it can alternately be connected across the beta portion thereof as indicated in Fig. 3 where it shunts the series coupling resistor in the input circuit of the first stage amplifier tube. In this position the crystal 20 serves to reduce the amount of negative feedback at the desired pilot frequency substantially in the manner and for the purpose explained with reference to Fig. 2.

The preferred embodiment of the invention as illustrated in Fig. 4 is similar in general outline to the embodiment shown in Fig. 2 except that oscillations are confined to the desired frequency by controlling the attenuation characteristic of the positive feedback circuit rather than by controlling the gain of the amplifier or the amount of negative feedback at the desired frequency.

The amplifier connecting source S and line L in Fig. 4 is essentially the same as that shown in Fig. 2, although it is specifically different in that the input and output transformers form a part of the bridge circuits at the respective ends of the negative feedback path. The difference noted, however, is not important to the principal objects of the invention. For the generation of pilot frequency oscillations, the anode of the last stage tube is connected by a positive feedback circuit to an anterior point of the amplifier, specifically indicated as being the grid of the second stage tube although it could equally well be the ungrounded primary terminal of the input transformer, for example. In this connection there is a series resistor 14 adjacent the anode mentioned, and in series circuit sequence, a blocking condenser 16, a resistor 13 and a piezoelectric crystal 30 or equivalent means, the impedance of which is low at the desired pilot frequency and high at all other frequencies. Thermistor 7 is connected between the junction of resistor 13 and condenser 16 and ground, the cathodes of the three amplifier tubes also being connected to ground. A resistor 18 is connected between ground and the junction of crystal 30 and resistor 13.

The gain of the last two stages of the amplifier, which constitutes the mu portion of the positive mu-beta loop, is substantially constant not only at all signaling frequencies but also at the pilot frequency, and it may be the same for both signal and pilot frequencies. In accordance with the principles discussed in connection with Fig. 1, the attenuation of the positive feedback path is made such that at the pilot frequency, 61 kilocycles, for example, it is approximately equal to the gain of its associated mu portion and at all other frequencies much greater, for example, 40 decibels, than the gain of the mu portion or at least sufficiently great as to preclude the generation of oscillations at such other frequencies. By proper proportioning of the various circuit elements, the thermistor 7 can be made to hold the total wave power output of the amplifier substantially constant by causing the pilot frequency oscillations to vary in power in equal and opposite relation to the normal variations in the signal power, as described more fully with reference to Figs. 1 to 3.

Resistor 14 in Figs. 2 and 4 may be comparable in resistance to thermistor 7 in its normal operating condition, and preferably two or three times greater than the thermistor resistance, so that the thermistor is presented in the one circuit direction with an impedance more favorable than the low impedance presented by the mu circuit. Resistor 13 in Fig. 4 serves to avoid shunting of the thermistor 7, at the pilot frequency, by the low impedance of crystal 30 and the first inter-stage network. Resistor 18 affects the virtual band width of crystal 30 and influences the sluggishness or speed of response of the positive mu-beta loop to changes in the resistance of thermistor 7 and it may be appropriately designed in any particular case to control these factors. In one specific case where the normal operating resistance of thermistor 7 was 4,000 ohms, satisfactory operation was obtained with a resistor 14 of 7,500 ohms, a resistor 13 of 30,000 ohms, a resistor 18 of 3,000 ohms, a blocking condenser 16 of 4 microfarads and a crystal 30 having a resonant frequency of 60 kilocycles.

Modulation products arising in thermistor 7 in Fig. 4 are reduced by attenuation and substantially blocked by crystal 30 in the one direction of transmission through the positive beta circuit, and in the other direction they are subject to substantial reduction by negative feedback and thus are reduced to negligible proportions in the transmission line L.

Whereas the present invention has been described with reference to specific illustrative embodiments thereof and to its application to a wire line transmission system, it should be apparent that the features thereof are capable of a variety of other embodiments and applications within the spirit and scope of the appended claims.

What is claimed is:

1. In combination, a source of signals of variable intensity, an amplifier connected to receive the signals from said source, said amplifier having a positive mu-beta loop and a negative mu-beta loop, said loops having a mu portion in common, means for generating substantially single-frequency oscillations in said positive mu-beta loop, and an impedance variable under the joint control of said signals and oscillations in said positive mu-beta loop for regulating the amplitude of said oscillations.

2. A combination in accordance with claim 1 in which said variable impedance comprises a thermistor.

3. A combination in accordance with claim 1 in which said variable impedance comprises a self-heating thermistor.

4. A combination in accordance with claim 1 in which said impedance is so varied under the control of said current as to maintain the average intensity of said signals and oscillations combined substantially constant at the output of said amplifier.

5. In combination, an amplifier having input and output terminals, a source of signals connected to said input terminals, said amplifier having a positive feedback path connected in conjugate relation to said input and output terminals, said feedback path including means having a frequency selective transmission characteristic such that substantially single frequency oscillations are developed in said feedback path, and an impedance that is variable under the control of the average intensity of said signals and oscillations connected in said feedback path for varying the intensity of said oscillations.

6. A combination in accordance with claim 5 in which said impedance comprises a thermistor.

7. In combination, an amplifier having input and output terminals, a source of signals connected to said input terminals, said amplifier having a positive mu-beta loop, means in the beta portion of said loop having relatively low attenuation at a frequency not included in said signals whereby oscillations are generated in said loop at said frequency, and a thermistor connected to introduce into said loop a resistance that is variable under the control of said signals and oscillations.

8. A combination in accordance with claim 7 in which said thermistor and said beta portions are so proportioned as to maintain the total wave power appearing at said output terminals substantially constant.

9. In combination, a source of signals, an amplifier connected to said source for amplifying said signals, said amplifier having a positive mu-beta loop, the gain of the mu portion and the loss of the beta portion of said loop being so proportioned with respect to frequency that self-sustaining substantially single-frequency oscillations are generated in said loop, a thermistor connected in said loop for controlling said oscillations, and means for applying heating power to said thermistor in proportion to the varying power content of said signals whereby said oscillations are modulated by said signals.

10. In combination, an amplifier having a negative mu-beta loop and a positive mu-beta loop for generating self-sustaining oscillations, said loops having a mu portion in common, and means electrically connected in the mu-portion of one of said loops outside of said common portion for confining said oscillations to a substantially single frequency.

11. A combination in accordance with claim 10 including a thermistor heated by said oscillations for fixing the intensity of said oscillations.

12. In combination, an amplifier having overlapping positive and negative mu-beta loops, the beta portion of said positive loop having an attenuation characteristic that is substantially flat over a wide frequency range, said negative mu-beta loop having a non-uniform attenuation-frequency characteristic such that substantially single-frequency oscillations are generated in said positive mu-beta loop within said frequency range, and a thermistor heated by said oscillations and so connected in said positive mu-beta loop as to stabilize the intensity of said oscillations.

13. In combination, a source of signals of variable intensity, an amplifier connected to said source, said amplifier having a positive mu-beta loop, means in the beta portion of said loop inhibiting oscillations therein except at a substantially single frequency and a thermistor heated by said oscillations of single frequency connected in the mu portion of said loop.

14. In combination, a source of signals of varying intensity, an amplifier for translating said signals, said amplifier having a gain reducing feedback channel for said signals and a positive feedback channel for the generation of substantially single-frequency oscillations, and a thermistor controlling the intensity of said oscillations in predetermined relation to the variations in intensity of said signal, said thermistor being so connected that modulation prod-

ucts arising therein are transmitted to said gain reducing feedback channel.

15. In combination, a source of signals of varying intensity, an amplifier connected to said source, said amplifier having a negative mu-beta loop the beta portion of which has substantially uniform attenuation over the frequency range of said signals, said amplifier having also a positive mu-beta loop the mu portion of which is at least in part common to said negative mu-beta loop, the beta portion of said positive mu-beta loop including a self-heating thermistor, an impedance element, and means having a substantially single-frequency transmission characteristic, said means being nearest the output end of said last-mentioned beta portion and said thermistor being electrically interposed between said means and said element, said beta portion of said positive mu-beta loop being so proportioned that oscillations are generated therein at substantially said single frequency, said thermistor being connected to receive substantially equal fractional parts of the signal and oscillation power outputs, respectively, of said amplifier, and said thermistor being so proportioned and arranged that a change in the power of the signals applied to it effects an equal and opposite change in the power of said oscillations.

16. In combination, a source of signals of variable intensity, an amplifier connected to receive said signals, a feedback path for said amplifier having a narrow band-pass characteristic whereby substantially single-frequency oscillations are generated therein, a thermistor in said feedback path directly heated by said oscillations and by signals entering said path, the heating power so applied to said thermistor from said signals and oscillations, respectively, being in the same proportion as the signal power and oscillation power in the output of said amplifier, said thermistor being so connected in said feedback path as to tend to increase the attenuation in said path as the heating power applied to said thermistor tends to increase,

whereby the oscillation power output varies substantially inversely with variations in signal power output.

17. A combination in accordance with claim 16 comprising a second path for the gain-reducing feedback of said signals and oscillations, said second path embracing at least the input end of said first-mentioned feedback path so that distortion products in the output of said amplifier arising in said thermistor are substantially reduced.

18. In combination, a source of signals of normally variable initial intensity, an amplifier connected to receive and amplify said signals, said amplifier comprising a positive mu-beta loop for the generation of oscillations and means for confining said oscillations to substantially single-frequency oscillations, a thermistor connected in the beta portion of said loop for controlling the loss therein, and means for heating said thermistor with power derived from said signals and said oscillations, respectively, in the same proportion as obtains in the output of said amplifier, said thermistor being so connected in said beta portion as to tend to offset any change in the heating power applied to it.

19. In combination, a source of signals having normal initial variations in intensity, an amplifier connected to receive said signals, said amplifier having a positive feedback path for the generation of oscillations at frequencies not occupied by said signals, a common output circuit for said signals and oscillations, a variable loss element in said feedback path, and means tending to vary the loss introduced by said loss element in inverse relation to variations in the respective power contents of the signals and oscillations in said output circuit, whereby a change in the signal power content, tending to cause a corresponding inverse change in the loss introduced by said element, gives rise to an inverse change in the intensity of said oscillations.

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