

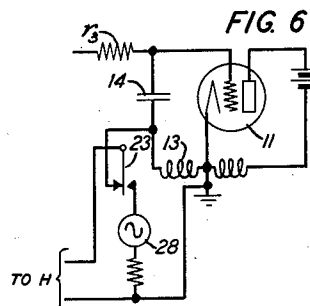
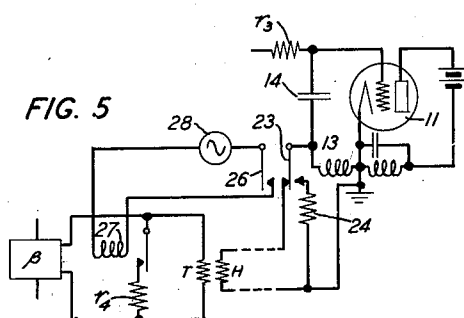
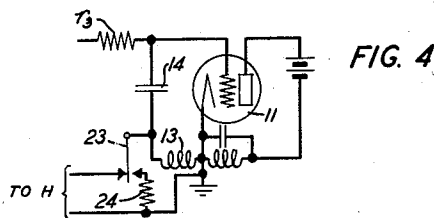
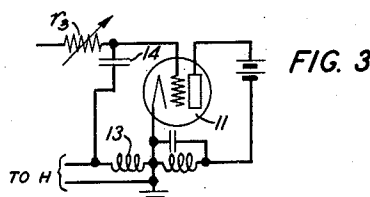
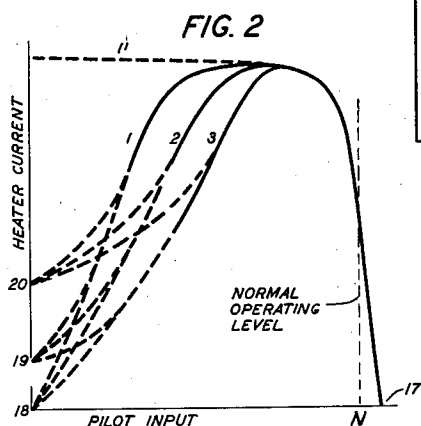
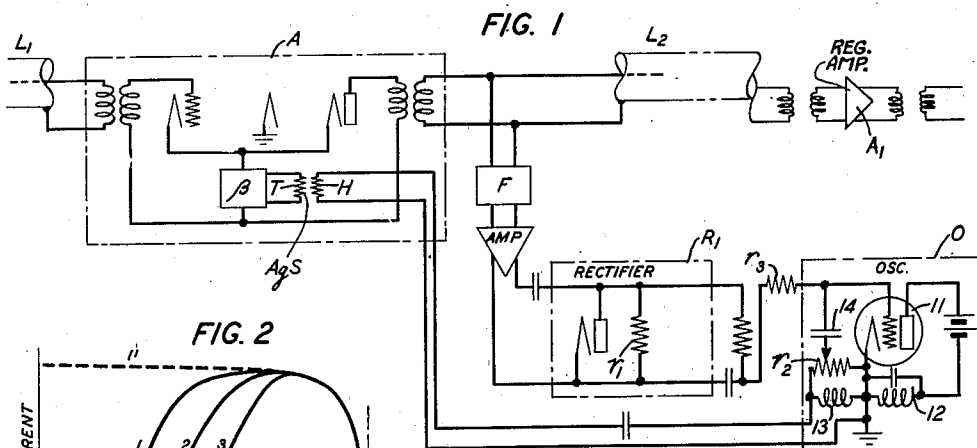
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2,269,408

GAIN CONTROL CIRCUITS

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GAIN CONTROL CIRCUITS

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8 Claims. (Cl. 178-44)

The present invention relates to gain control circuits and particularly to gain control circuits for controlling the energy level of signals in transmission lines in which a pilot frequency current on the line or on an adjacent line gives an indication of the condition of the transmission line.

In such gain control circuits if the pilot current coming in at a given point is below a certain level the gain of the amplifier or set of amplifiers in the transmission line is automatically increased by regulator circuits, whereas if it is above the said level the gain is decreased; in each case by an amount to compensate for the increased loss or gain on the line being supervised. If the pilot signal fails, the repeaters all along the line tend to be brought to maximum gain which would ordinarily lead to serious overloading of the repeaters or associated circuit elements.

It is the purpose of my invention to prevent such overloading and I accomplish this by means which will be better understood by reference to the following specification and the accompanying drawing in which:

Fig. 1 shows a regulator circuit at one repeater point for carrying out the purpose of my invention;

Fig. 2 gives curves showing the characteristics which may be obtained by suitable selection and adjustment of certain parts of the regulator circuit of Fig. 1;

Fig. 3 is a modification of the regulator circuit of Fig. 1; and

Figs. 4, 5 and 6 are further modifications by which the purpose of my invention is obtainable.

Referring more particularly to Fig. 1, there is shown an incoming line such as a coaxial cable L_1 feeding into an amplifier A with an associated gain regulating circuit to be described which is then connected with a similar outgoing line L_2 feeding into another regulated amplifier A_1 .

The amplifiers A, A_1 , may be of any suitable form but I contemplate particularly the application of my invention to the type of amplifier known as the broad band amplifier which finds application in such broad band signaling systems as coaxial cable carrier telephone systems. The amplifier A may, for example, very well be of the negative feedback type such as is described in the application of J. M. West, Serial No. 218,300, filed July 9, 1938, which issued as Patent No. 2,227,048 on December 31, 1940. That particular type of amplifier comprises three stages of amplification with the feedback or β circuit in the cathode cir-

cuit. The gain of such an amplifier may be controlled automatically in response to variations in the attenuation of the line by operating on the β circuit. In this particular instance I have shown this control as being obtained through a resistance T connected in the β circuit, the element T being one the resistance of which is highly sensitive to changes in temperature. A suitable material for such an element, which is frequently referred to in the art as a "thermistor," is silver sulphide. Adjacent to the element T is a heating coil H and variations in current through the coil H modify the resistance of the thermistor in the direction to alter the gain of the amplifier as will now be described.

For the circuit of Fig. 1 the pilot frequency current comes over the transmission line L_1 , with the signal current and is amplified by the amplifier A. In the output of the amplifier and in parallel to the load L_2 there is a branch circuit with a filter F which passes the pilot frequency current only. This current is then amplified and rectified in the rectifier R_1 giving rise to a direct current voltage across a resistance r_1 . An oscillator 0 is shown comprising the vacuum tube 11 with a tuned plate circuit 12 inductively coupled to a grid coil 13. A coupling from the coil 13 to the grid of tube 11 is obtained through condenser 14, the characteristics of the oscillations being determined in part by the point of connection of said condenser 14 with a resistance r_2 connected across the coil 13. The grid of the tube 11 is also associated through resistance r_3 with the negative side of the the resistance r_1 . Shunted across the winding 13 is a circuit leading to the heater coil H which is adjacent to the thermistor T. If the loss of the line L_1 decreases, then the amplitude of the pilot signal current increases and the increased negative bias from r_1 impressed upon the oscillator decreases the amplitude of oscillations and thus decreases the current through the heater H. The corresponding increase in the resistance T increases the amount of negative feedback and so decreases the gain of the amplifier. A reverse action takes place in the event that losses on the line L_1 increase.

The characteristics of the oscillator described above are shown in Fig. 2. With this particular circuit and with appropriate values given to the elements therein, I find it possible to control the amplitude of oscillations by the bias introduced on the grid through the resistance r_3 . With a sufficiently large negative bias over r_3 the amplitude of oscillations and therefore the heater current will be reduced to zero as indicated at point

17. As the bias falls off the circuit starts oscillating and the amplitude rises rapidly, being controlled by the bias on the grid. As the bias is further decreased the amplitude of oscillation increases to a maximum value and then has the peculiar property of decreasing as indicated by the curve 1. By suitable choice of parameters this particular behavior can be repeated and consistently maintained.

The amount of negative bias transmitted through the resistance r_3 from the direct current drop in r_1 is dependent on the amplitude of the pilot frequency current impressed on the rectifier. The adjustments of the circuit are made such that for normal or average conditions on the line L_1 the bias from r_1 will be such that operation takes place at or near the portion N of the oscillator current characteristic. If the pilot frequency current decreases the oscillator current amplitude increases, the current through H increases, the resistance of T decreases and the gain of the amplifier is stepped up. It might be expected that were the pilot frequency to fall completely the gain of the amplifier would be brought to a maximum by virtue of increase in the heater current in accordance with the curve 1', this being associated with maximum of amplitude of current from the oscillator 0. Actually with my form of oscillator the heating current does rise indefinitely as the pilot frequency current decreases but with further decrease of the pilot signal, i. e., with further decrease of the rectified voltage across r_1 , the amplitude of the oscillations and, therefore, the amplitude of the heating current decreases as shown by curve 1 of Fig. 2 and thus the overloading of this and successive repeaters is prevented.

I find that the extent to which amplitude of the oscillations and therefore the amplitude of the heating current will fall off when the rectified voltage across r_1 falls to zero is controllable by the point of connection of condenser 14 on the resistance r_2 and by the size of the capacity 14. As a result it is possible to make the characteristic of Fig. 2 follow the course of curves 1, 2 or 3 and to make it terminate at any desired point such as 18, 19 or 20 or intermediate points. Fig. 3 is a modification of Fig. 1 in that the condenser 14 is connected at a fixed point of the winding 13 and the control of the oscillator by which the terminating point 18, 19 or 20 of the characteristic curves of Fig. 2 is determined, is obtained by adjustment of the resistance r_3 .

It is apparent that the purpose of my invention may be obtained by other means. For example, one may make use of variations in the magnitude of the alternating current flowing through the winding 13 to operate a marginal relay. Thus, in Fig. 4 the relay armature 23 normally makes contact so that oscillator current flows through the heater H. In case the amplitude of oscillations rises above a certain value due to decrease in pilot current then the armature 23 opens the circuit of H and the thermistor cools off thus decreasing the gain of the amplifier to a fixed value. In order to maintain the oscillator in operating condition it may be desirable that the armature 23 on breaking the circuit for the heater H shall replace it by connecting a load 24 of substantially the same impedance as the heater H across the winding 13 as indicated.

A further modification of the circuit is shown in Fig. 5 in which again the coil 13 serves as the winding of an alternating current relay. In addition to the armature 23 which serves as in Fig.

4 there is another armature 26 which upon operation introduces an operating current from the source 28 in the alternating current relay 27 which upon operation places the resistance r_4 in shunt to the thermistor T in the β circuit of the amplifier. With the opening of the circuit H the resistance of the thermistor will have become very high but it is virtually replaced by the fixed resistance r_4 which is given a value to fix the gain of amplifier A at a desired value.

A further modification is shown in Fig. 6 in which increase of the amplitude of the oscillations produced by the oscillator will cause operation of the relay 13, 23 to disconnect the heater H from the winding 13 and connect it to the generator 28, current from which is adjusted to maintain the temperature of the thermistor T at a fixed and desired value. In both Figs. 5 and 6 the source 28 is shown as an alternating current generator. In practice these could be suitable small alternating current voltages derived by transformer from the main power line supplying power for the repeater unit as a whole.

It is to be observed that in each of Figs. 1 and 3 to 6 the circuit is self-curing in the sense that when the pilot frequency current is restored to normal value the circuits themselves are each restored to normal operating condition.

What is claimed is:

1. In combination, a signal transmission line including one or more signal amplifiers, means for transmitting pilot currents over said line, a regulating circuit responsive to level changes in the transmitted pilot currents to adjust the gain of each amplifier so as to compensate for the line attenuation changes and means to prevent the overloading of each amplifier with failure in the pilot current supply thereto comprising means making the characteristic of the regulating circuit such that the gain for each regulated amplifier is automatically stabilized at a fixed minimum value when the level of the controlling pilot currents is reduced below a certain value which is appreciably lower than the values which would cause normal regulation of the amplifier.

2. The combination of claim 1 in which the last-mentioned means comprises a feedback path in the regulated amplifier circuit, which feedback path becomes operative to reduce the gain of the amplifier to said fixed minimum value when the level of the controlling pilot current falls below said certain value.

3. The combination of claim 1 in which the characteristic of said regulating circuit is such that when the level of the controlling pilot currents falls below said certain value the gain of each controlled amplifier first rises and after reaching a maximum begins to fall off and finally stabilizes at said fixed minimum value.

4. In combination, a signal transmission line including one or more signal amplifiers, means for transmitting pilot currents over said line, a regulating circuit responsive to level changes in the transmitted pilot currents to adjust the gain of each amplifier so as to compensate for line attenuation changes, the said regulating circuit comprising an oscillator, the amplitude of the oscillations of which is controlled by the amplitude of the transmitted pilot currents and the amplitude of the oscillations operating to control the gain of the amplifier to compensate for line attenuation changes, the characteristics of the said oscillator being such that when the level of the controlling pilot currents falls below a certain value appreciably lower than those values

which would be due to normal attenuation changes, the amplitude of the oscillations first rises and after reaching a maximum begins to fall off and finally stabilizes at a fixed minimum value.

5. The combination of claim 4 in which current from the oscillator operates on a feedback path in the amplifier changing the amplifier gain in proportion to the amplitude of the oscillator current.

6. The combination of claim 1, in which the regulating circuit for each amplifier comprises a negative feedback path including a thermistor between the amplifier output and input, and means controlled by the pilot currents received over said line for producing and supplying to said thermistor heating current of amplitude varying inversely with the level of the pilot currents, to vary the resistance value of said thermistor, and thus the amount of feedback and the gain of the amplifier, and the last-mentioned means comprises marginal relay means operating when the level of the pilot currents falls below said certain value to disable the heating circuit for said thermistor, the resistance value of said thermistor when it is cooled off being selected such as to provide said fixed minimum gain for the amplifier.

7. The combination of claim 1, in which the regulating circuit for each amplifier comprises a negative feedback path including a thermistor

for said amplifier, and means to produce and supply to said thermistor heating current of amplitude varying inversely with the level of the pilot currents received from said line, to vary the resistance value of said thermistor and thus the amount of feedback and gain of the amplifier, and the last-mentioned means comprises marginal relay means operating when the level of the pilot currents falls below said certain value to effectively replace said thermistor in said feedback path with a resistance of fixed value such as to fix the gain of the amplifier at said minimum value.

8. The combination of claim 1, in which the regulating circuit comprises a negative feedback path including a thermistor for said amplifier, and means to produce and supply to said thermistor heating current varying in amplitude inversely with the level of the pilot currents received over said line, to vary the resistance value of said thermistor and thus the amount of feedback and the gain of the amplifier, and the last-mentioned means comprises marginal relay means operating when the level of the pilot currents falls below said certain value to effectively replace the varying amplitude heating current with a fixed amplitude heating current to maintain said thermistor at a fixed temperature and thus resistance value which will fix the gain of the amplifier at the desired minimum value.

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