July 23, 1935. L. F. SMITH 2,009,074

SIGNAL TRANSMISSION SYSTEM

Filed June 16, 1933

FIG. 1

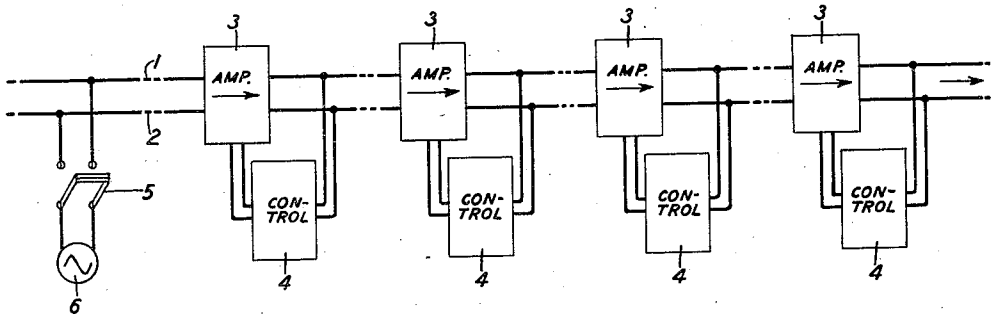
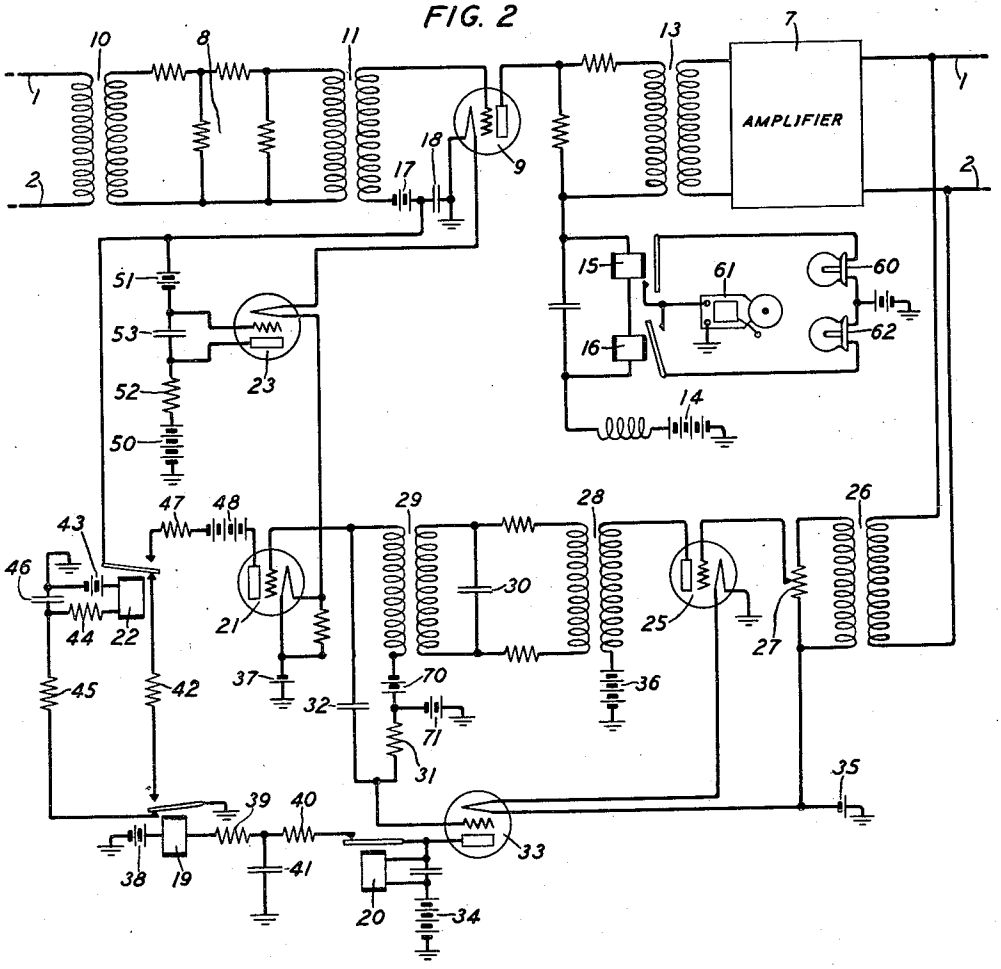


FIG. 2



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SIGNAL TRANSMISSION SYSTEM

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16 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to signal transmission systems having gain adjusting circuits at the repeater stations therein.

One object of the invention is to provide a transmission line with transmission adjusting circuits at a repeater station having a gain-control space discharge device that shall adjust the gain at the repeater station according to the energy level of a tone on the transmission line.

Another object of the invention is to provide a repeater station on a transmission line with a gain-control space discharge device for governing the gain at the repeater station that shall be controlled by a tone on the line having a frequency within the frequency range of the signals on the line and that shall be unresponsive to the signals on the line.

A further object of the invention is to provide a repeater station on a transmission line with a gain-control space discharge device governed according to the charge on a condenser to control the gain at the repeater station that shall charge the condenser in accordance with the energy level of a tone on the line and that shall have a capacity in the form of a space discharge amplifier connected in parallel with the condenser to lower the leakage loss of the charge from the condenser.

It is desirable to correct the energy level of signals on a transmission line at different points along the line in order to prevent undue amplification of the noise at the ends of the line. It is preferable to control the gain at repeater stations along a transmission line in order to hold the energy level along the line within predetermined limits.

In a signal transmission system constructed in accordance with the present invention, the repeater stations along a transmission line are provided with gain-control circuits under the control of a tone on the transmission line. The tone preferably has a frequency within the frequency range of the signals on the line but if so desired may have a frequency outside the frequency range of the signals. If the tone has a frequency within the frequency range of the signals, it is only impressed on the line at intervals and when a gain adjustment is desired. The tone may be kept on the line if the frequency thereof is outside the frequency range of the signals on the line. When the frequency of the tone is within the frequency range of the signals means are provided to prevent simultaneous adjustment of the gain at the various repeater stations.

In gain control circuits constructed in accordance with the invention a loss device comprising an impedance pad and a space discharge device is inserted in the line ahead of the amplifier of the repeater. The impedance of the space discharge device which is connected effectively in series with the line is controlled by varying the negative potential on a grid according to the charge on a control condenser. The charge on the control condenser is set in accordance with the energy level of a tone on the line beyond the repeater amplifier. Means are provided for placing the tone on the line whenever an adjustment of the gain of the repeater is desired.

A control circuit tuned to the frequency of the tone and including an amplifier is connected to the line beyond the amplifier of the repeater. The control circuit governs a biaser space discharge device for controlling the charge put on the control condenser and a starter relay. The starter relay when operated breaks the circuits of a gain-increaser relay which is normally energized and is slow to release. The gain-increaser relay when released completes a circuit for reducing the charge on the control condenser to zero. The gain-increaser relay also breaks the energizing circuit of a biaser relay. The biaser relay releases after a time delay to complete a circuit for charging the control condenser from the biaser space discharge device. The biaser space discharge device is preferably a three-element gas-filled tube which operates below the critical or triggering off point. The biaser space discharge device serves to place a charge on the control condenser in accordance with the energy level of the tone on the line beyond the amplifier of the repeater. The impedance of the loss device varies in accordance with the negative potential impressed on the grid of the space discharge device by the control condenser. In this manner the gain of the repeater is controlled by the control condenser in accordance with the energy level of the tone on the line.

When the frequency of the tone on the line is within the frequency range of the signals, the time of release of the gain-increaser relays at the various repeater stations is varied in order to prevent simultaneous adjustment of the gain at the different repeater stations. It is apparent that if all the repeater stations adjusted their gain together a constant hunting action would take place. However, if the tone were maintained on the line at all times as would be possible if the frequency of the tone were outside the frequency range of signals, no trouble would be encountered because of the hunting action.

In order to lower the leakage loss from the control condenser an amplifier having high input capacity is connected in parallel with the control condenser. The amplifier is made regenerative by a condenser connected between plate and grid thereof in order to raise the input capacity and a resistance of very high value is placed in the amplifier plate circuit. The input circuit of the regenerative amplifier is connected directly in parallel with the control condenser. This means tends to keep the charge on the control condenser substantially constant between periods of adjustment when the tone is impressed on the line.

In the accompanying drawing,

Figure 1 is a diagrammatic view of a transmission line having a number of repeater stations; and

Fig. 2 is a diagrammatic view of the gain control apparatus at one of the repeater stations.

Referring to Fig. 1 of the drawing a west to east transmission line comprising conductors 1 and 2 is shown provided with repeater stations 3. The gain at each repeater station is governed by gain control circuits 4. Although a gain control circuit 4 is shown associated with each repeater station, it is to be understood that if so desired only selected ones of the repeater stations may be provided with gain control circuits. The gain control circuits 4 are each controlled in accordance with the energy level beyond the associated repeater of a tone impressed upon the line. The tone preferably has a frequency within the same frequency range as the signals on the line. However, if so desired the tone may have a frequency outside the frequency range of the signals on the line. A switch 5 is provided for connecting a source of alternating current 6 to the line whenever it is desired to impress the tone on the line for adjusting the gain at the repeater station. The source 6 preferably has a frequency of the order of about 1000 cycles.

Referring to Fig. 2 of the drawing, gain control circuits are illustrated for controlling the gain at a repeater station within an accuracy of plus or minus ½ db. or closer if the transmission level is less than plus or minus 4 db. from a specified value. An amplifier 7 is provided at the repeater station and preceding the amplifier 7 in the transmission line is a pad 8 and a three-element space discharge device 9. The pad 8 which is ahead of the space discharge device 9 inserts 4 db. loss in the line. The pad serves to lower the input voltage on the grid of the space discharge device 9 so as to tend to minimize the distortion and produces a mean input level of zero to the device 9. The pad 8 is connected in the line between transformers 10 and 11. The output circuit of the space discharge device 9 is connected to the amplifier 7 by means of a coupling resistance 12 and a transformer 13. A battery 14 is provided for supplying plate potential to the space discharge device 9. The circuit from the battery 14 includes a coil of a low gain alarm relay 15 and the coil of a high gain alarm relay 16. A battery 17 is provided for impressing a constant negative bias on the grid of the space discharge device 9 which serves with the pad 8 as the variable loss device at the repeater station. A control condenser 18 is provided for impressing a variable negative bias on the grid of the device 9 according to the charge on the condenser. The charge on the condenser 18 is controlled in accordance with the energy level of the tone on the line.

In the apparatus employed to describe the invention it is assumed that the tone which is transmitted over the line for adjusting the gain at the repeater stations has a frequency within the voice frequency range and within the frequency range of the signals on the line. In a system wherein the tone has a frequency within the frequency range of the signals, the tone can only be impressed on the line at intervals and can not be maintained on a line without interfering with the communication currents. The gain-control apparatus for controlling the charge on the control condenser 18 comprises a gain-increaser relay 19 which is under the control of a starter relay 20, a biaser space discharge device 21, a biaser relay 22 and a gain-maintainer space discharge device 23. The gain-increaser relay 19 serves when the tone is impressed upon the line for completing a circuit to discharge the condenser 18. The biaser relay 22 completes a charging circuit for the control condenser 18 to the biaser space discharge device 21 shortly after the release of gain-increaser relay 19 and the completion of a circuit for discharging the control condenser. The biaser space discharge device 21 preferably is a three-element gas-filled tube. This tube charges the control condenser 18 in accordance with the energy level of the tone on the line beyond the amplifier 7. The gain-maintainer space discharge device 23 tends to keep the charge on the control condenser 18 constant between periods of adjustment.

A three-element space discharge amplifier 25 is connected to the line beyond the amplifier 7 by means of a transformer 26. The input circuit of the amplifier 25 is connected to the secondary winding of the transformer 26 by means of a potentiometer 27. The potentiometer 27 serves to adjust the point of operation of the starter relay 20 and the biaser space discharge device 21 with respect to the energy level of the tone on the line beyond the amplifier 7. The output circuit of amplifier 25 is connected by two transformers 28 and 29 to the input circuit of the biaser space discharge device 21. The primary winding of the transformer 29 is tuned to the frequency of the tone by means of a condenser 30. The tuned circuit comprising the primary winding of the transformer 29 and the condenser 30 insures the operation of a biaser space discharge device 21 and the starter relay 20 only by currents having the frequency of the tone impressed on the line.

A coupling resistance 31 is connected across the secondary winding of the transformer 29 in circuit with the condenser 32. The input circuit of a three-element detector tube 33 is connected across the coupling resistance 31. The output circuit of the detector tube 33 includes the energizing coil on the starter relay 20. A plate battery 34 is provided for the detector tube 33. Battery 35 is provided for heating the filaments of the detector tube 33 and the amplifier 25 and for supplying grid bias to the amplifier tube 25. A battery 36 supplies plate potential to the amplifier 25. A battery 37 supplies filament heating current to the biasing space discharge device 21, the gain-maintainer space discharge device 23 and the space discharge device 9 in the line. A battery 79 and a battery 71 are provided for supplying the grid bias to the biasing space discharge device 21. The battery 71 supplies grid bias to the detector tube 33.

The armature of the starter relay 20 when in a released position completes an energizing circuit for the coil of the gain-increaser relay 19 from a battery 38. The gain-increaser relay 19 is normally operated and will remain in an oper-

ated position until the starter relay 20 is held operated for a given length of time. This interval of time is determined by the values of two resistance elements 38 and 40 and a condenser 41. The slow release of the gain-increaser relay 19 insures against any operation of the gain-control circuits during communication over the line. In order to effect operation of the gain-increaser relay 19 the tone must be impressed on the line for a predetermined length of time, which is set so that the gain-increaser relay will not be operated during communication over the line. The function of the gain-increaser relay 19 is to completely discharge the control condenser 18 prior to the charging of the condenser by the biaser space discharge device 21. The discharge circuit completed by the armature of the gain-increaser relay 19 extends from one terminal of the control condenser 18 through the armature of the biaser relay 22, resistance element 42, armature of the gain-increaser relay 19 and ground return to the other terminal of the condenser 18.

A fraction of a second after the gain-increaser relay 19 releases the biaser relay 22 which is normally operated releases. The biaser relay 22 is normally energized by a circuit extending from battery 43 through resistance elements 44 and 45, and ground return to the battery 43. The condenser 46 cooperates with the resistance elements 44 and 45 to delay the release of the biaser relay 22 a definite interval after the release of the gain-increaser relay 19 to insure the complete discharge of the control condenser 18.

The release of the biaser relay 22 completes a charging circuit from the biaser space discharge device 21 for the control condenser 18. The charging circuit for the control condenser 18 may be traced from one terminal of the condenser through the armature of the biaser relay 22, resistance element 47, plate battery 48 for the device 21, space discharge device 21, battery 37 and ground return to the other terminal of the control condenser 18. The biaser space discharge device 21 is preferably a gas-filled detector tube having a charging resistance 47 in the plate circuit and an ungrounded plate battery 48. The biaser device 21 serves to charge the control condenser 18 and thus to impress a negative bias on the grid of the loss device 9. This lowers the gain at the repeater station.

The gain-maintainer device 23 comprises a three-element space discharge amplifier having its input circuit connected across the control condenser 18. The device 23 is provided with a plate battery 50 and a grid biasing battery 51. A relatively high resistance 52 is provided in the plate circuit of the device 23. Maintenance of the gain at a repeater station during the periods between adjustment by the tone is made difficult by the leakage of the charge on the condenser 18 to ground. In order to tend to prevent this leakage of the charge on the control condenser 18 to ground, a relatively large capacity in the form of the gain-maintainer space discharge device 23 is connected in parallel with the control condenser 18. It is well known that the input circuit of a space discharge device has a capacity reaction. This property of a space discharge amplifier is referred to on pages 207 and 208 of "The Thermionic Vacuum Tube" by H. G. Van der Bijl, first edition, published by the McGraw-Hill Book Company, New York, and is also referred to in the patent to R. C. Mathes No. 1,557,860, dated October 20, 1924. A condenser 53 is connected between the grid and plate of the device 23 to furnish a degenerative path and increase the input capacity of the device 23 to a very large value.

When a tone is placed on the conductors 1 and 2 by operating the switch 5, the starter relay 20 is operated at the repeater station. When the tone has been maintained on the line for a predetermined length of time, the gain-increaser relay 19 is released. The release of the gain-increaser relay 19 completes a circuit for completely discharging the control condenser 18 and for raising the gain at the repeater station to a maximum. This maximum gain is maintained for a very brief interval of time according to the time taken to release the biaser relay 22. The release of the biasing relay which is controlled by the gain-increaser relay 19 completes a charging circuit for the control condenser 18 from the gas-filled space discharge device 21. The gas-filled space discharge device 21 charges the condenser 18 according to the energy level of the tone on the line beyond the amplifier 7. When the tone is removed from the line by opening the switch 5, the gain-maintainer space discharge device 23 serves to insure against discharge of the control condenser 18 until the tone is again impressed on the line.

The relays 15 and 16 in the plate circuit of the loss device 9 operate alarms in case the adjustment required at the repeater station is beyond that which can be made by the automatic gain control circuits. When the plate current for the loss device 9 and hence the gain rises higher than the maximum allowable value plus 3 db. the relay 15 is operated to complete a circuit through a signal light 60 and a bell 61. When the gain and consequently the plate current for the loss device 9 falls below the minimum allowable value minus 4 db. the relay 16 releases to complete a circuit through a signal light 62 and the bell 61. The bell alarm 61 is preferably of the slow-operated type and will not operate until current has been flowing through its winding for approximately one half a second. This delay in the operation of the alarm bell 61 is necessary because every time the measuring tone is applied to the line for operating the gain-increaser relay 19, the plate current of the loss device 9 will momentarily rise to its maximum value. However, $\frac{1}{10}$ of a second after the gain-increaser relay 19 releases, the biaser relay 22 releases to complete the charging circuit for control condensers from the biaser space discharge device 21. The delay of one half a second in the operation of the bell alarm is sufficient to prevent its operating every time the measuring tone is applied to the line.

Modifications in the system and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a communication system, a signal line having a repeater station thereon, a three-element space discharge device connected effectively in series with said line at said repeater station for controlling the gain at the repeater station, means for transmitting a tone over said line, a control condenser for governing the negative potential impressed on the grid of said device, control means for governing the charge on said condenser according to the energy level beyond the repeater station of the tone transmitted at intervals over the line and means for maintain-

ing the charge on said condenser and for insuring against charging the condenser when the tone is off the line.

2. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device connected in series with said line, means for transmitting a tone over the line having a frequency within the voice frequency range, a control condenser for controlling the potential on the grid of said device according to the charge thereon, means governed according to the energy level of the tone beyond said amplifier for impressing a charge on said condenser only when the tone is on said line to determine the gain effected at the repeater station, and means comprising a space discharge device having the input capacity thereof connected in parallel to said control condenser for preventing loss of the charge on the condenser when the tone is off the line.

3. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device connected in series with said line, a control condenser for controlling the potential on the grid of said device according to the charge thereon to govern the impedance of the device, means at intervals for transmitting a tone over the line having a frequency within the voice frequency range, means governed according to the energy level of the tone beyond said amplifier for controlling the charge on said condenser only when the tone is on said line to determine the gain effected at the repeater station, and means comprising a space discharge device having the input capacity thereof connected in parallel to said control condenser for retaining the charge on said condenser between the times of transmitting said tone.

4. In combination, a transmission line, tandem connected repeaters therein, a three-element space discharge device connected in series with the line ahead of certain of said repeaters, means for transmitting a tone at intervals over the line having a frequency within the voice frequency range, and means for controlling the impedance of the devices associated with said repeaters according to the energy level of the tone beyond the repeaters to determine the gain effected at said repeater stations, said control means including a slow acting relay for preventing simultaneous adjustment of the gain by the different repeaters and for increasing the gain at a repeater station to a maximum when the tone is on the line for a predetermined period and prior to the governing of the impedance according to the tone.

5. In combination, a signal transmission line, tandem connected repeaters therein, a space discharge device connected effectively in series with the line ahead of certain of said repeaters, means for transmitting a tone at intervals over the line having a frequency within the frequency range of the signals transmitted over the line, means for controlling the impedance of the devices associated with said repeaters according to the energy level of the tone beyond the repeaters, and means comprising a slow acting relay for lowering the impedance of said device to a minimum when the tone is on the line for a predetermined time and prior to the setting of the impedance by the tone and for preventing control of said devices by the signals on the line.

6. In combination, a signal transmission line, tandem connected repeaters therein, a three-element space discharge device connected in series with the line ahead of certain of said repeaters, a control condenser associated with each device for impressing a negative potential on the grid of the device according to the charge on the condenser, means for transmitting a tone over the line having a frequency within the frequency range of the signals transmitted over the line, control means for charging each of said condensers according to the energy level of the tone beyond the associated repeater, and means comprising a slow acting relay associated with each condenser for preventing control of the charge on the condenser by the communication currents on the line and for preventing simultaneous adjustment of the gain at the different repeater stations.

7. The method of controlling the gain at a repeater station on a signal transmission line which consists in transmitting a tone over the line having a frequency within the frequency range of the signals transmitted over the line, in raising the gain at the repeater station to a maximum and in setting the gain at the repeater station according to the energy level of the tone on the line beyond the repeater station.

8. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device, means for transmitting a tone over said line having a frequency within the voice frequency range, a control condenser for governing the potential on the grid of said device, control means governed according to the energy level of said tone beyond said amplifier for controlling the charge on said condenser to govern the potential on the grid of said device, and means comprising a slow-acting relay associated with said control means for discharging said control condenser when the tone is impressed on the line for a predetermined period and for preventing control of said device by the communication currents on the line.

9. In a communication system, a signal line, a repeater station on said line, means comprising a control condenser for governing the gain effected at the repeater station according to the charge thereon, means for charging said condenser according to a tone on the line, and means comprising a degenerative amplifier having the input capacity thereof connected in parallel to said control condenser to maintain the charge on the control condenser.

10. In combination, a control condenser, means for charging said condenser, a space discharge amplifier having the input circuit thereof connected in parallel with said condenser, and an auxiliary condenser connected between the plate and grid of said amplifier for providing a degenerative path to increase the input capacity of the amplifier to lower the leakage loss by said control condenser.

11. In combination, a control condenser, means for charging said condenser, a space discharge amplifier having means for effecting a degenerative path, said amplifier having a resistance sufficiently high in the plate circuit to increase the grid to filament capacity and having the input circuit thereof connected in parallel with said control condenser to lower the leakage loss of said condenser.

12. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge de-

vice, means for impressing on the line at intervals a tone having a frequency within the frequency range of the signals on the line, a control condenser for controlling the impedance of said device according to the charge thereon, means for charging said condenser only when the tone is on the line and according to the energy level of the tone beyond said amplifier, and means comprising a space discharge device having the input circuit thereof connected across said control condenser and provided with a degenerative path from plate to grid for effectively placing a large capacity in parallel with the smaller capacity of the control condenser to maintain the charge on the control condenser.

13. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device, means for impressing a tone on said line having a frequency within the frequency range of the signals on the line, means comprising a control condenser for governing the impedance of said device and the gain at the repeater station according to the charge on the condenser, means for discharging said condenser to raise the gain at the repeater station to a maximum a predetermined period after the tone is impressed on the line, and means operative after the repeater gain is raised to a maximum for charging said condenser according to the energy level of the tone on the line beyond the amplifier.

14. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device, means for impressing on the line at intervals a tone having a frequency within the frequency range of the signals on the line, means for controlling the impedance of said device and the gain at the repeater station according to the charge on a control condenser, means for adjusting the charge on the condenser according to the energy level of the tone on the line beyond said amplifier, and means tending to prevent leakage of the charge on the condenser when the tone is off said line.

15. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device, a control condenser for impressing a potential on the grid of said device according to the condenser charge to control the gain at the repeater station, means for impressing a tone on said line having a frequency within the frequency range of the signal on the line, a control circuit for selecting the tone frequency, said circuit being connected to the line beyond said amplifier, a slow-acting gain-increaser relay governed by said control circuit for discharging said control condenser when the tone is impressed on the line for a predetermined period, means comprising a biaser relay controlled by the gain-increaser relay for opening the discharge circuit for the control condenser after the operation of the gain-increaser relay and means comprising a biaser discharge device governed by the control circuit for charging the condenser according to the level of the tone on the line beyond said amplifier.

16. In a communication system, a signal line, a repeater station on said line comprising an amplifier and a three-element space discharge device, a control condenser for governing the potential on the grid of said device to control the gain at the repeater station according to the charge on the condenser, means for transmitting a tone over said line having a frequency within the voice frequency range, a gain-increaser relay normally operated and slow releasing, a starting relay for opening the operating circuit of said gain-increaser relay, a biaser space discharge device for impressing a charge on said control condenser, and a control circuit connected to the line beyond the repeater and comprising a circuit tuned to the frequency of said tone for releasing said gain-increaser relay to discharge said control condenser and for governing said biaser device a predetermined interval after the discharge of said control condenser for charging said control condenser according to the energy level of the tone on the line beyond said amplifier.

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