Oct. 24, 1933. R. A. HEISING 1,931,866

GAIN CONTROL CIRCUITS

Filed June 16, 1932

FIG. 1

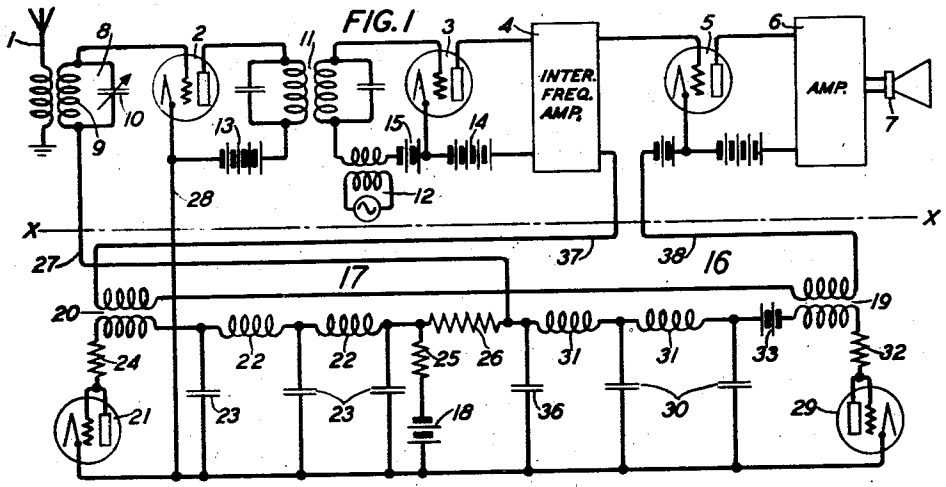


FIG. 2

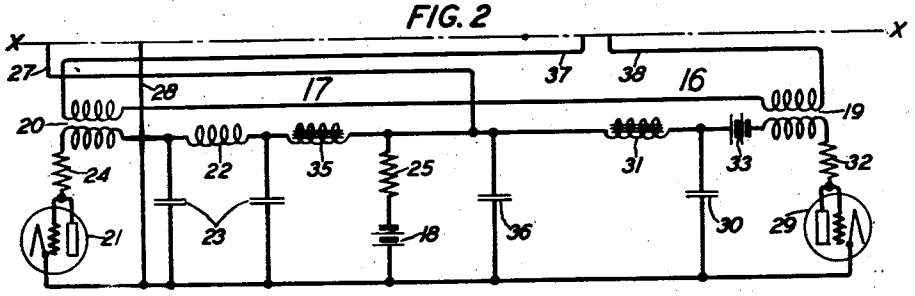


FIG. 3

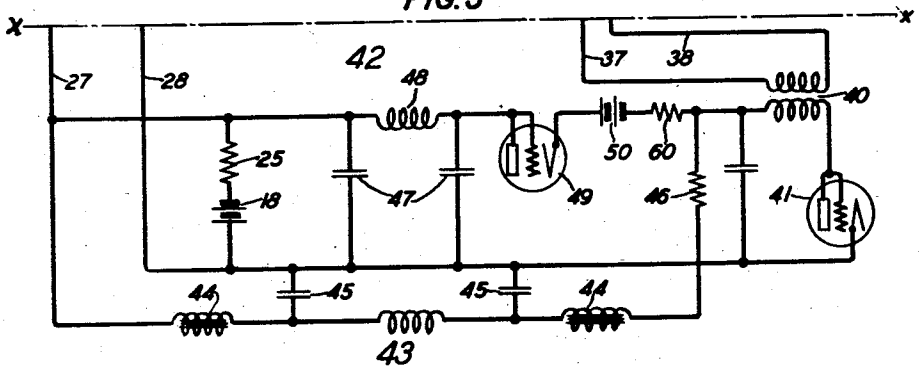
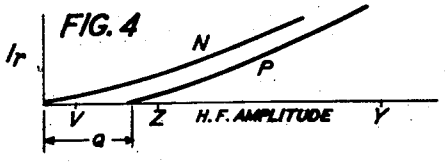


FIG. 4



INVENTOR
R. A. HEISING
BY Wayne B Wells
ATTORNEY

Patented Oct. 24, 1933 1,931,866

UNITED STATES PATENT OFFICE

1,931,866

GAIN CONTROL CIRCUITS

Raymond A. Heising, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 16, 1932. Serial No. 617,510

18 Claims. (Cl. 250—20)

This invention relates to gain control circuits and particularly to gain control circuits for radio receivers.

One object of the invention is to provide two gain control circuits for governing the gain of a space discharge device, one gain control circuit having a relatively small time constant and the other gain control circuit having a larger time constant.

Another object of the invention is to provide gain control circuits for a radio receiver that shall not only prevent slow volume variations due to fading but shall prevent short excessively large volume variations.

Another object of the invention is to provide two gain control circuits having different time constants for governing the gain of a space discharge amplifier, the gain control circuit having the smaller time constant being operative only when signal waves of excessively high amplitude are being controlled.

A further object of the invention is to provide a radio receiver with a gain control circuit that shall have a time constant of the order of 1/5 of a second and a gain control circuit that shall have a time constant of the order of 1/100 of a second, the gain control circuit having the smaller time constant being biased to prevent control of the gain of the receiver thereby except when signal waves having excessively large amplitude are being controlled.

In a radio receiver trouble is often experienced in receiving signal waves having excessively high amplitude which cause unusually loud signals to be delivered by the receiver. The gain control circuits now in service on radio receivers usually have a time constant of the order of 1/5 of a second and serve to prevent the relatively slow variations due to fading. It is undesirable to reduce the time constant of the usual gain control circuit as a reduction in the time constant would prevent syllable variations and even wipe out audio-frequency currents. If the usual gain control circuit is set for maximum gain, as would be the case if the carrier wave at transmitting station is cut off, and the signals from the transmitting station are transmitted at the time the carrier wave from the transmitting station is turned on, then the receiver will produce excessively loud signals for a period of 1/5 of a second. Loud signals for periods of less than a 1/5 of a second may also be caused by lightning.

In accordance with the present invention, it is proposed to prevent the above mentioned loud signals by providing the radio receiver with a second gain control circuit having a very small time constant, for example, of about 1/100 of a second. The second gain control circuit will be biased so as only to become operative when waves of excessively high amplitude occur in the receiving circuit.

The present invention is illustrated by means of a super-heterodyne radio receiving circuit. Rectifying means is connected to the output circuit of the intermediate frequency amplifier for supplying rectified current to two filter circuits. The rectifying means may consist of a single rectifier of any suitable type or may consist of two rectifiers of any suitable type respectively connected to the two filter circuits. In describing the invention, the rectifiers connected to the filters are shown as space discharge devices. The two filter circuits are connected to the input circuit of a radio frequency amplifier in the radio receiving circuit. The two filter circuits complete two gain control circuits for governing the gain of the radio frequency amplifier in the radio receiver. One of the gain control circuits will have a relatively small time constant and the other gain control circuit will have a much higher time constant. The time constant of each gain control circuit is determined according to the construction of the filter included therein and resistance means associated with the filter. The gain control circuit having a small time constant will preferably have a time constant of the order of about 1/100 of a second and the other gain control circuit will have a time constant of the order of about 1/5 of a second. Although the gain control circuits are referred to as having certain time constants, they may also be referred to as eliminating certain frequencies. Employing the expression "time constants" may be considered as another way of stating the range of frequencies which may pass through the filter in the gain control circuit.

The gain control circuit having a time constant of the order of 1/100 of a second will eliminate some currents of frequencies within the voice frequency range, whereas the gain control circuit having a time constant of the order of 1/5 of a second will not eliminate currents having frequencies within the voice frequency range. If the gain control circuit having the smaller time constant were operative at all times, it will be apparent that part of the voice frequency currents would be eliminated which is undesirable. Accordingly, biasing means is provided in the gain control circuit having a smaller time constant. Such biasing means insures that the gain con-

trol circuit having the smaller time constant will only be operative when currents having exceedingly high amplitudes appear in the output circuit of the intermediate frequency amplifier. During normal operation, the gain control circuit having a smaller time constant will be inactive and the gain of the radio receiver circuit will be controlled by the gain control circuit having the larger time constant. However, the gain control circuit having a smaller time constant would become active at any time the amplitude of the waves in the intermediate frequency amplifier output circuit becomes excessively high. Although the gain control circuits are illustrated as being controlled in accordance with the output from the intermediate frequency amplifier, it is apparent the gain control circuits may be controlled from other points in the radio receiving circuit as, for example, as shown in the patent to P. H. Evans, 1,869,323, dated July 26, 1932. Moreover, the gain control circuits are not restricted to controlling the gain of one radio frequency amplifier inasmuch as it is apparent that other tubes in the radio receiving circuit may be controlled if so desired.

In the accompanying drawing, Fig. 1 is a diagrammatic view of a radio receiver provided with gain control circuits constructed in accordance with the invention;

Figs. 2 and 3 are diagrammatic views showing modified gain control circuits which may be connected to the radio receiver shown in Fig. 1;

Fig. 4 is a diagrammatic view showing curves illustrating the operation of the gain control circuits.

Referring to Fig. 1 of the drawing, a radio receiver is shown connected to an antenna 1. The radio receiver comprises a radio frequency amplifier 2 which is preferably of the pure electron discharge type, an intermediate frequency detector 3, an intermediate frequency amplifier 4, a detector 5 and a voice frequency amplifier 6 which is connected to a suitable loudspeaker 7. The detectors 3 and 5 and the amplifiers 4 and 6 preferably comprise pure electron discharge tubes. The radio frequency amplifier tube 2 is connected to the antenna 1 by means of a tuned circuit 8 comprising inductance 9, and adjustable capacity 10. The output circuit of the radio frequency amplifier tube 2 is connected to the input circuit of the detector 3 by means of a transformer 11. The windings of the transformer 11 form parts of tuned circuits in the output circuit of the amplifier tube 2 and the input circuit of the detector 3. A suitable oscillator 12 is coupled to the input circuit of the detector 3 in the usual manner employed in superheterodyne circuits. A battery 13 is provided for supplying plate potential to the amplifier 2 and a battery 14 is provided for supplying plate potential to the detector 3. A grid biasing battery 15 is provided in the input circuit of the detector 3.

The biasing potential impressed on the grid of the radio amplifier 2 is obtained from two gain control circuits 16 and 17 and from a grid biasing battery 18. The two gain control circuits 16 and 17 are controlled from the output from the intermediate frequency amplifier 4 to maintain not only substantially constant volume on a radio receiver circuit, but also to prevent sudden variations in amplitude of the waves in the radio receiver. The two gain control circuits 16 and 17 are respectively coupled to the output circuit of the intermediate frequency amplifier 4 by means of two transformers 19 and 20.

The gain control circuit 17 comprises a rectifier 21 of any suitable type, inductance elements 22, condensers 23 and resistance elements 24 and 25. The current supplied to the gain control circuit from the output circuit of the intermediate frequency amplifier 4 by the transformer 20 is rectified by the rectifier 21 and is impressed on the resistance element 25 to produce additional negative bias which is added to the negative bias of the battery 18. The negative bias from the battery 18 and potential drop across the resistance element 25 is impressed through a resistance element 26 to the condenser 36 and the grid of the radio frequency amplifier 2 by means of conductors 27 and 28. The inductance elements and the capacity elements in the gain circuit 17 serve as a filter to exclude any immediate frequency current in the gain control circuit. Preferably the circuit is so adjusted as to have a time constant of the order of 1/5 of a second. The resistance 25 and the size of the condensers 23 determine the control rate of the circuit. The resistance element 24 is added to the gain control circuit in order to insure that the rate of control of the circuit is the same following an increase in amplitude, as in following a decrease in amplitude. The resistance element 24 insures that the charging of the condensers 23 will be effected at substantially the same rate as the discharging of the condensers through the resistance element 25.

The gain control circuit 16 comprises a rectifier 29 of any suitable type, capacity elements 30, inductance elements 31, a resistance element 32 and an opposing battery 33. The condensers 30 and the inductance elements 31 in the gain control circuit 16 form a filter in the same manner as like elements in the gain control circuit 17. However, the condenser elements 30 in the gain control circuit 16 are much smaller than the condenser elements 23 in the gain control circuit 17. The filter in the gain control circuit 16 eliminates any intermediate frequency current in the gain control circuit. The elements of the gain control circuit 16 are adjusted to produce a gain control circuit having a much shorter time constant than the time constant of the gain control circuit 17. Preferably the gain control circuit 16 has a time constant of the order of 1/100 of a second. The resistance element 32 in the gain control circuit 16 serves the same purpose as the resistance element 24 in the gain control circuit 17. The opposing battery 33 in the gain control circuit 16 serves to prevent operation of the gain control circuit except when waves of very high amplitude appear in the output circuit of the intermediate frequency amplifier 4.

Referring to Fig. 4 two curves N and P, respectively, represent the rectified current in the two gain control circuits 17 and 16. The abscissa of the curves may be considered the amplitude of the waves in the output circuit of the intermediate frequency amplifier and the ordinates may also be considered negative biasing potential impressed on the grid of the amplifier 2 from the gain control circuits. The operating amplitude of the waves in the intermediate frequency amplifier output circuit may be considered V as shown in Fig. 4 of the drawing. When operating the radio receiver with waves of amplitude V in the intermediate frequency amplifier output circuit, it is apparent no rectified current passes through the rectifier 29 in a gain control circuit 16. No current will pass through the rectifier 29 unless

waves of an amplitude larger than Q appear in the output circuit of the intermediate frequency amplifier 4. The amplitude Q as shown in Fig. 4 of the drawing should be approximately twice the steady carrier amplitude which would occur in the primary windings of the transformers 20 and 19 when operating on the strongest signal which the gain control circuit 17 is expected to control.

If the carrier wave disappears in the radio receiver circuits the rectified current disappears in the gain control circuits and the gain of the set changes immediately to its maximum. If the carrier should come on suddenly and go through the receiving set, it may produce waves in the transformers 20 and 19 having an amplitude represented by Y in Fig. 4 of the drawing. In this case, both rectifiers 21 and 29 will pass rectified current but the current through the rectifier 29 will be enabled by the construction of the filter in the gain control circuit 16 and the resistance elements 32 and 26 to build up a bias across the resistance element 26 in a very much shorter time than the current passing through the rectifier 21. The potentials on the condensers in the gain control circuit 16 will build up as heretofore set forth in the order of 1/100 of a second and the steady rectified current through the rectifier 29 will pass through the resistances 25 and 26 producing a bias for the grid of the radio frequency amplifier 2 which will cut the gain of the receiving set down such as to produce a resulting amplitude Z for the waves in the output circuit of the intermediate frequency amplifier 4. This is a great reduction from the amplitude Y and is such as not to overload the set and not to produce an excessively loud signal. The amplitude Z for the waves in the intermediate frequency amplifier output circuit is still larger than normal amplitude V. However, after the lapse of time required for the rectifier 21 to charge the condensers 23 a potential will be built up across the resistance element 25 due to the rectified current from the rectifier 21 which will cause the gain to be further reduced. The gain control circuit 17 reduces the amplitude of the waves in the output circuit of the intermediate frequency amplifier 4 from an amplitude Z as shown in Fig. 2 to the required amplitude V. When the gain control circuit 16 is functioning, audio-frequencies of the order of 100 cycles and below will be eliminated from speech in the radio receiving circuit. However, the gain control circuit 16 is only in operation when waves of excessively high amplitude appear in the output circuit of the intermediate frequency amplifier 4. The resistance element 26 is preferably of the same order as the resistance element 25 or larger.

Referring to Fig. 2 of the drawing two modified gain control circuits are shown for controlling the gain of the radio receiver shown in Fig. 1. Like parts in Fig. 2 to those shown in Fig. 1 will be indicated by similar reference characters. The gain control circuit 17 in Fig. 2 of the drawing, which has a time constant of the order of 1/5 of a second, is provided with a choke coil 35 to prevent the charge built up on the condenser 36 by the current through the rectifier 29 from passing into the filter of the gain control circuit 17 during the period of time when the rectifier 29 and its circuit is supposed to control the gain of the radio receiving circuit. This action takes place before the gain control circuit 17 builds up and takes control of the gain of the radio receiving circuit. The two gain control circuits 16 and 17 shown in Fig. 2 otherwise operate in the same manner as the two gain control circuits 16 and 17 shown in Fig. 1 of the drawing. The primary windings of the transformers 19 and 20 shown in Fig. 2 of the drawing are connected in the output circuit of the intermediate frequency amplifier 4 by means of conductors 37 and 38. Similar conductors 37 and 38 are provided in Fig. 1 of the drawing.

Referring to Fig. 3 of the drawing the output circuit of the intermediate frequency amplifier 4 is connected by transformer 40 through the conductors 37 and 38 to a rectifier 41. The rectifier 41 supplies rectified current to two gain control circuits 42 and 43. The gain control circuit 42 is assumed to have a time constant of the order of 1/100 of a second and the gain control circuit 43 is assumed to have a time constant of the order of 1/5 of a second. The gain control circuit 43 which has a relatively large time constant is provided with choke coils 44 and condensers 45. A resistance element 46 is also provided in this gain control circuit which performs the same function as the resistance 24 in the gain control circuit 17 shown in Fig. 1 of the drawing. The gain control circuit 42 which has a relatively small time constant comprises condensers 47, inductance 48, rectifier 49, resistance element 60, and opposing battery 50. The rectifier 49 and the opposing battery 50 serve to prevent operation of the gain control circuit 42 except when waves of exceptionally high amplitude appear in the output circuit of the intermediate frequency amplifier 4. The gain control circuits 43 and 42 shown in Fig. 3 of the drawing operate in the same manner as the gain control circuits 17 and 16 in Fig. 1 of the drawing. The biasing battery 18 and the resistance element 25 associated therewith in Fig. 3 of the drawing have been designated by the same reference characters as the biasing battery and the resistance associated therewith in Fig. 1 of the drawing.

Modifications in the circuits 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 combination a radio receiving circuit comprising an amplifier having input and output circuits, means comprising a filter connected between the amplifier input and output circuits for completing a gain control circuit having a relatively small time constant, and means comprising a second filter connected between the amplifier input and output circuits for completing a second gain control circuit having a larger time constant than that of said first mentioned gain control circuit.

2. In combination a space discharge device having input and output circuits, means comprising a filter connected between the output and input circuits of said device for completing a gain control circuit having a relatively small time constant, means comprising a second filter connected between the output and input circuits of said device for completing a second gain control circuit having a larger time constant than that of said first mentioned gain control circuit, and means for preventing control of the gain of said device by the gain control circuit having the smaller time constant except when currents of relatively high amplitude appear in the output circuit of said device.

3. In combination a three-element space discharge amplifier, two filters connected to the input circuit of said amplifier and adapted to eliminate currents of different frequencies, and means for supplying said filters with rectified current according to the amplitudes of the currents in the amplifier output circuit to control the amplifier gain.

4. In combination an amplifier having input and output circuits, two filters connected to the input circuit of said amplifier and adapted to pass currents having different frequency ranges, means for supplying said filters with rectified current according to the amplitudes of the currents in the amplifier output circuit to control the amplifier gain, said filters completing two gain control circuits having different time constants, and means for insuring the operation of the two gain control circuits according to currents in the amplifier output circuit having different amplitudes.

5. Gain control circuits comprising an amplifier having input and output circuits, means comprising two filters and rectifying means for completing two gain control circuits from the output to the input circuits of said amplifier to control the amplifier gain, said gain control circuits having different time constants, and means for insuring the operation of the two gain control circuits respectively by currents in the amplifier output circuit having different amplitudes.

6. Gain control circuits comprising an amplifier having input and output circuits, means comprising two filters and rectifying means for completing two gain control circuits from the output circuit to the input circuit of said amplifier, said gain control circuits serving to prevent the generation of undesired oscillatory currents of different frequencies and having different time constants, and means for preventing control of the gain of the amplifier by the gain control circuit having the smaller time constant except when currents of relatively high amplitude appear in the output circuit of said amplifier.

7. In combination a space discharge amplifier having input and output circuits, rectifying means supplied with current according to the output from said amplifier, and means comprising two filters connecting said rectifying means with the input circuit of said amplifier to complete two gain control circuits having different time constants.

8. Gain control circuits comprising a space discharge amplifier having input and output circuits, rectifying means supplied with current according to the output from said amplifier, means comprising two filters for connecting said rectifying means with the input circuit of said amplifier to complete two gain control circuits having different time constants and means for preventing control of the gain of the amplifier by the gain control circuit having the smaller time constant except when currents of relatively high amplitude are supplied to said rectifying means.

9. Gain control circuits comprising a three-element space discharge amplifier, a detector connected to the output circuit of said amplifier, rectifying means supplied with current varying in amplitude according to the output from said detector, means comprising two filters for connecting said rectifying means with the input circuit of said amplifier to complete two gain control circuits having different time constants and means for preventing control of the gain of the amplifier by the gain control circuit having the smaller time constant except when currents of relatively high amplitude are supplied to said rectifying means.

10. Gain control circuits comprising a space discharge amplifier having input and output circuits, rectifying means supplied with current according to the output from said amplifier, means comprising a filter for connecting the rectifying means with the input circuit of said amplifier to complete a gain control circuit having a relatively small time constant, means comprising a second filter for connecting the rectifying means with the input circuit of said amplifier to complete a gain control circuit having a larger time constant than said first mentioned gain control circuit, and biasing means associated with said first mentioned filter for insuring control of the gain of said amplifier by the first mentioned gain control circuit only when waves of relatively high amplitude are supplied to said rectifying means.

11. Gain control circuits for a radio receiver comprising an amplifier having input and output circuits, two rectifiers connected to the output circuit of said amplifier, and means comprising two filter circuits for respectively connecting said rectifiers with the input circuit of said amplifier to comple e gain control circuits having different time constants.

12. Gain control circuits for a radio receiver comprising a three-element space discharge amplifier, two rectifiers connected to said amplifier, means comprising two filter circuits for respectively connec ing said rectifiers with the input circuit of said amplifier to complete gain control circuits having different time constants, and means for preventing control of the amplifier by the gain control circuit having the smaller time constant except when currents of relatively high amplitude are supplied to the rectifiers.

13. Gain control circuits for a radio receiver comprising a three-element space discharge amplifier having input and output circuits, two rectifiers supplied with current according to the output from said amplifier, means comprising a filter circuit for connecting one of said rectifiers with the input circuit of said amplifier to complete a gain control circuit having a relatively small time constant, means comprising a filter circuit for connecting the other rectifier with the input circuit of said amplifier to complete a gain con'rol circuit having a relatively large time constant, and means for insuring against simultaneous control of the amplifier by the two gain control circuits.

14. Gain control circuits for a radio receiver comprising a three-element space discharge amplifier having input and output circuits, two rectifiers connected to said amplifier output circuit, means comprising two filters respectively connected to said rectifiers for impressing potentials on the grid of said amplifier to control the gain effected by said amplifier, said filter means preventing the generation of undesired oscillatory currents and serving to complete gain control circuits having different time constants, and means associated with the filter means in the gain control circuit having the shorter time constant for preventing control of the amplifier gain thereby except when currents of relatively high amplitude are supplied to said rectifiers.

15. Gain control circuits for a radio receiver comprising a three-element space discharge radio-frequency amplifier, an intermediate frequency detector connected to said amplifier, a rectifier

coupled to the output circuit of said detector, means comprising a filter for connecting said rectifier to the grid of said amplifier to complete a gain control circuit having a relatively small time constant, biasing means associated with said filter for insuring control of the amplifier gain only when relatively high amplitude current is supplied to the rectifier, a second rectifier coupled to the output circuit of said detector, and means comprising a second filter for connecting the second rectifier to the grid of said amplifier to complete another gain control circuit having a relatively large time constant.

16. In combination, a translating device having input and output circuits, two frequency discriminating circuits connected to the input circuit of said device and adapted to eliminate currents of different frequencies, and means for suppling said discriminating circuits with rectified current according to the amplitude of current in the output circuit of said device.

17. In combination, a translating device having input and output circuits, rectifying means supplied with current according to the output from said device, and means comprising two frequency discriminating circuits having different frequency discriminating characteristics for connecting said rectifying means with the input circuit of said device.

18. Gain control circuits comprising a translating device having input and output circuits, rectifying means connected to the output circuit of said device, and means comprising two frequency discriminating circuits having different frequency discriminating characteristics for connecting said rectifying means with the input circuit of said device to complete gain control circuits having different time constants.

RAYMOND A. HEISING.