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A. CROSSLEY ET AL

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AUTOMATIC VOLUME CONTROL SYSTEM

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Fig. 1.

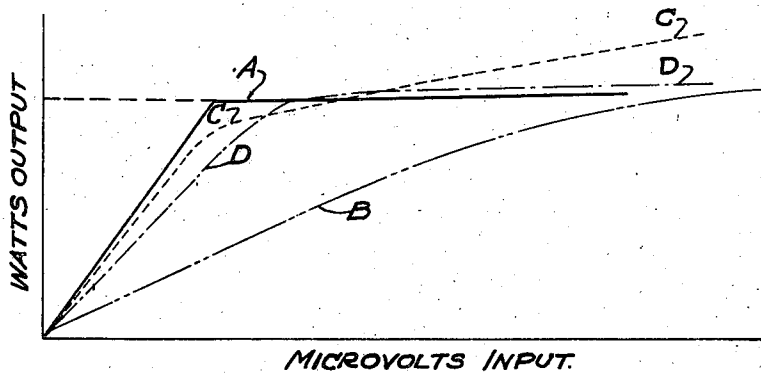
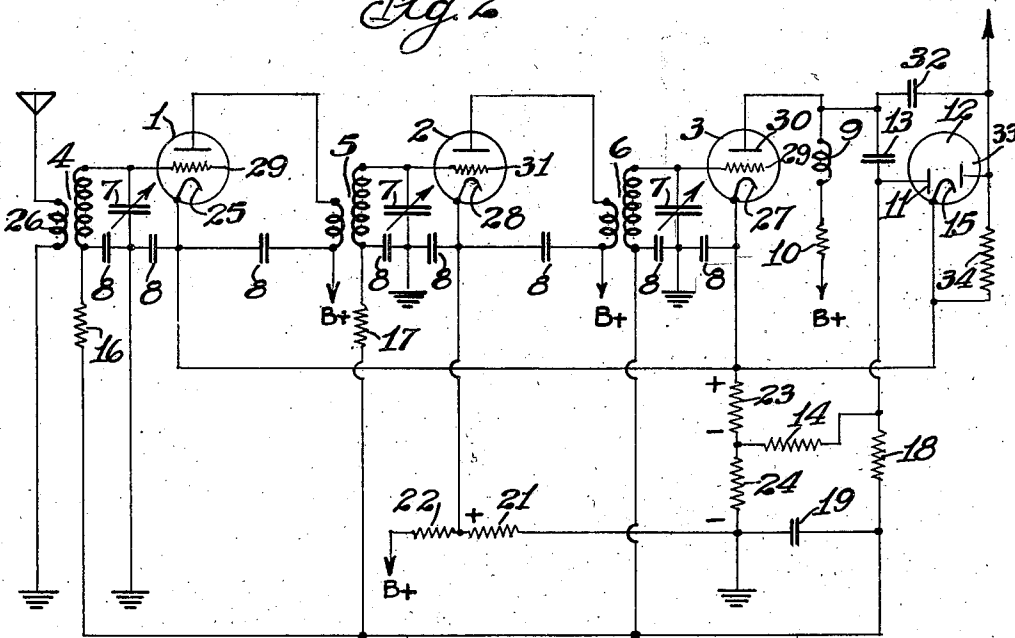


Fig. 2.



INVENTORS,
ALFRED CROSSLEY,
HERBERT E. MEINEMA,
BY
Thomas G. Steward,
ATTORNEY.

UNITED STATES PATENT OFFICE

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AUTOMATIC VOLUME CONTROL SYSTEM

Alfred Crossley and Herbert E. Meinema, Chicago, Ill., assignors to Johnson Laboratories, Inc., Chicago, Ill., a corporation of Illinois

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8 Claims. (Cl. 250—20)

This invention relates to improvements in vacuum-tube amplifying systems. More specifically, this invention relates to improvements in the means for automatically regulating the amplification of a vacuum-tube amplifying system.

An object of this invention is to provide an improved method of amplification control which automatically maintains the output level of a vacuum-tube amplifier substantially constant in spite of wide variations in the input voltage.

Another object of the present invention is to provide a system of automatic amplification control which is responsive to relatively small changes in the voltage at the output of a vacuum-tube amplifier.

A further object of this invention is to provide means whereby the control of amplification which is automatically applied to a vacuum-tube amplifier is self-increasing.

Still another object of the present invention is to provide an amplified control voltage for the automatic regulation of the amplification of a vacuum-tube amplifier, without the use of additional vacuum tubes other than a demodulator.

An additional object of this invention is to provide an automatic amplification control system which may be satisfactorily employed in conjunction with the high-frequency amplifier of a radio receiver, to maintain the signal level at the demodulator substantially constant in spite of wide variations in the input signal voltage.

Still a further object of the present invention is to provide an automatic amplification control system which has a desirable input vs. output characteristic, but which does not prevent the full utilization of the amplification of a vacuum-tube amplifying system.

Although a discussion of the principles underlying our invention is necessary to a full understanding thereof, certain portions of this specification will be best understood when taken in connection with the drawing, in which

Fig. 1 is a graph showing the usual automatic amplification control characteristics under several different sets of conditions; and

Fig. 2 is a schematic wiring diagram of a portion of a radio receiving apparatus incorporating our invention and serving as an illustrative embodiment thereof.

Vacuum-tube amplifiers of the type herein contemplated are used in both low-frequency and high-frequency communication systems. Low-frequency amplifiers are commonly employed in telephone systems. High-frequency amplifiers are widely used in systems employing modulated

high-frequency signals for the transmission of intelligence. Although the arrangements of the present invention are applicable to vacuum-tube amplifiers of all types, they are of especial advantage in the high-frequency amplifiers of radio receivers. In this case, it is usually desirable that the output signal level remain substantially constant in spite of wide variations in the input signal voltage due to fading or to the widely different signal strengths which are encountered in tuning from one signal to another from a different source.

The usual radio receiver consists of a high-frequency amplifying system, a demodulator, and a low-frequency amplifier. Since the demodulator performs most satisfactorily within a relatively narrow range of signal levels, it is the usual practice to regulate the amplification of the high-frequency amplifying system either manually or automatically, in such a way as to maintain the signal at the demodulator substantially constant despite large variations in the strength of the incoming signal. If this operation is performed manually, constant attention on the part of the user is required to compensate for the relatively rapid changes in the incoming signal strength. Furthermore, whenever the receiver is adjusted to receive a different station the manual amplification control must be re-adjusted to produce the desired output level from the new signal. These requirements are objectionable in any receiver, and are especially disadvantageous in the case of receivers intended for mobile use, as in automobiles or motor boats.

Various arrangements have been employed in the past to automatically vary the amplification of the high-frequency amplifying system of a radio receiver in accordance with changes in the input signal level. These arrangements are usually operated by rectifying a portion of the output voltage, and applying the rectified voltage to a control electrode of one or more of the high-frequency amplifying vacuum tubes, thereby regulating the amplification of the system in approximate accordance with the amplitude of the input signal. In some cases, the control is applied also to a low-frequency amplifying vacuum tube, the aim being to supplement the regulation of amplification which is obtained in the high-frequency portion of the receiver.

The simplest forms of automatic amplification control systems decrease the amplification as soon as any output signal is present, the degree of reduction increasing as the output signal increases in amplitude. These arrangements prevent the full utilization of the high-frequency amplifica-

tion of the receiver, since the amplification is reduced by any signal at the output. Furthermore, the reduction in amplification does not keep pace with the increasing input signal voltage, with the result that the output level increases appreciably as the input signal increases in strength.

The first of these objections may be overcome to a considerable extent by so delaying the operation of the automatic amplification control that there is no reduction in the amplification until the output signal exceeds a predetermined level. The delay effect may be obtained in the rectifier circuit, or an additional biasing voltage which opposes the rectifier output voltage may be introduced by suitable means. In either case, delaying the action of the automatic control permits the full sensitivity of the receiver to be utilized.

The problem of decreasing the amplification at a sufficiently high rate to keep pace with an increasing input signal is especially acute in the case of small receivers having only a limited number of high-frequency amplifying vacuum tubes to which the control voltage may be applied. The number of stages which may be controlled is further limited by the fact that a vacuum tube which drives a diode rectifier should preferably be operated at a fixed bias voltage. With only a limited number of vacuum tubes to be controlled, therefore, the only alternative is to amplify the output voltage from the rectifier before applying it to the control electrodes of one or more high-frequency amplifying vacuum tubes.

Amplification of the control voltage has, prior to the present invention, required either an additional vacuum tube or a substantial sacrifice in the effective plate potential available for the controlled amplifying vacuum tubes, or both. The arrangements of the present invention, however, provide for the amplification of the control voltage without the necessity for an additional vacuum tube and without an appreciable sacrifice in effective plate potential on the controlled amplifying vacuum tubes. The advantage of such an arrangement is obvious in any receiver, and this is especially the case in receivers intended for mobile service, where extreme compactness, wide-range automatic amplification control and economical operation are essential features of a satisfactory receiver. Furthermore, the arrangement of the present invention includes provision for obtaining a desirable delayed operation of the automatic amplification control, permitting the full sensitivity of the receiver to be efficiently utilized.

The performance characteristics of various forms of automatic amplification control systems are shown graphically in Fig. 1. Curve A represents the ideal form, the output rising rapidly to the normal level and thence remaining constant at this level. This characteristic is not attained in any simple arrangement. Curve B shows the performance of a simple control system in which a portion of the output signal is rectified and used to control the amplification of one or more preceding amplifying tubes. A very large input is required to produce normal output, and normal output is reached very gradually as the input increases. Curve C represents the performance of a system similar to that of curve B, except that a delay effect has been introduced to prevent the automatic control from operating until the output almost reaches its normal level. From this

point on, however, the output increases appreciably as the input increases. Curve D is the characteristic of a system according to the present invention, in which provision is made for both delaying and amplifying the control voltage which is applied to the amplifying vacuum tubes. In this case, the output soon reaches its normal level, and is closely maintained at this level as the input increases many times. This curve closely approaches the ideal curve, indicating that the performance of the system of the present invention is very satisfactory.

Although the arrangements of the present invention may be applied to various types of amplifying systems, the embodiment shown in Fig. 2 as an illustrative example consists of a three-stage high-frequency amplifier followed by a diode rectifier. This type of amplifier is commonly employed in radio receivers. The diode rectifier may be used simultaneously as the control rectifier and as the signal detector or demodulator, or a separate rectifier may be employed as the demodulator. Both forms are within the scope of the present invention.

Referring to Fig. 2, high-frequency amplifying vacuum tubes 1, 2 and 3, respectively, are coupled in cascade by means of transformers 4, 5 and 6. Each transformer secondary is tuned to the signal frequency by variation of a capacitor 7, or by variation of the effective inductance of the secondary itself. By-pass capacitors 8 furnish a low-impedance path for all high-frequency currents. Amplifying vacuum tube 3 has in its plate circuit, inductor 9 and resistor 10, and its plate 30 is coupled to the anode 11 of rectifier vacuum tube 12 by blocking capacitor 13. Diode load resistor 14 is connected between anode 11 and the junction of resistors 23 and 24. The direct-current grid returns of amplifying vacuum tubes 1 and 2 are connected through blocking resistors 16 and 17 and through filter resistor 18 to diode anode 11. High-frequency currents from the diode circuit are prevented from reaching the grids of vacuum tubes 1 and 2 by by-pass capacitor 19.

The cathode 25 of vacuum tube 1 is connected to the cathode 27 of vacuum tube 3. The cathode 28 of vacuum tube 2 is connected to the junction of voltage-divider resistors 21 and 22. The cathode 27 of vacuum tube 3 is connected to ground through resistors 23 and 24. The direct-current grid return of vacuum tube 3 is connected to the junction of resistors 17 and 18. The input signal to the amplifier is applied to primary 26 of coupling transformer 4.

Vacuum tube 12 is a duplex diode, and includes a second diode anode 33 which in connection with cathode 15 is employed as the demodulator, the audio-frequency voltage being developed across resistor 34, connected between diode anode 33 and cathode 15. The amplified signal is fed to diode anode 33 through blocking capacitor 32.

When no input signal is present, an initial bias voltage for vacuum tubes 1, 2 and 3 is developed across resistor 23. The values of resistors 21 and 22 are so chosen that the cathode 28 of vacuum tube 2 has the same potential relative to ground as the cathode 25 of vacuum tube 1. In the absence of a signal, there is no appreciable voltage across resistor 14.

When a signal is applied to primary 26 and amplified by vacuum tubes 1, 2 and 3, and it exceeds the negative delay voltage on the diode anode 11 due to the voltage drop across resistor

23, it will be rectified by vacuum tube 12. As soon as rectification takes place, a direct-current voltage appears across resistor 14. This voltage adds to the initial bias on vacuum tubes 1, 2 and 3, thereby tending to reduce their mutual conductance and hence their amplification. A decrease in voltage drop across resistor 23 occurs when the plate currents of vacuum tubes 1 and 3 decrease due to the increasing negative grid bias which is being applied to these vacuum tubes. This change in the voltage drop across resistor 23 decreases the initial bias voltage which is applied to the grids of vacuum tubes 1, 2 and 3, but simultaneously the delay voltage on diode anode 11 is decreased and permits the development of a larger control voltage across resistor 14. The net result, if this were the only means for automatically regulating the amplification of the system, would be a performance characteristic substantially like that represented by curve C of Fig. 1.

As the voltage across resistor 24 decreases, however, the left-hand terminal of resistor 14 becomes less positive with respect to ground. Since the cathode 28 of vacuum tube 2 is at a substantially fixed positive potential relative to ground, the effective negative bias on grid 31 of vacuum tube 2 increases. This increase is in addition to the bias voltage developed across diode load resistor 14. These two arrangements combine to produce a very desirable self-increase in the overall degree of amplification control, so that the performance of the system is similar to that represented by curve D of Fig. 1.

The operation of the system will be better understood by noting that, in effect, vacuum tube 1 acts as a direct-current amplifier. Resistors 23 and 24 are in the direct-current plate circuit of vacuum tubes 1 and 3, and any change in the direct-current voltage on grids 29 changes the plate current of the tubes, and produces a magnified change in the voltage across resistors 23 and 24. The amplified voltage change is utilized in two distinct ways to produce a greater degree of amplification control, with the result that the range of input signal amplitudes which may be handled by the receiver without overloading the output tube is substantially increased. This feature is especially desirable in receivers for mobile service, where great variation in the field strengths of the signals is commonly encountered.

It will be understood that vacuum tube 12 may be replaced by any other suitable type of rectifier, as for example a copper-oxide rectifier. In a preferred embodiment, inductor 9 is resonant at a frequency approximately midway between the extreme frequencies to which the system may be tuned, and its resonance characteristic is broadened by means of resistor 10. It will be understood, however, that any other suitable means may be employed for coupling amplifying vacuum tube 3 to rectifier 12. The arrangements of the present invention may be applied to amplifiers having more or less than three stages without departing from the scope thereof, the increased control voltage being applied to one or more amplifying vacuum tubes, some or all of which may be the intermediate-frequency amplifiers in a superheterodyne type of receiving apparatus; and the increased control voltage may also be applied to tubes which are subsequent to the demodulator, within the scope of this invention.

In an embodiment of the present invention

according to Fig. 2, the following components and constants will be found satisfactory. It will be understood, however, that any of these values may be altered, and they are not to be taken as in any way limiting the scope of the present invention.

Reference numeral	Type or value
1	Type 78
2	Type 78
3	Type 6B7 (pentode portion)
12	Type 6B7 (diode portion)
8	0.1 microfarad
9	0.4 millihenry
10	5000 ohms
13 & 32	200 micromicrofarads
14	1.0 megohm
16	0.1 megohm
17	0.1 megohm
18 & 34	1.0 megohm
19	0.01 microfarad
21	750 ohms
22	25,000 ohms
23	750 ohms
24	750 ohms

Vacuum tubes 3 and 12 are shown above as being combined in a single type 6B7 vacuum tube, which contains a diode portion and a pentode portion with a common cathode, since the cathodes of these vacuum tubes are connected together in a preferred embodiment. Separate vacuum tubes may be used if desired, or any other suitable types may be substituted. Furthermore, any of the other vacuum tubes may be of the multi-function type, the portions not used in the arrangements shown in Fig. 2 being used for any other desired purpose, as for example as a first stage of low-frequency amplification.

Having thus described our invention, what we claim is:

1. In a radio receiver, a multi-stage amplifier including plural amplifying vacuum tubes, a first means for automatic control of the amplification of a first and a second of said vacuum tubes, and a second means for controlling the amplification of said second vacuum tube, said second means including plural resistors in the cathode circuit of said first vacuum tube whereby said first vacuum tube acts additionally as a direct-current amplifier to increase the degree of control exerted upon said second vacuum tube by said first control means.

2. In a multi-stage vacuum-tube amplifier, means for automatic amplification control including a diode rectifier coupled to the output of said amplifier and having a direct-current connection from its negative output terminal to a control electrode of at least a first and a second vacuum tube of said amplifier, means for successively delaying and increasing the effect of said automatic amplification control including a connection between the cathode of said first vacuum tube and the cathode of a third vacuum tube; a connection between the cathode of said diode rectifier and the cathode of said third vacuum tube; a connection including a first and a second resistor between the cathode of said third vacuum tube and ground; a connection between the junction of said first and second resistors and the positive terminal of a third resistor in the output circuit of said diode rectifier; and means for maintaining the cathode of said second vacuum tube at substantially the same potential relative to ground as that of the cathode of said first vacuum tube when no input voltage is applied to said amplifier.

3. In a radio receiver including a multi-stage high-frequency vacuum-tube amplifier and a diode detector-rectifier, means for automatically regulating the amplification of said amplifier in accordance with changes in the direct-current output of said diode detector-rectifier, said means including a direct-current connection between the anode of said diode detector-rectifier and a control electrode of at least a first and a second vacuum tube of said amplifier; a connection between the cathode of said first vacuum tube and the cathode of a third vacuum tube; a connection including a first and a second resistor between the cathode of said third vacuum tube and ground; a connection between the junction of said first and second resistors and the positive terminal of a third resistor in the output circuit of said diode detector-rectifier; a connection between the cathode of said third vacuum tube and the cathode of said diode detector-rectifier; and means for maintaining the cathode of said second vacuum tube at substantially the same potential relative to ground as that of the cathode of said first vacuum tube when no input is applied to said radio receiver.

4. In a radio receiver, a multi-stage high-frequency vacuum-tube amplifier, the last vacuum tube of which has its cathode in common with the cathode of a diode rectifier coupled to the output of said amplifier, and means for automatically regulating the amplification of said amplifier in accordance with changes in the direct-current output of said diode rectifier, said means including a direct-current connection between the anode of said diode rectifier and a control electrode of at least a first and a second vacuum tube of said amplifier; a connection between the cathode of said first vacuum tube and the cathode of said last vacuum tube; a connection including a first and a second resistor between the cathode of said last vacuum tube and ground; a connection between the junction of said first and second resistors and the positive terminal of a third resistor in the output circuit of said diode rectifier; and means for maintaining the cathode of said second vacuum tube at substantially the same potential relative to ground as that of the cathode of said first vacuum tube when no input voltage is applied to said radio receiver.

5. In a radio receiver, means for successively delaying and increasing the range of the amplification control of a diode rectifier coupled to the

output of a multi-stage high-frequency vacuum-tube amplifier and having a direct-current connection from its anode to a control electrode of at least a first and a second vacuum tube of said amplifier, said means including a connection between the cathode of said first vacuum tube and the cathode of a third vacuum tube; a connection including a first and a second resistor between the cathode of said third vacuum tube and ground; a connection between the junction of said first and second resistors and the positive terminal of a third resistor in the output circuit of said diode rectifier; a connection between the cathode of said third vacuum tube and the cathode of said diode rectifier; and means for maintaining the cathode of said second vacuum tube at substantially the same potential relative to ground as that of the cathode of said first vacuum tube when no input voltage is applied to said radio receiver.

6. In a radio receiver, plural high-frequency amplifying tubes and a detector, means including a diode rectifier for automatic control of the amplification of at least some of said vacuum tubes, and means whereby one of said controlled tubes acts additionally as a direct-current amplifier to increase the degree of control exerted upon at least one other of said vacuum tubes by said automatic control means.

7. In a radio receiver, plural high-frequency amplifying tubes and a detector-rectifier, means for automatic control of the amplification of at least some of said vacuum tubes, and means whereby one of said controlled tubes acts additionally as a direct-current amplifier to increase the degree of control exerted upon at least one other of said vacuum tubes by said automatic control means.

8. In a multi-stage amplifier, plural amplifying vacuum tubes, means for automatic control of the amplification of at least some of said vacuum tubes including a rectifier coupled to the output of said amplifier, and means whereby one of said controlled tubes, in the presence of an input signal to said amplifier exceeding a pre-determined minimum value, acts additionally as a direct-current amplifier to increase the degree of control exerted upon at least one other of said vacuum tubes by said automatic control means.

ALFRED CROSSLEY.
HERBERT E. MEINEMA.