April 21, 1936. I. WOLFF 2,037,842

AMPLIFYING SYSTEM

Original Filed April 25, 1931

Fig.1.

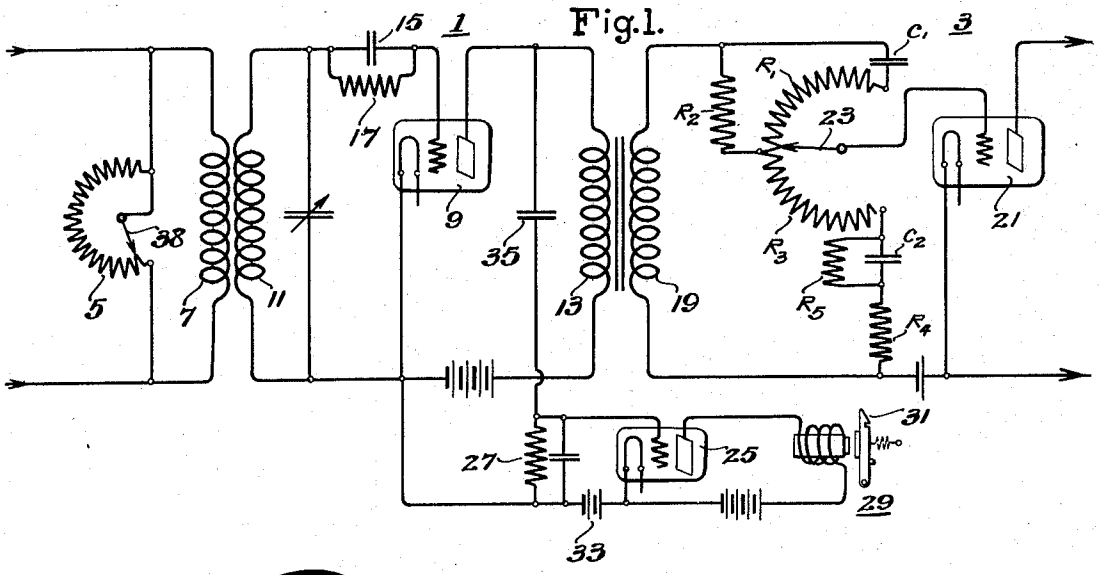


Fig.2.

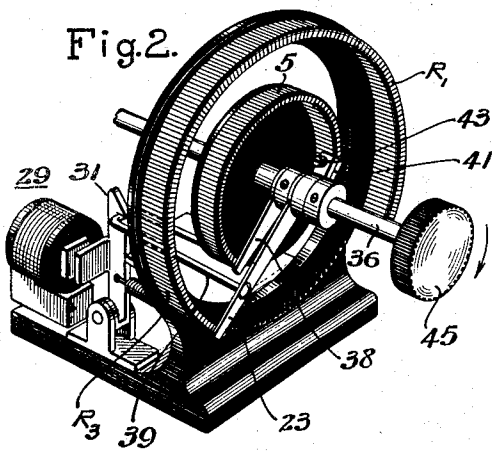


Fig.3.

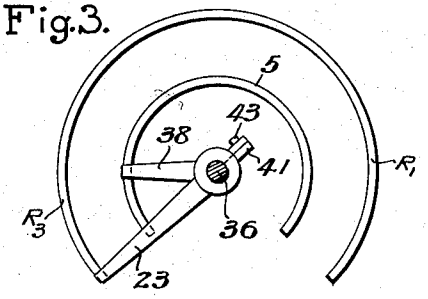


Fig.4.

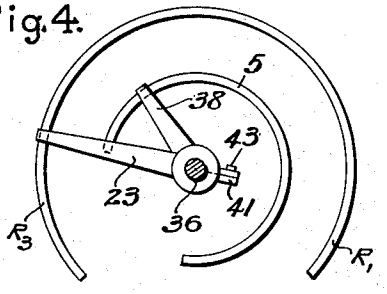
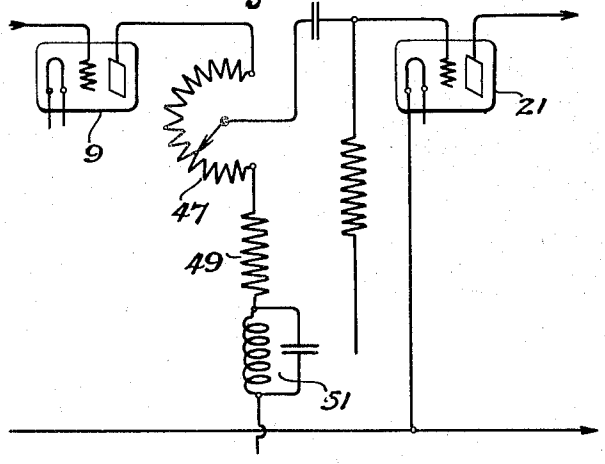


Fig.5.



INVENTOR.
Irving Wolff.
BY J. R. Goldsborough
HIS ATTORNEY.

Patented Apr. 21, 1936 2,037,842

UNITED STATES PATENT OFFICE

2,037,842

AMPLIFYING SYSTEM

Irving Wolff, Merchantville, N. J., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application April 25, 1931, Serial No. 532,778
Renewed May 23, 1933

14 Claims. (Cl. 179—1)

My invention relates to amplifying systems and, more particularly, to systems designed for the amplification of currents at radio and audio frequencies.

It has been observed that although a loudspeaker associated with radio receiving apparatus or the like may sound quite natural, when the acoustic intensity is medium, speech becomes "tubby" when the intensity is greatly increased and "thin" when the intensity is decidedly reduced. Even when the most perfect amplifiers, as heretofore constructed, are operated well below the overload point, there is an apparent change in the fidelity of sound reproduction with change in sound-output intensity, the phenomenon not being a result of the characteristics of the amplifier but being occasioned by the frequency-pressure-sensitivity characteristics of the human ear.

In other words, the ear is relatively less sensitive to low frequencies at low intensity than it is when the volume is raised and, at low intensity, a much smaller increase in sound-pressure is required for low than for high frequencies to give the same increase in apparent loudness. Furthermore, at low intensity, if the high and low frequencies are to give equal apparent loudness the sound-pressure occasioned by the low frequencies must be many times that from the high frequencies. At very high intensities, however, the same sound-pressure causes substantially the same loudness at all frequencies within the acoustic range.

Having the above facts in mind, it is clear what happens when the usual volume-control of a radio receiver, a phonograph amplifier or the like is advanced past the normal position. Sound pressures set up by the loudspeaker at all frequencies are increased in the same proportion but the same proportionate increase in sound pressure means a much greater apparent increase in loudness at the lower frequencies and, therefore, the reproduction assumes the "tubby" sound mentioned above and the converse is true when the intensity is below normal.

It is, accordingly, an object of my invention to provide an amplifying system that, when it is utilized to energize a sound reproducer, shall give rise to "natural" sound impressions on the ear irrespective of changes in the volume-level introduced by a volume-control device.

Another object of my invention is to provide a volume-control for an amplifying system that shall function to maintain such correspondence between volume-level and frequency characteristics of the sound output therefrom that a change in volume is unaccompanied by an apparent change in fidelity of reproduction.

There is another psychological phenomenon which relates to the present invention and which enables us to hear low notes which are entirely missing from the sound reproduction. This phenomenon results from the fact that the human ear is unable to detect any change in pitch of a note if the fundamental and lower harmonics are removed. In fact, the pitch is recognizable if but three consecutive higher harmonics remain and, if proper control of the harmonic frequencies of the lower notes is had, the naturalness of the loudspeaker response may be preserved through volume changes, even though the fundamentals are missing.

It is, therefore, an ancillary object of my invention to provide an amplifying system that shall be of value in improving the apparent low frequency response, at low intensities, of loudspeakers.

According to my invention, one of the thermionic devices included in an audio frequency amplifier is provided with an input circuit constituted by a resistance-reactance network and with means whereby audio frequency potentials may be impressed, at substantially constant amplitude, across the input terminals thereof from a preceding stage such as the detector in a radio receiver. I also provide means whereby one of the resistors in the network may be utilized as a potential dividing device to control the amplitude of the potentials impressed upon the amplifying tube and so arrange and dispose the several reactors that the rate of control of the potentials at frequencies in one range exceeds the rate of control of the said potentials at frequencies in a different range. In short, the network referred to is such that when the amplitude of the potentials impressed upon the amplifying tube is increased, corresponding to an advance of the volume-control, the potentials at low frequencies are preferentially attenuated in order that the ultimate sound output shall not be "tubby".

I also may include reactance elements of other types such as tuned circuits in the network in order that the amplifier shall have a peaked response at frequencies corresponding to the harmonics to which I referred previously.

In addition, when applying my invention to radio receiving apparatus, I find it preferable to provide means for raising the average audio frequency output from the detector tube, automati-

cally, to a predetermined standard value before setting the acoustically compensated volume-control device into operation. This provides a definite minimum low intensity sound output from the apparatus that is independent of the intensity of the received signal. Further increase in sound-intensity is secured by means of the volume-control device which is so compensated as to keep the apparent fidelity of reproduction constant at all sound intensities.

A still further and more specific object of my invention, therefore, is to provide a control-device particularly adapted for use in amplifying systems of the aforementioned type.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment, when read in connection with the accompanying drawing, in which

Fig. 1 is a diagrammatic view of a portion of a radio receiving system constructed according to my invention,

Fig. 2 is a perspective view of a control-device of preferred type,

Figs. 3 and 4 are diagrammatic end views of the control-device, indicating the successive positions it assumes in operation, and

Fig. 5 is a diagrammatic view of a circuit modified according to one phase of my invention to provide peaked amplifier response at low audio frequencies.

Referring to Fig. 1 of the drawing, an amplifying system constructed according to my invention preferably includes one or more stages (not shown) for amplifying an incoming signal at radio frequency, a detector stage 1 and at least one audio frequency amplifying stage 3.

The radio frequency amplifier is provided with automatic or manually actuated volume-control devices exemplified, in the drawing, by a variable resistor 5 connected in shunt relation to an inductor 7 included in the output circuit of the amplifier. Further reference to the variable resistor will be made in describing the operation of my improved system.

A thermionic tube 9, included in the detector stage, is provided with an input inductor 11, coupled to the output inductor 7 of the radio-frequency amplifier and with an output circuit including the primary winding 13 of an audio frequency transformer. Detection may be secured by interposing a grid condenser 15, shunted by a grid leak 17, in the input circuit, as shown, or the tube may be biased to substantially the cut-off point, to give plate-rectification, instead.

The terminals of the secondary winding 19 of the audio-frequency transformer are connected to a resistance-reactance network from which variable potentials may be impressed between the grid and filament of a thermionic tube 21 which functions as an audio-frequency amplifier. Additional stages of audio frequency amplification, of any desired type, may be added if necessary.

As previously pointed out, the network interposed between the detector and the first audio frequency amplifier, according to my invention, has two primary functions, namely, control of volume of sound-output and compensation of the said output in accordance with the frequency-pressure sensitivity characteristics of the ear. The desired result is substantially attained if the network includes means for simultaneously increasing, through the actuation of a volume-control device, the average audio potentials applied to the amplifier tube 21 and causing the potentials at high audio frequencies to increase at a rate exceeding the rate at which potentials at low audio frequency are increased.

The volume-control device per se is constituted by a potentiometer, the movable contact arm 23 of which is connected to the grid of the amplifying tube 21 and the terminals of the series connected resistance elements R_1 and R_2 of which are, respectively, connected to the cathode of the tube and a terminal of the secondary winding 19 through one or more fixed resistors R_4, R_5, and to the opposite terminal of the secondary winding through a condenser C_1. An intermediate point between the resistance elements is connected also to the last mentioned secondary winding terminal through a fixed resistor R_3. The fixed resistor R_5 between the resistance element R_3 and the cathode of the tube 21, is provided with a shunting condenser C_2.

For best results the volume-control impedance, at any setting, should be smaller than the input impedance of the amplifier tube whereby it functions substantially the same as an unmodified potentiometer of usual type. The impedance of the resistor R_5 should be large as compared to that of the condenser C_2.

In general, the relations among the several circuit elements, in a preferred commercial embodiment of my invention may be expressed by the following formulæ:

1. $R_4=\frac{1}{300}(R_3+R_2)$

2. $R_3=\frac{1}{2}R_2$

3. $R_1=3R_2$

4. $C_2=\frac{1}{(2\pi)(360)R_4}$

5. Impedance of C_2 @ 360 cycles = impedance of R_4

6. $C_1=\frac{1}{(2\pi)(180)(R_1)}$

7. Impedance of C_1 @ 180 cycles = impedance of R_1

From a consideration of the foregoing formulæ, and of the drawing, it will be clear that a movement of the potentiometer arm away from the mid-position thereof, corresponding to normally loud sound, for volume-control, is accompanied by a change in the ratio of high to low frequency potentials appearing between the grid and cathode of the amplifier tube.

That is to say when the ultimate current output volume is increased by moving the arm 23 toward the upper end of the resistance element R_1, the effect of the condenser C_1, is increased with the result that the potentials at high frequencies impressed on the amplifying tube 21 become relatively greater than potentials at low frequencies, thus counteracting the tendency for the sound-output to become "tubby" as hereinbefore mentioned. This action may be seen by considering the potential drop between the contact arm and the point of connection of R_2 to R_1. Since R_2 has approximately ⅓ of the resistance of R_1, the potential of the point of connection is not affected materially by the increased impedance of C_1 at the lower frequencies. If, however, the

contact arm is near the juncture of R_1 and C_1 it will be evident that at high frequencies C_1 has low impedance, thus allowing the full potential available from the secondary of the transformer to be impressed on the grid of the tube, while at low frequencies, C_1 has a material impedance compared to the resistance of R_1 and that, therefore, the potential on the grid of the tube is decreased due to the drop in potential over the condenser C_1.

Conversely, when the contact arm is moved toward the lower end of the resistance element R_3 the condenser C_1 becomes of less effectiveness as a coupling element for high frequencies while the condenser C_2, the reactance of which, at high frequencies, is low, by-passes the high frequencies to a certain extent. At lower than normal sound intensities, therefore, the high frequencies are attenuated in favor of the low frequencies and the objectionable "thinness" of the reproduced sound is eliminated.

In order that the sound output from the system shall be definitely related to the setting of the volume-control device irrespective of the differences in carrier amplitude which exist among transmitting stations, I have found it desirable to provide means whereby the average potentials appearing across the secondary winding of the audio frequency transformer may be adjusted to a constant pre-determined volume.

For this purpose I prefer to provide either automatic or manually adjustable volume-control means in the radio frequency amplifier and automatic limiting means associated with either the input or the output circuit of the detector tube.

In the modification of my invention chosen for purposes of illustration, the volume-control means in the radio frequency amplifier is constituted by the variable resistor **5** connected in shunt relation to the output circuit of the said amplifier. The limiting means associated with the detector comprises a thermionic tube **25** having an input circuit constituted by a resistor **27** and an output circuit including the winding of a relay **29**. The armature of the relay is constructed in the form of a detent device **31** for a purpose which, hereinafter, will be explained in more detail. A biasing battery **33** is included in the input circuit of the limiter tube, the potentials thereof being such as to bias the tube to substantially the cut-off point.

The input resistor **27** is connected in shunt relation to the primary winding **13** of the audio frequency transformer, in series with a by-pass condenser **35**.

Referring now to Fig. 2 of the drawing, the volume-control resistor **5** in the radio frequency amplifier and the resistance elements R_1, R_3, included in the network between the detector tube and the amplifier tube, are disposed concentrically with respect to an actuating shaft **36**. The resistor **5** is loosely journaled upon the shaft **36** while the resistance elements R_1 and R_3 are rigidly mounted on a supporting base **37**.

The shaft carries a contact arm **38** which engages the resistor **5**, as shown in Fig. 1, and also the contact arm **23**. The contact arm **38** is rigidly attached to the actuating shaft, while the contact arm **23** is rigidly attached to the resistance element **5** through any convenient means such as a U-shape bridging member **39** and is frictionally engaged with the shaft. The frictional engagement of the arm **23** with the shaft may be provided by a split collar **41** having an adjusting screw **43**. The detent device **31** is so disposed with respect to the bridging member as to maintain the contact arm **23** at the low potential end of the resistance element R_3 in the absence of energizing current in the relay winding.

In the operation of the volume-control device, the shaft, through manipulation of a knob **45** affixed thereto, is first turned completely to the left, as shown in Figs. 1 and 2. The detector tube is, accordingly, deprived of input potentials and no radio frequency potentials appear across the input resistor **27** of the limiter tube **25**. In this position the bridging member **39** engages and is held by the detent device **31**.

Upon slowly turning the knob to the right, as indicated by the arrow, the arm **38**, engaging the resistor **5** in the radio frequency amplifier, moves with respect to the said resistor, thus causing an increase in the input potential applied to the detector tube **9**. Since the output, at radio frequency, from the detector tube, is impressed across the input resistor **27** of the limiter tube **25**, the plate current of the latter tube, flowing in the winding of the relay **29**, is representative of the amplitude of the audio signal delivered to the secondary winding **19** of the audio frequency transformer.

By proper adjustment of the various circuit constants, therefore, the relay **29** may be caused to retract the detent **31** at the instant when the output from the detector is just sufficient to give minimum response from the loudspeaker (not shown). One possible setting of the control device at the moment the relay operates is indicated in Fig. 3 of the drawing.

As soon as the detent device is retracted, the contact arm **23** is free to turn with respect to the resistance elements R_3, R_1 to increase the audio output to the desired point. Inasmuch, however, as rotary motion is transmitted to the resistor **5** in the radio frequency amplifier through the bridging member **39**, the said resistor and the contact arm associated therewith move as a unit during the continued adjustment of the volume-control device, as indicated in Fig. 4, in order that the input to the detector tube shall remain substantially constant during the reception of signals from any given station.

In the event that it is desired to receive signals from some other transmitting station, the control device is reset to zero position and the sequence of operation just described is again followed.

Under certain circumstances it may be desirable to so modify the amplifier that it shall have a peaked response at frequencies in the neighborhood of 200 cycles per second in order that the apparent response of the sound producing device shall be greater at frequencies below 200 cycles. This result may be accomplished, as shown in Fig. 5 of the drawing, by connecting the resistance element of a volume-control potentiometer **47** in series with a resistor **49** and a circuit **51** tuned to the frequency at which peaked response is desired. At high volume-settings of the potentiometer, the effect of the tuned circuit is negligible, while at low volume-settings its reactance becomes appreciable.

It will be apparent from the foregoing description of my improved amplifying system that, by its use I am enabled to greatly improve the realism of sound reproduced through a radio receiving set. My system is also advantageous in that the sound output therefrom is always proportional to the setting of the volume-control de-

vice irrespective of the strength of the incoming radio signals.

Although I have illustrated and described certain proferred embodiments of my invention, numerous modifications thereof will be apparent to those skilled in the art to which it pertains. My invention, therefore, is not to be limited except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In an amplifying system, a thermionic tube having an input circuit including a potential dividing device, means for impressing audio frequency potentials upon said device, means for utilizing said device for controlling the potentials impressed across the input terminals of the thermionic tube, means directly connected in circuit electrically with said device for simultaneously attenuating potentials at frequencies lying in a predetermined range, and means responsive to signal potentials above a predetermined amplitude for controlling an operation of said device.

2. In an amplifying system, a thermionic tube having an input circuit including a potential dividing device, means for impressing audio frequency potentials upon said device, means for utilizing said device for controlling the potentials impressed across the input terminals of the thermionic tube, means directly connected in circuit electrically with said device for simultaneously attenuating potentials at frequencies lying in a predetermined range, and means for maintaining substantially constant the average audio frequency potentials impressed upon the potential dividing device.

3. In an amplifying system, a radio frequency amplifier, an audio frequency amplifier, volume-control means associated with said radio frequency amplifier, a second volume control means associated with said audio frequency amplifier, common means for operating said volume control means independently of each other, high audio frequency attenuating means connected with said audio frequency volume control means whereby it operates simultaneously as a tone control means and volume control means, and means operative in response to signal amplitudes above a predetermined value for selectively controlling the operation of said volume control means.

4. In a signal amplifying system, a thermionic tube having an input circuit including a potential dividing device, means for impressing audio frequency potentials upon said device, means for utilizing said device for controlling the potentials impressed across the input terminals of the thermionic tube, means for simultaneously attenuating potentials at frequencies lying in a predetermined range, and means for sequentially controlling (1) the amplitude of the audio frequency potentials impressed upon the potential dividing device and (2) the potentials impressed across the input terminals of the thermionic tube.

5. In an electrical amplifying system including a detector, the combination of volume control means connected in circuit preceding and succeeding said detector, said means being associated with circuits other than the detector circuit, means associated with the volume control means in circuit, succeeding the detector for attenuating the high frequency end of the audio frequency range at low volume and for attenuating the low frequency end of the audio frequency range at high volume, means for operating said volume control means in sequential relation to each other, and means responsive to signals of an amplitude exceeding a predetermined value for controlling the transition from the one volume control means to the other in said sequential operation.

6. A volume control means for a signal amplifying system including, in combination, two variable potentiometer type resistors each having a resistor element and a contact relatively movable therewith, means providing a fixed support for one of the elements of one of said variable resistors, the other element of said variable resistor and an element of the second variable resistor being mechanically connected and movable together, means for releasably holding said mechanically connected elements in a fixed position, means responsive to signals of an amplitude exceeding a predetermined value for operating said releasable holding means, whereby said elements are movable, means for moving the remaining element of said second variable resistor, and means providing a frictional connection between said last named element and said mechanically connected elements.

7. In a signal transmission circuit including a plurality of cascade connected thermionic devices, the combination of a volume control device in circuit preceding one of said thermionic devices and a second volume control device in circuit succeeding said thermionic device, a tone control compensating circuit connected with said second named volume control device, and common means for sequentially operating said volume control devices.

8. In a signal amplifying system, a vacuum tube amplifier device having an input circuit including a tapped potential dividing device, automatic volume control means for impressing audio frequency potentials upon said device at predetermined amplitudes, means connected with a separate tap point and one terminal of said potential dividing device for attenuating potentials at audio frequencies lying in a predetermined audio frequency range, and a tap connection movable along said potential dividing device within and without the section shunted by said last named means for controlling audio frequency potentials impressed across the input terminals of the thermionic tube simultaneously in amplitude and frequency characteristic.

9. In a signal amplifying system, a vacuum tube amplifier device having an input circuit including a potential dividing device, automatic volume control means for impressing audio frequency potentials upon said device at predetermined amplitudes, means connected in shunt with a fixed portion of said potential dividing device, and means connected with a variable portion of said potential dividing device for simultaneously attenuating potentials at audio frequencies lying in a predetermined audio frequency range and controlling audio frequency potentials impressed across the input terminals of the thermionic tube.

10. In an audio frequency volume control system, a tapped volume control potentiometer device comprising a resistor element having at least two resistor sections, means providing a fixed tap connection between said sections, an electrical circuit impedance means connected in shunt with one of said sections through said tap connection, circuit means connected with said resistor element for supplying thereto signal potentials of substantially constant average amplitude, and an output circuit variably connected with said resistor element.

11. In an audio frequency volume control system, a tapped volume control potentiometer device comprising a resistor element having at least two resistor sections, means providing a fixed tap connection between said sections, an electrical circuit impedance means connected in shunt with one of said sections through said tap connection, means connected with said resistor element for applying signals of substantially constant average amplitude thereto, and an output circuit variably connected with said resistor element.

12. In a radio receiving system, automatic volume control means for providing substantially constant average signal amplitude, an audio frequency signal transmission circuit for receiving signals controlled by said automatic volume control means, an audio frequency volume control means including a tapped resistor in shunt with said circuit, an output circuit having a variable tap connection with the resistor substantially throughout its length for volume control, an impedance network connected in shunt with a portion of said resistor including one end thereof, said network and said portion of said resistor having a predetermined impedance ratio whereby tone compensation is provided simultaneously with volume control, the compensation increasing as the volume control tap connection is moved to a position to reduce the volume.

13. In a radio receiving system having an audio frequency signal transmission circuit, the combination of means for supplying to said circuit audio frequency signals of substantially constant average amplitude, a variable audio frequency volume control means having an impedance element connected in shunt with said circuit, means providing a shunt impedance network in connection with a fixed portion of the impedance element of said volume control means, and an output circuit variably connected with said first named circuit through said volume control means.

14. In a radio receiving system including an audio frequency signal transmission circuit, the combination of means for supplying to said circuit audio frequency signals of substantially constant average amplitude, a variable audio frequency volume control means having an impedance element connected in shunt with said circuit, means providing a signal attenuating shunt impedance network in connection with a fixed portion of the impedance element of said volume control means including a terminal end, and an output circuit variably connected with said first named circuit through said volume control means, said last named variable connection being movable along said fixed portion of the impedance element whereby said network is adapted to be variably connected in shunt with said output circuit through said volume control means.

IRVING WOLFF.