

April 16, 1935.

R. A. BIERWIRTH

1,997,762

TONE CONTROL SYSTEM

Filed Aug. 30, 1932

Fig. 1.

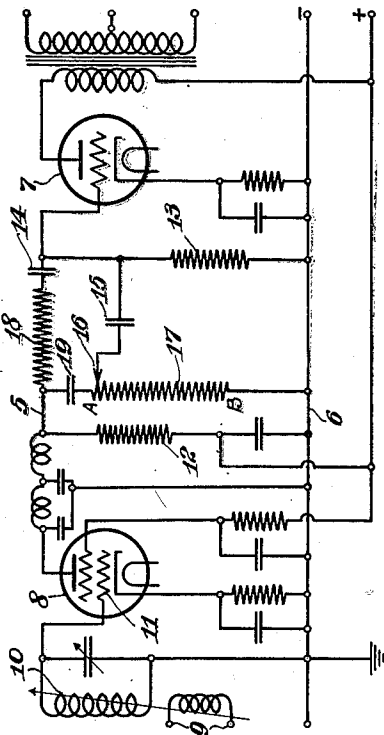


Fig. 2.

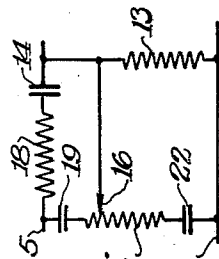


Fig. 4.

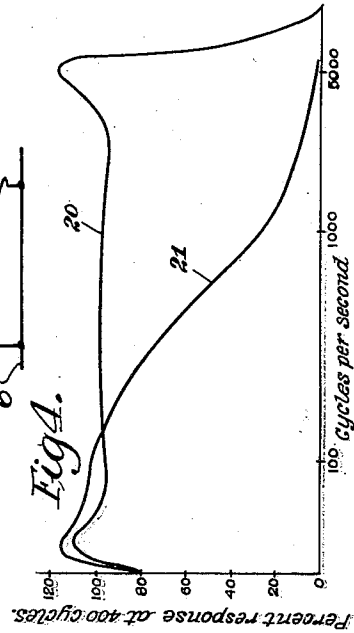
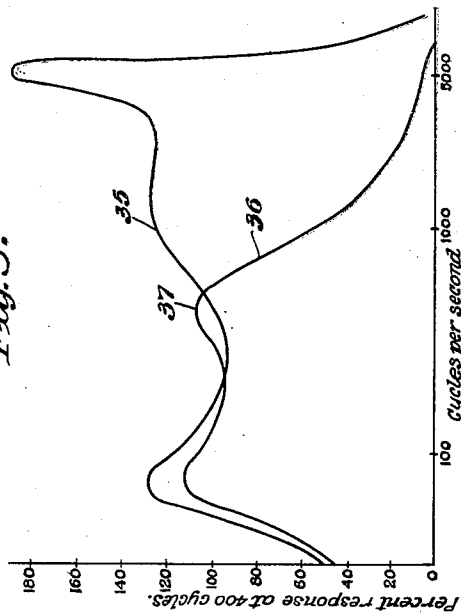


Fig. 5.



INVENTOR:
Rudolph A. Bierwirth,
BY *JR Goldbrough*
HIS ATTORNEY.

UNITED STATES PATENT OFFICE

1,997,762

TONE CONTROL SYSTEM

Rudolph A. Bierwirth, West Collingswood, N. J.,
assignor to Radio Corporation of America, a
corporation of Delaware

Application August 30, 1932, Serial No. 630,991

13 Claims. (Cl. 178—44)

The present invention relates to tone control systems for audio frequency amplifiers and the like, and has for its object to provide an improved tone control system which is adapted to compensate certain portions of the audio frequency range of an amplifier, and which may have also a wide range of tone control.

A further object of the invention is to provide a compensating tone control system having a relatively wide range of control, wherein a single variable means may be employed to adjust the system.

In accordance with the invention, an audio frequency transmission circuit is provided with a series impedance device, which may be any suitable impedance device adapted to attenuate signal potentials in a desired range. A shunt tone control circuit is provided for the transmission circuit and is so combined therewith that frequency compensation is effected by the same control means, in connection with an output impedance of any suitable type.

In providing a practical embodiment of the invention, a series impedance device and a shunt impedance device are arranged in circuit with a third and manually variable impedance device, preferably of the potentiometer resistance type, whereby at one end of the control range of the variable impedance device the series impedance device is by-passed by means providing a low impedance shunt path therefor and at the opposite end of the range the shunt impedance device is connected across the audio frequency circuit.

A tone control system embodying the invention may be arranged for tone control and audio frequency compensation in any suitable audio frequency amplifier circuit, and is particularly adapted for use in connection with impedance and transformer coupled thermionic amplifiers.

As is well known, a tone control system is desirable in a radio receiver circuit and is of practical use when arranged to vary the high frequency response characteristic of the receiver for the purpose of reducing background noises incident to signal reception under unfavorable weather conditions or in locations unfavorable to radio reception.

A tone control system arranged in accordance with the present invention is adapted not only to provide a compensating control in the higher portions of the audio frequency range, but in other portions thereof as well, through a single variable instrumentality, and in addition it may provide a desired compensation for undesirable transmission characteristics of the radio receiver,

of the audio frequency amplifier connected therewith, and in which last named apparatus, preferably, the tone control system is incorporated, or for unfavorable acoustic characteristics of the room or hall wherein the receiver is located.

The invention will, however, be better understood from the following description when taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a schematic wiring diagram of a portion of a radio receiver, including an audio frequency amplifier circuit provided with a tone control system embodying the invention, the audio frequency amplifier being impedance coupled;

Fig. 2 is a portion of the same diagram as shown in Fig. 1, showing a detail modification of the tone control system;

Fig. 3 is a similar wiring diagram showing a modification in which the audio frequency amplifier is transformer coupled; and

Figs. 4 and 5 are curve diagrams illustrating certain operating characteristics of the tone control systems shown in connection with Figs. 1 and 2, respectively.

Referring to Fig. 1 of the drawing, 5 and 6 are circuit leads, indicating generally, an audio frequency transmission channel or circuit, which, in the present example, is included in the cascade connection between an audio frequency amplifier tube 7 and a preceding tube 8. The latter tube is represented as a screen-grid, equi-potential cathode detector which receives modulated signals through input terminals 9 and a tuned coupling transformer 10 connected between said terminals and the control electrode or grid 11 of the detector.

The detector device 8 and the audio frequency amplifier device 7 are connected in cascade relation through the audio frequency amplifier channel 5—6, by an impedance coupling network or circuit means of the resistance-condenser type, including the usual output or plate resistor 12, an input or grid resistor 13 and a coupling capacitor 14. The resistors and condenser represent any suitable impedance coupling elements for the input and output circuits of a cascade connected amplifier. The condenser is of a value, such as .01 mfd. for example, whereby it offers a relatively low impedance to signal potentials or currents within the desired audio frequency range for which the transmission circuit 5—6 is designed, and is intended to have no appreciable effect upon the transmitted signal.

It has been found that, in connection with impedance coupled amplifier circuits of the type above described, particularly in connection with high impedance screen grid tubes, such as the detector or tube 8, the plate capacity of said detector, or first tube, the capacity of the leads in the coupling means between tubes, and the grid or internal capacity of the following tube, such as the tube 7, with such coupling means, as well as that introduced by other connected circuit elements, is sufficient to form an appreciable load at the high frequency end of the audio frequency range, whereby signals in that range are unduly attenuated, with consequent distortion.

It will be appreciated that the high frequency attenuation load cannot be reduced below certain practical limits, and in order to compensate for this, and the tendency to loss of high frequency response in an audio frequency signal transmission circuit, such as that provided in a thermionic audio frequency amplifier, for example, the circuit is, in accordance with the invention, provided with compensating and tone control means wherein the tone control and frequency compensating functions are combined, and the means provided for each function cooperate through single control means to provide an improved operating characteristic in a tone control system.

The system in accordance with the invention may be considered to have a tone control portion including a condenser 15 arranged to be connected gradually in shunt relation to the transmission circuit 5-6, and the input or grid coupling resistor 13, through a variable impedance device such as a potentiometer comprising movable tap 16 in connection with a resistor 17, substantially in series with said condenser across the transmission circuit and the coupling resistor 13.

In the present example, the condenser 15 is connected between the variable tap 16 and the high potential or grid end of the coupling resistor 13 which is also the high potential side of the audio frequency transmission circuit. However, the condenser may be arranged in any suitable connection with the variable resistor 16-17, whereby it is in series with said resistor and arranged to be connected thereby gradually in shunt relation to the transmission circuit, preferably at a point adjacent to the output or grid circuit end in which the coupling or input resistor 13 is included.

With the above described arrangement it will be seen that, as the resistance in series with the condenser 15 is reduced, the shunting effect of the condenser across the audio frequency transmission channel is increased. The condenser is of a capacity value, such for example as .0012 mfd., that its impedance within the high frequency end of the audio frequency range is relatively low, and thereby, when fully in shunt to the audio frequency transmission circuit, it serves to attenuate appreciably, the signal potentials within that end of the audio frequency range.

The effect of the condenser 15 upon the circuit is likewise reduced by movement of the variable tap 16 in the opposite direction along the resistor 17 and the latter is of such value that when fully in circuit with the condenser, the effect of the latter is negligible as a shunt impedance means. Resistor 17 may be of the order of 2 megohms in the circuit network of the present example.

As a tone compensating means in connection with the tone control circuit 15-16-17 there is provided in the audio frequency transmission

channel 5-6 and preferably in the high potential side 5, an impedance means 18 which is not responsive to variations in the frequency of transmitted signals.

The impedance means or device 18 is connected in series with the audio frequency transmission channel and in the present example, between the coupling resistors 13 and 17, whereby it is introduced into the coupling network formed by said resistors and the coupling condenser 14. The impedance device 18 is preferably a resistor, as indicated in the drawing, whereby, as above stated, it has no appreciable frequency response characteristic tending to cause attenuation of any particular portion of the audio frequency range.

In the above described circuit arrangement it will be seen that signal potentials transmitted through the audio frequency channel, or, as in the present example, delivered by the detector tube 8, are divided in their application to the control electrode of the amplifier tube 7 between the series impedance element 18 and the coupling resistor or shunt impedance element 13 in the grid circuit of the amplifier tube 7. This results in an apparent loss of amplification. However, the circuit then operates to compensate for attenuation of signals in the higher audio frequency range through the cooperative relation of said resistors and condensers including a second condenser or similar circuit impedance means 19, arranged to be variably connected in shunt relation to the series impedance element 18 all by the same control means 16-17.

The capacity value of the condenser 19 is so chosen that at the lower end of the audio frequency range, its impedance is high as compared with that of the resistor element 18, and the circuit arrangement is such that, with the variable contact 16 located as shown, at the maximum "high" position of adjustment, A, the condenser 19 is connected effectively in shunt relation to the series impedance element 18 through the condensers 14 and 15, both of which are of such high capacity values relative to the capacity value of condenser 19, that they have no appreciable effect upon the controlling effect of the condenser 19.

With this arrangement it will be seen that only a portion of the low frequency signal potential or detector output voltage will be applied to the output of the network and to the grid of the amplifier tube 7, the ratio of the low frequency voltages available across the resistor element 18 and the coupling resistor 13 being dependent upon the respective values of said resistors. In the present example and as preferred values, the resistor 13 is substantially $\frac{1}{2}$ megohm while the series impedance element 18 is substantially one megohm, and the shunt capacity element 19 is of a value substantially .0001 mfd.

At the high frequency end of the audio frequency range, the impedance of the condenser 19 becomes low enough practically to short circuit the resistor element 18 so that nearly all of the signal potential or the detector output voltage is applied to the coupling resistor 13 and to the grid of the amplifier tube 7. It is, therefore, clear that the ratio of the amplifier or output voltage to the detector or input voltage will increase as the upper end of the audio frequency range is approached. This rising characteristic, combined with the drooping or falling detector output characteristic hereinbefore pointed out, tend to counteract one another, and the result is substantially

a uniform signal output potential supplied to the grid of the output tube.

It is obvious that the values of the resistor element 18, the condenser 19, and the resistor element 13, may be so chosen that the frequency transmission characteristic of the coupling network may have any desired form whereby, for example, the high frequency end of the range may be slightly peaked for emphasizing the high frequency response.

From the foregoing description it will be seen that the two functions of tone control and tone compensation may be combined in the same coupling network and may be controlled by the same instrumentality, as by the manually variable impedance element or potentiometer device 17.

It will further be seen that the coupling network includes an output circuit impedance element or resistor 13 connected in shunt relation to the audio frequency transmission channel, a series circuit impedance element or resistor 18 in the audio frequency transmission channel so connected with the first named impedance element that the low frequency signal potentials transmitted through said channel may divide between them in a predetermined relation, dependent upon the relative resistance values of said elements. The manually variable circuit impedance element 17 is connected also substantially in shunt relation to the audio frequency transmission channel on the input end of the channel or network. It is also so connected with a shunt impedance element 19 for the impedance element 18 and a third shunt impedance element 15 for the transmission channel, that each of said last named elements may selectively and gradually be connected effectively with the network to function in the attenuation of certain portions of the audio frequency range.

At the high frequency or maximum "high" position of adjustment A of the contact 16 as shown in the drawing, the shunt impedance element 19 is connected effectively in shunt with the series impedance element 18, while the shunt impedance element 15 is rendered ineffective as a shunt means across the transmission channel through the introduction of impedance element 17 in series therewith.

At the opposite end B of the control range of the variable impedance element 17 it will be seen that the resistor element 17 is then connected in series with the impedance element 19 thereby to render it substantially ineffective as a shunt for impedance means 18 and that the impedance element 15 is effectively connected in shunt relation to the signal transmission circuit and the signal output impedance 13, whereby the condenser 15 is effective as a tone controlling means across the signal channel.

Referring to Fig. 4, the overall operating characteristic of the combined tone control and tone compensating system shown in Fig. 1 is illustrated for the two above described extreme positions of adjustment, A and B, of the signal control device 17 by the curves 20 and 21, respectively, applied with respect to frequency and percent response of the coupling network at 400 cycles.

It should be understood that intermediate points between positions A and B provide characteristics between those illustrated.

It will be seen from an inspection of the curves 20 and 21 that the normal response is substantially flat throughout the audio frequency range and that the high and low ends thereof are slightly peaked for pleasing tone. This result is

effected by a proper choice of the circuit elements which have hereinbefore been pointed out.

It will further be seen that in accordance with the curve 21, the tone control means serves to attenuate disturbing signals in the high frequency end of the audio frequency range without materially suppressing the mid-frequency range which is desirable for a good speech characteristic.

The flat characteristic curve 20 is the result of compensating for the attenuation of the high frequency end of the audio frequency range by the inherent load on the system, which as has been hereinbefore described, is a function of the compensating series impedance element 18 and the high frequency shunt means 19 therefor, together with the shunt circuit impedance 13.

The circuit shown and described has a further advantage in that, as the variable contact 16 is moved toward the position B the high frequency compensation provided by the condenser 19 in association with the series impedance element 18 is gradually removed, while at the same time the high frequency shunt path provided by the condenser 15 is gradually applied across the transmission circuit so that in the maximum low position at B, the high frequency compensation is wholly removed and only the tone control circuit is effective. This circuit arrangement results in reducing the high frequency response a desired amount when moving the tone control device to the minimum position at B and without affecting the middle range of audio frequency response appreciably.

It will further be seen that with the combined tone control and audio frequency compensation means provided in the signal transmission network illustrated, not only is the single instrumentality such as the potentiometer 17, arranged to control both the compensation and the tone, but it is arranged in such a way that the effects of the tone control and tone compensation in either direction are additive, that is, each contributes in the same and in a co-operative manner to produce the same desired result.

The tone control condenser 15 may be located at 22, Fig. 2 in series with the potentiometer resistor 17, for the reason that it has no cooperative relation with the condenser 19 per se and, since it is of a relatively greater capacity value, it may be connected in series with the condenser 19 anywhere in circuit without affecting the operation of the condenser 19.

Referring now to Fig. 3, a further modification of the tone control circuit is shown, which is adapted for use in a transformer coupled audio circuit, but not necessarily limited thereto, wherein the tone control condenser indicated at 22 in Fig. 1 is utilized in series with a tone control potentiometer.

In Fig. 3 a detector or amplifier device 23 corresponding to the device 8 of Fig. 1 is connected with the audio frequency signal circuit 24—25 to an output transformer 26 having a primary winding 27. Interposed between the primary winding 27 and the tube 23 is a tone control and compensating system including a series impedance device 28 in the form of a choke coil or reactance winding, a tone control potentiometer device 29 connected in shunt relation to the transmission or output circuit 24—25 and in series with a tone control condenser 30 at its low potential end.

The high potential end of the potentiometer is connected with a input end or terminal 31 of the series impedance device 28, while the variable

contact 32 thereof is connected with the output end or terminal 33, all as shown in figure 3 of the drawing. As an impedance limiting means, a resistor 34 is connected in parallel with the potentiometer device 29 and the condenser 30 as shown. The operation of the circuit network above described is substantially like that of the preceding embodiment, the series impedance device 28 being effectively short circuited when the tone control contact 32 is moved to the maximum "high" position, A. The resistance of the potentiometer 29 is such that in position A the condenser 30 is also effectively out of circuit and ineffective for tone control purposes, and consequently the circuit offers practically no attenuation to the signal at any frequency.

As the potentiometer arm 32 is moved toward the minimum "high" position B, the series impedance device 28 becomes more and more effective in circuit as an impedance for attenuating the high frequency end of the audio frequency range, while the condenser 30 is gradually connected more and more effectively into circuit in shunt with the transmission circuit 24—25. The condenser 30 is of such value that it also serves to attenuate the high frequency end of the audio frequency range and signal potentials which at such frequencies may appear on the output side of the impedance device 28. The combined action of the series impedance device 28 whose impedance rises with frequency and of the condenser 30 whose impedance decreases with frequency tend to give a sharp cut-off of the higher audio frequencies without materially affecting the middle range. This has the advantage of suppressing the high frequency disturbances without appreciably affecting the volume of the desired signal.

The value of inductance 28 is of a suitable value such as 8 henries, while the resistance of the potentiometer 29 is of any suitable value such as $\frac{1}{2}$ megohm and the condenser 30 has a capacity value of substantially .01 mfd.

The operating characteristics of a tone control and compensating network of the character above described are indicated in Fig. 5, plotted to the same scale as the preceding figure and showing at 35 a curve indicating the response characteristic of the network when the potentiometer contact 32 is at position A, while the curve 36 shows a characteristic as changed when the contact 32 is moved to the extreme position B.

It will be appreciated that the response characteristics for other positions of adjustment of the tone control device will fall between the curves 35 and 36. The middle frequency response is maintained at a relatively high level as is desirable when the high frequency response is fully attenuated, as indicated by the curve 36.

A characteristic of the tone compensating means in the network of the circuit of Fig. 3 will be noted in connection with the curve 36. In this case the compensation is provided at the lower or bass portion of the control range of the device 29—32, and serves to maintain a high quality in the mid frequency range as indicated by the high mid frequency response 37 and the sharp cut-off of higher frequency signals.

As hereinbefore described, this desired compensation is effected by the circuit of Fig. 3 by the tuned relation of the choke coil 28 and the condenser 30 in series when the contact 32 approaches the position B.

In an ordinary impedance coupled amplifier

the response with a tone control means is much less pronounced than that provided by the improved circuit and is characterized by a gradual slope of the response curve in the mid frequency range indicating a lack of sharp cut-off.

From the foregoing description it will be seen that the control circuit shown in Fig. 3 embodies a single variable control device which in operation serves not only to provide a variable tone control action, but also a frequency response compensation. It is, therefore, similar to the circuit of Fig. 1 in its operation and application, but is more particularly adapted to output or transmission circuits in which the output terminals are connected with an inductive device, such as a transformer primary winding as shown.

In each of the circuits shown, the audio-frequency transmission circuit is connected with a vacuum tube device, but it should be understood that it is applicable to any audio frequency transmission circuit requiring a tone control system and for which frequency compensation simultaneously therewith is desired.

The advantages in a tone control system embodying the invention lie in the fact that a single instrumentality is provided and arranged in a network circuit such that, in association with other impedance elements, a wide range of control is provided and also undesirable frequency response characteristics of the system may be compensated, such as a falling high frequency characteristic of the impedance coupled amplifier circuit of Fig. 1 and the circuit of Fig. 3 wherein the elements 28 and 30 cooperate to improve the high frequency cut-off and the mid-frequency range when the tone control is adjusted to reduce the high frequency response.

I claim as my invention:

1. The combination with an audio frequency transmission circuit, of a series impedance element connected in said circuit, audio frequency coupling means connected in said circuit and including a shunt impedance element, means adapted to provide a frequency-compensating shunt connection in parallel with one of said impedance elements, and a single variable means for selectively establishing said connection in parallel with either of said elements.

2. The combination with an audio frequency transmission circuit, of a series impedance element connected in one side of said circuit, a shunt impedance element connected across said circuit, means adapted to provide frequency compensating shunt connections in parallel with said impedance elements, said last named means including a common variable impedance device for gradually connecting one of said elements in circuit substantially to the exclusion of another.

3. The combination with an audio frequency transmission circuit, of a tone control and frequency compensating circuit network therefor, including a series impedance element in said circuit, means providing shunt paths across said circuit on opposite sides of said impedance element, said last named means including a condenser, and a common variable means for variably and selectively connecting said impedance element and said condenser effectively in circuit as signal attenuating means, the one to the exclusion of the other.

4. The combination with an audio frequency transmission circuit, of a series impedance device therein, means providing a high frequency shunt connection for said device, means providing a high frequency shunt connection for the

audio frequency transmission circuit, and a single variable potentiometer device included in both of said shunt connections for simultaneously controlling the same.

5 5. The combination with an audio frequency transmission circuit, of a series impedance device therein, an output impedance device for said circuit, means providing a variable shunt connection for said series impedance device and a variable shunt connection for the audio frequency
10 transmission circuit, and said output impedance device including a condenser having a capacity value such that it serves to tune the output impedance device within a predetermined frequency range, and a single variable impedance device
15 common to both of said shunt connections.

6. In an audio frequency transmission circuit, a tone control and frequency compensating network including an impedance device connected
20 in series with said circuit, a shunt impedance device connected in parallel with said circuit and in series with said first named impedance device whereby signal potentials transmitted through said circuit are divided between said devices, a
25 shunt impedance means connected across said circuit and including a variable resistance device and a condenser in series therewith, said variable resistance device having a variable contact connected with the series impedance device at the
30 output end thereof.

7. In an audio frequency transmission circuit, a tone control and frequency compensating network including an impedance device connected
35 in series with said circuit, a shunt impedance device connected in parallel with said circuit and in series with said first named impedance device whereby signal potentials transmitted through said circuit are divided between said devices, a
40 shunt impedance means connected across said circuit and including a variable resistance device and a condenser in series therewith, said variable resistance device having a variable contact connected with the series impedance device at the output end thereof and a second condenser
45 in said connection.

8. The combination with an impedance coupling network providing an audio frequency transmission circuit and including an output coupling impedance, an input coupling impedance, and a
50 coupling condenser connected therebetween, of a series impedance device connected in said circuit, a condenser and a potentiometer device connected in series across said circuit, said potentiometer device having a movable contact connected with the transmission circuit adjacent to the output
55 end of said series impedance element.

9. The combination with an audio frequency transmission system having an inductive output

circuit, of a choke coil impedance device connected in series with said output circuit, a condenser, and potentiometer means for selectively connecting said condenser gradually in parallel
5 with said output circuit when operated in one direction and for gradually providing a shunt connection for said series impedance device when operated in another direction.

10. The combination with an intertube coupling network having a variable frequency-transmission characteristic, characterized by the fact that
10 signal potentials in a portion of the audio frequency range are attenuated thereby, of signal potential attenuating means in said network, means providing a frequency variable shunt
15 connection therefor, a tone control circuit in said network, and a single variable impedance device connected in the tone control circuit and interconnected with said attenuating means and shunt connection means therefor whereby said last
20 named means is simultaneously controllable with said tone control circuit.

11. The combination with a thermionic vacuum tube having an output circuit and an output
25 coupling impedance means in said circuit, of a second impedance means in said circuit in series therewith, a high frequency bypass condenser for said second named impedance means, a tone control condenser, and a potentiometer resistor connected with said condensers for selectively
30 connecting the bypass condenser effectively across the series impedance means and the tone control condenser across the output circuit, whereby the tone control and frequency response compensation of said output circuit are controlled by a
35 single instrumentality.

12. The combination with an audio frequency signal transmission circuit, of a coupling network including a coupling impedance in shunt with
40 said circuit, means providing a series impedance in said circuit, a shunt reactance device for said series impedance, a shunt reactance device for said circuit, and a potentiometer device having a variable tap connection and terminals connected in circuit with said shunt reactance devices for
45 selectively connecting said devices effectively in circuit.

13. An audio frequency tone control system including in combination, an audio frequency signal transmission circuit, a series impedance means
50 and a shunt impedance means therein interconnected to divide signal potentials applied to said circuit, means providing a high frequency shunt connection selectively across the one or the other of said impedance means, and including a variable
55 impedance device interconnected with said last named means to control said connections.

RUDOLPH A. BIERWIRTH.