June 30, 1931. C. R. KEITH 1,811,941

APPARATUS FOR REDUCING DISTURBING CURRENTS

Filed June 20, 1928 2 Sheets-Sheet 1

FIG. 1

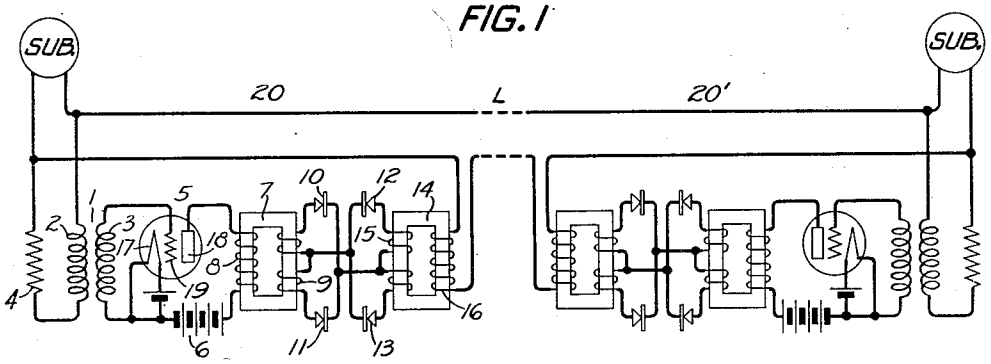

FIG. 2

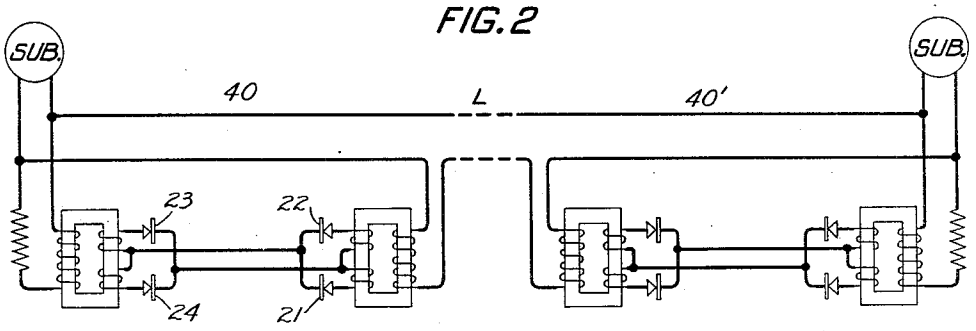

FIG. 3A

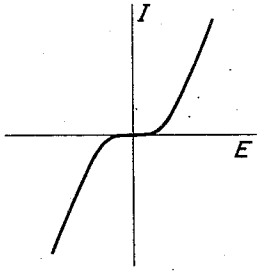

FIG. 3B

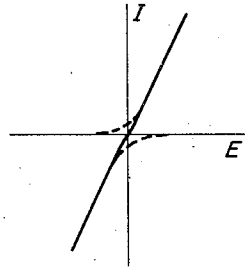

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FIG. 4

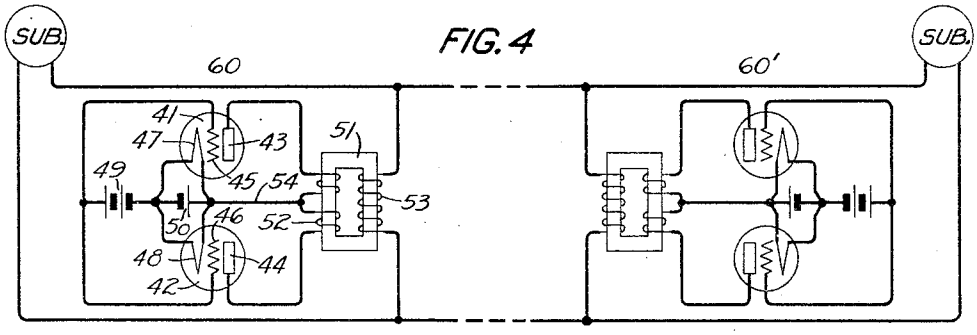


FIG. 4A

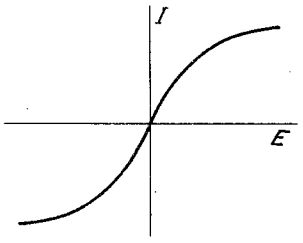


FIG. 5A

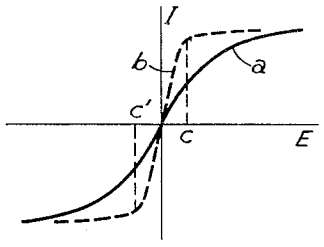


FIG. 5

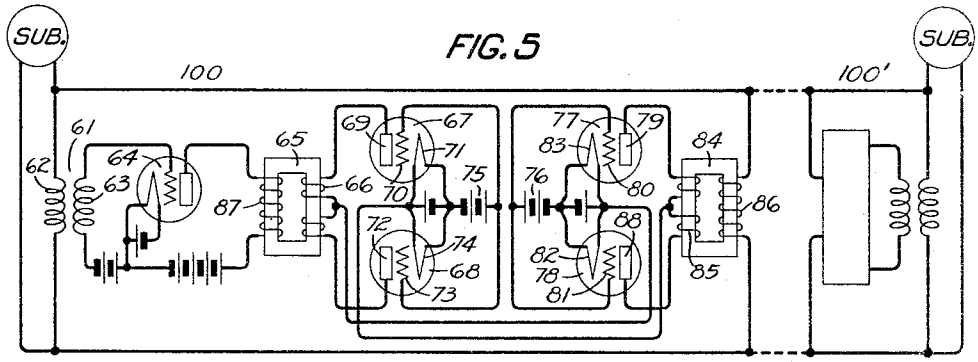
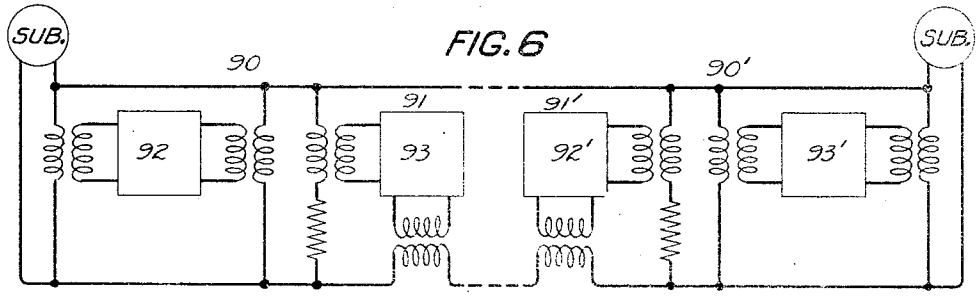


FIG. 6



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UNITED STATES PATENT OFFICE

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APPARATUS FOR REDUCING DISTURBING CURRENTS

Application filed June 20, 1928. Serial No. 286,848.

This invention relates broadly to apparatus for discriminating between currents of different amplitudes and especially to devices which may be used to eliminate noise or cross-talk from signaling circuits.

In the copending application of E. Peterson Serial No. 286,773, filed June 20, 1928, devices are disclosed by means of which noise or cross-talk currents, which are particularly annoying during pauses in conversation or signaling, are effectively prevented from being transmitted to the receiving apparatus.

As disclosed in the Peterson application a device having a non-linear impedance characteristic, such as a rectifier for example, may be used in a circuit, and the impedance characteristic of the circuit may be made such that currents of small amplitudes are highly attenuated while currents of signal amplitudes suffer comparatively small attenuation. The result is that a region of non-transmission is produced for small positive and negative currents which correspond to those due to noise or cross-talk. In this manner, the noise is excluded from the receiving apparatus, but, as the device offers small impedance to large currents, the voice or signals are readily transmitted therethrough.

In one of its forms the present invention is in the nature of an adjunct to or an improvement upon that disclosed in the Peterson application and operates to eliminate any distortion which might result due to the region of non-transmission or to harmonics resulting from an excess curvature of the rectifier characteristic curves. In the invention to be described herein the transmission characteristic is similar to that disclosed in the Peterson application referred to when disturbing noises due to extraneous voltages are on the line, namely, in that there is a region of non-transmission, but the present invention provides a characteristic when the signaling currents are transmitted which is substantially linear for all amplitudes.

In another form of the invention a device is used which has a transmission characteristic such that currents of large amplitudes suffer comparatively large attenuation whereas those of small amplitudes are readily transmitted. This arrangement is connected in shunt to the transmission line so that cross-talk currents of small amplitudes are short-circuited from the subscriber's receiver, whereas practically none of the speech current which is of large amplitude is excluded therefrom.

An object of the invention is to reduce the effect of disturbing currents in a signaling system during intervals between the signal impulses.

A further and related object of the invention is to reduce noise or cross-talk in a transmission circuit during intervals between conversation without materially affecting the quality when speech is being transmitted.

Another object of the invention is to provide a source of biasing potential for an amplitude discriminating device, the value of which is determined by the voltage across the line with which it is associated.

A feature of the invention resides in a circuit having a variable transmission characteristic which is determined by the voltage upon the line.

Another feature of the invention is a variable biasing means which operates to maintain a region of non-transmission during pauses in conversation, but which alters as the conversation is renewed so that currents of all amplitudes are readily transmitted.

A better understanding of the invention may be had from the following description when read in connection with the accompanying drawings of which Figs. 1 and 2 are circuit diagrams of two series arrange-

ments embodying the principles of the invention and Figs. 3A and 3B are curves illustrating the operation thereof, while Figures 4 to 6 illustrate the shunt arrangements.

Referring to Fig. 1 two current amplitude discriminating devices 20 and 20′ are shown associated with subscriber sets located at the terminals of the line L. In the discriminator 20 a transformer 1 has a winding 2 and a resistance 4 in a series path which is shunted across the line L. The other winding 3 of the transformer is included in the input circuit of an amplifier of any well known type which in this instance is represented by the three-element space discharge device 5. The output circuit of the tube 5 may be traced from the plate 18 of the tube through a winding 8 of the transformer 7, a source of plate potential 6 to the filament 17 of the tube. Two rectifier elements 10 and 11 of any well known type having a larger resistance to current flow in one direction than in the other, have two homologous electrodes connected together while their other two homologous electrodes are connected through another winding 9 of the transformer 7. Two other rectifier elements 12 and 13 preferably similar to 10 and 11, are associated with the transformer 14 in a manner very similar to the way in which the other rectifiers are associated with the transformer 7, that is the corresponding electrodes of rectifiers 12 and 13 are connected directly together while the other electrodes are connected together through the winding 15 of the transformer 14. The electrodes of rectifiers 12 and 13 which are connected directly together are connected to the midpoint of winding 9 while the electrodes of rectifiers 10 and 11 are connected to the midpoint of winding 15 in a similar manner. The other winding 16 of the transformer 14 is connected in series with the line.

The discriminator 20′ at the other terminal of the line is similar in construction and operation to 20 and will not therefore be described.

In order to give a clear conception, of the operation of this embodiment of the invention, it must be remembered that the rectifiers 10, 11, 12 and 13 have substantially unilateral impedance and that the impedance is high upon the application of small potentials but low when comparatively large voltages are applied. These rectifiers are placed in the circuit in such a manner that when small voltages such as those due to cross-talk are generated in the line L, the circuit characteristic is similar to that shown in Fig. 3A which illustrates that there is a region of non-transmission or high impedance for small cross-talk voltages. However, for comparatively large voltages in the line, as when speech is being transmitted, the biasing potentials upon the rectifiers 12 and 13 are changed causing the transmission characteristic of the circuit to be comparatively straight as in Fig. 3B.

The change of biasing potential is accomplished as follows: In order to supply biasing potential to the rectifiers 12 and 13, the potential from the line is repeated through the transformer 3 and is amplified by the amplifier 5. The full wave rectifier comprising elements 10 and 11 rectifies the amplified current so that a direct current biasing potential is impressed upon the elements 12 and 13. The resistance 4 is high in order that as little of the current as necessary be shunted from the line.

As the rectifiers 12 and 13 are oppositely poled the impedance introduced into the line L through the transformer 14 is the same for both positive and negative currents, since each rectifier furnishes a path for current of a different polarity. Thus, when the voltage is induced in winding 15 in the direction for which the rectifier 12 will transmit current, the circuit is traced from the upper half of winding 15, the rectifier 12 to the transformer winding 9, through the rectifiers 10 and 11 in parallel, back to the midpoint of winding 15. When the voltage induced in 15 is in the other direction for which rectifier 13 will transmit current, a similar circuit may be traced which includes the lower half of winding 15 and rectifier 13. When small voltages are generated in the line L during intervals in conversation resulting in noise or cross-talk the voltages across the rectifier elements 12 and 13 are small and as the biasing potential in this instance is so small as to have comparatively no effect, substantially no current will flow in the line.

This is evident from the manner in which the elements 12 and 13 are connected in the line. Transformer 14 is preferably of the step-up type with the low winding in series in the line. As the elements 12 and 13 are connected to the other winding 15 of the transformer 14 they introduce an impedance effectively in series in the line which is a function of the transformer ratio. Since the voltage across the elements 12 and 13 must assume an appreciable value before current is transmitted a region results in the neighborhood of small voltages wherein no transmission occurs. This region is represented by the horizontal portion of the characteristic curve shown in Fig. 3—A.

During conversation, however, the voltages present in the line are comparatively large compared with the cross-talk voltages which are present during pauses in coversation. When the speech voltages are amplified and rectified by the circuit heretofore described the biasing potential available for

the elements 12 and 13 is sufficiently large to permit current to be transmitted in proportion to the voltage wave over its entire cycle. The region of non-transmission is thereby eliminated and the transmission characteristic of the circuit assumes the shape shown in Fig. 3—B. In this manner a considerable amount of loss and distortion which would occur due to the region of non-transmission, in the characteristic curve is substantially eliminated. The even harmonics produced by the amplifier-rectifier, enhance the effect of the direct current component but do not produce distortion in the line since the harmonics are balanced out in the rectifiers 12 and 13.

Fig. 2 shows another form of the invention in which the biasing current is rectified directly by rectifiers 23 and 24 without amplification. In other respects the circuit is the same as that in Fig. 1 elements 21 and 22 corresponding to elements 12 and 13 of Fig. 1.

Fig. 4 illustrates one embodiment of the shunt type cross-talk reducer. Two current amplitude discriminators 60 and 60′ are shown associated with subscribers' sets at opposite terminals of line L. These discriminators are identical so that a description of one will suffice. Two vacuum tubes 41 and 42 are arranged in balanced relation with their plates connected to opposite ends of winding 52 of the transformer 51. The other winding 53 of transformer 51 is connected in shunt to the line L. The filaments 47 and 48 of vacuum tubes 41 and 42 respectively are connected in parallel and are energized from the battery source 50. The grids of the tubes are connected to their respective filaments through a common branch including a source of potential 49 which supplies a comparatively high positive biasing potential to the grids. The plate circuits of vacuum tubes 41 and 42 may be traced to the respective filaments of the tubes through opposite halves of transformer winding 52 through common lead 54 which is connected to the midpoint thereof. It is to be noted that this arrangement differs from the usual vacuum tube amplifier circuit and that it has a symmetrical transmission characteristic, which is shown in Fig. 4—A. From this characteristic curve it may be seen that currents of small amplitudes are but slightly attenuated whereas currents of larger amplitudes are practically suppressed.

Thus when currents of small amplitudes are generated in the line causing cross-talk during pauses in conversation the amplitude discriminator provides a path of small resistance so that these currents are effectively shunted from the subscriber's receiver. However, during speech transmission the signal voltages are comparatively large, causing the amplitude discriminating device to operate in that region which offers large attenuation to the current being trasmitted. The subscriber's receiver offering a much smaller resistance than the shunt path provided by the discriminating device under these circumstances receives practically all of the voice currents.

Fig. 5 illustrates another embodiment of the shunt type amplitude discriminating device which has a transmission characteristic similar to that shown in Fig. 4 when currents of small amplitudes are generated in the line but which changes during the transmission of speech currents so that practically all the current transmitted is attenuated equally. The circuit characteristic is shown in Fig. 5—A, curve A representing transmission characteristic during pauses between conversation while curve B shows the transmission characteristic while conversation is taking place. Subscribers' sets at opposite ends of the line L are equipped with discriminators 100 and 100′ which are identical. In the discriminator 100 a transformer 61, preferably a step-up transformer, has its primary winding 62 connected in shunt to the line L and its secondary winding 63 connected to the input of the vacuum tube amplifier 64 which may be of any well-known type. The output of the amplifier is impressed upon the plate circuits of tubes 67 and 68 arranged in balanced relation through the transformer 65. Another pair of balanced vacuum tubes 77 and 78 have their plate circuits connected to the line L through the transformer 84 which also has a winding 86 connected in shunt to the line. As in the circuit described in Fig. 4 both pairs of vacuum tubes have comparatively large positive grid potentials but in this embodiment a plate voltage is supplied by vacuum tubes 67 and 68, of a value dependent upon the voltage in the line. The grid circuits of the vacuum tubes 67 and 68 may be traced to their respective filaments through the common branch which includes source of potential 75 while the grid circuits of tubes 77 and 78 may be traced from their respective grids 80 and 81 through the common branch comprising source of potential 76. Plate circuits of both pairs of tubes are interconnected and may be traced from plates 69 and 72 of vacuum tubes 67 and 68 through the upper and lower halves respectively of the transformer winding 66 to the filaments of tubes 77 and 78 and thence through the parallel paths comprising the space path of vacuum tube 77 and the upper half of winding 85 and space path of tube 78 and the lower half of winding 85 and back to the filaments of tubes 67 and 68. The operation of the circuit is as follows.

In operation during intervals between conversation small voltages are generated in the

line which produce disturbing noises or cross-talk in the receiver. If the shunt path provided by the discriminator has much smaller resistance than the subscriber's receiver the disturbing currents will be shunted around the receiver with little consequent effect thereon. For small voltages across the transformer windings 62 and 86 the current amplified by the amplifier 64 is small and the current induced in winding 66 is negligible. Under these circumstances the biasing potential introduced into the plate circuit of the tubes 77 and 78 is negligible and their operation is confined to that region of their characteristic curve wherein the current waves are but slightly attenuated. This region is shown in Fig. 4—A in the neighborhood of small voltages where the characteristic curve has its maximum slope.

However, as soon as signaling voltages are generated in the line the voltage drop across the transformer windings 62 and 86 is considerably greater. The current induced in winding 63 is amplified by the amplifier 64 and impressed upon the rectifier circuit comprising the tubes 67 and 68 through the transformer 65. As both halves of the wave are rectified a biasing potential is supplied to the plates of tubes 77 and 78 in parallel causing the transmission characteristic of the discriminator comprising tubes 77 and 78 to assume the shape shown at *b* in Fig. 5—A. As may be seen from this curve the resistance offered to small voltages is negligible whereas the larger voltages, as for instance those in excess of the value C and C′ are greatly attenuated. Thus when large voltages resulting from speech are impressed upon the plate circuits of the tubes 77 and 78 through the transformer 84 the impedance offered to current flow is large, permitting practically all the speech energy to pass through the subscriber's receiver. On account of the changing biasing voltage upon the discriminator when currents of large amplitudes are being transmitted the resistance of the discriminator is practically constant, for all values of the voltage wave even in the region of small voltages. This results in very little distortion of the speech signals.

In Fig. 6 a combination of the series and shunt current amplitude discriminators is shown. The box 92 is the shunt discriminator which may be either of the types shown in Fig. 4 and Fig. 5 while box 93 represents the series amplitude discriminator which may be either of those shown in Fig. 1 and Fig. 2.

Although the invention has been described herein with particular reference to a simple telephone circuit it is equally applicable to carrier systems, repeater systems, broadcast receivers, or in fact any system applicable to the transmission of intelligence by electrical waves wherein it is desirable to reduce extraneous noises which tend to interfere with clear reception. The circuits described represent only typical embodiments of the broad idea and various other embodiments will occur to those skilled in the art. The invention therefore is to be limited by the scope of the appended claims.

What is claimed is:

1. In combination with a transmission circuit, a device introducing varying attenuation into said circuit dependent upon the current amplitude in the circuit, said device having an attenuating region for currents of small amplitudes in said circuit, and means responsive to large current flow in said circuit for removing the current attenuation of said device in the region corresponding to small amplitudes.

2. In combination with a transmission circuit, a device introducing varying attenuation into said circuit dependent upon the current amplitude in said circuit, said device having high attenuation for currents of small amplitude but low attenuation for currents of large amplitude, and means controlled by the current in said circuit for removing the attenuation properties of the circuit when currents of large amplitudes are being transmitted.

3. In combination a transmission line and means for discriminating between the amplitudes of current being transmitted thereover, said means comprising a plurality of transmission elements of non-linear impedance characteristics having a high impedance when small currents are traversing said line and means for causing said elements to have small impedance and a substantially linear characteristic when normal currents are traversing said line.

4. The combination with a circuit for the transmission of signal waves of transmission means associated therewith having a non-linear transmission characteristic, said means having high impedance for waves of small amplitudes in said circuit but small impedance to waves of signal amplitude transmitted over said circuit, and auxiliary means associated with said transmission circuit for supplying a biasing voltage for said transmission means to cause said non-linear transmission characteristic to be substantially linear when signal waves are being transmitted.

5. The combination with a circuit for transmission of signal waves of transmission means associated therewith having a non-linear transmission characteristic, said means having high impedance for waves of small amplitudes transmitted over said circuit, but small impedance for waves of signal amplitude transmitted over said circuit, and auxiliary means associated with said transmission means for supplying a biasing

voltage thereto which varies in accordance with the amplitude of the current in said circuit to make the transmission characteristic linear during transmission of signal waves.

6. The combination with a circuit for the transmission of signal waves of transmission means associated therewith having a non-linear transmission characteristic, said means having high impedance for waves of small amplitudes transmitted over said circuit but small impedance to signal waves transmitted over said circuit, and auxiliary means associated with said transmission means for applying a biasing potential thereto which comprises means for completely rectifying a portion of the line voltage.

7. In a circuit for suppressing cross-talk during intervals between signaling, a line circuit, a plurality of rectifiers associated with said line circuit each having a uni-lateral impedance characteristic and arranged in balanced relation for introducing high impedances in said line for small currents therein but small impedance for signal currents, another pair of balanced rectifiers for rectifying a portion of the current from said line, said variation in impedance being controlled by the current rectified by said second pair of balanced rectifiers.

8. In a circuit for suppressing cross-talk during intervals between signaling, a transmission circuit, a non-linear impedance in said circuit comprising a pair of balanced rectifiers which offer high impedance to small voltages but comparatively small impedance to signal voltages, other means for biasing said balanced pair of rectifiers so as to make said impedance substantially linear when signaling voltages are generated in said transmission circuit, said means comprising another pair of balanced rectifiers for rectifying a portion of the voltage in said line and applying it to said first mentioned rectifiers.

9. The combination with a circuit for the transmission of signaling waves of a plurality of transmission elements each having the property of freely transmitting normal signaling waves of one polarity and of readily suppressing small voltages corresponding to cross-talk, said elements being arranged in balanced relation with respect to each other, means for supplying a variable biasing potential of the same sign to each of said elements at the same time, said elements being capable of suppressing the transmission of current over a range of amplitudes as determined by said variable biasing potential.

10. The combination with a circuit for the transmission of signaling waves, of a plurality of transmission elements each having the property of freely transmitting normal signal waves of but one polarity and of readily suppressing waves of small amplitudes corresponding to cross-talk, said elements being arranged in balanced relation with respect to each other and means for supplying a variable biasing potential to said elements determined by the amplitude of the signal waves in said transmission circuit, said elements suppressing the transmission of current over a range determined by said biasing potential.

11. The combination with a circuit for the transmission of signal waves of a plurality of transmission elements each having the property of freely transmitting normal signal waves of but one polarity and of readily suppressing waves of small amplitudes corresponding to cross-talk, said elements being arranged in balanced relation, means responsive to said signal waves for supplying a biasing potential to said elements determined by the amplitude of said signal waves in said transmission circuit, said biasing potential determining the extent to which said elements exercise their properties of suppressing waves of small amplitudes in said line.

12. The combination with a circuit for the transmission of signal waves of a plurality of transmission elements each having the property of freely transmitting normal signal waves of but one polarity and of readily suppressing waves of small amplitudes corresponding to cross-talk, said elements being arranged in balanced relation, means for supplying a biasing potential to sail elements determined by the amplitude of waves in said transmission circuit, said means comprising a pair of balanced rectifiers.

13. In combination, a transmission line, and means for discriminating between amplitudes of current transmitted thereover, said means comprising a plurality of rectifier elements, means under the control of the voltage of said line for providing a biasing voltage for changing the transmission characteristic of said discriminating means, such that a small voltage transmits no current whereas for large voltages the current is substantially proportional thereto.

14. In combination with a transmission circuit, means for receiving signals transmitted thereover, a plurality of transmission elements each having the property of effectively attenuating currents of large amplitudes but readily transmitting currents of small amplitudes, said elements being arranged in balanced relation with respect to each other but associated with said transmission circuit so as to permit currents of large amplitudes to pass to said receiving device but to exclude currents of small amplitudes therefrom.

15. In combination with a transmission circuit, means for receiving signals transmitted thereover and two current transmis-

sion paths both in shunt to said receiving means for determining the current to be transmitted thereto, said paths being substantially opaque to currents of large amplitudes but readily capable of transmitting currents of small amplitudes whereby said currents of small amplitudes are excluded from said receiving means.

In witness whereof, I hereunto subscribe my name this 13th day of June, 1928.

CLYDE R. KEITH.