

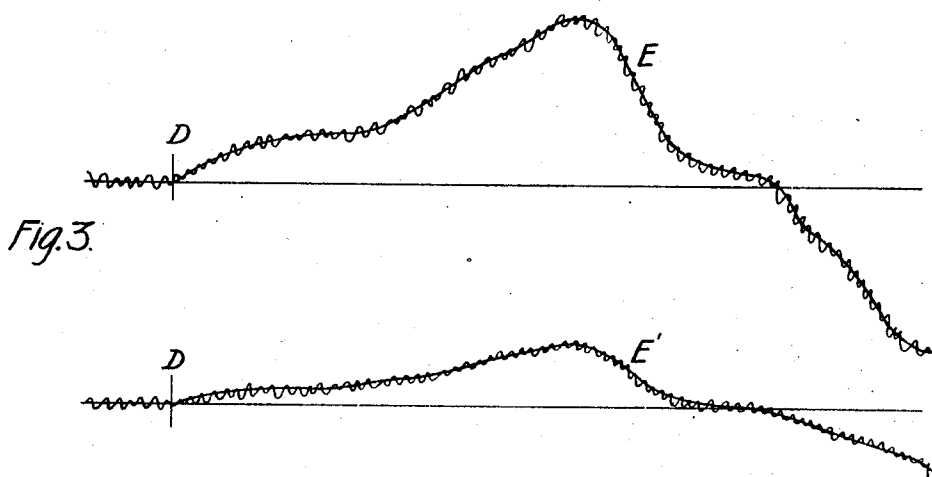
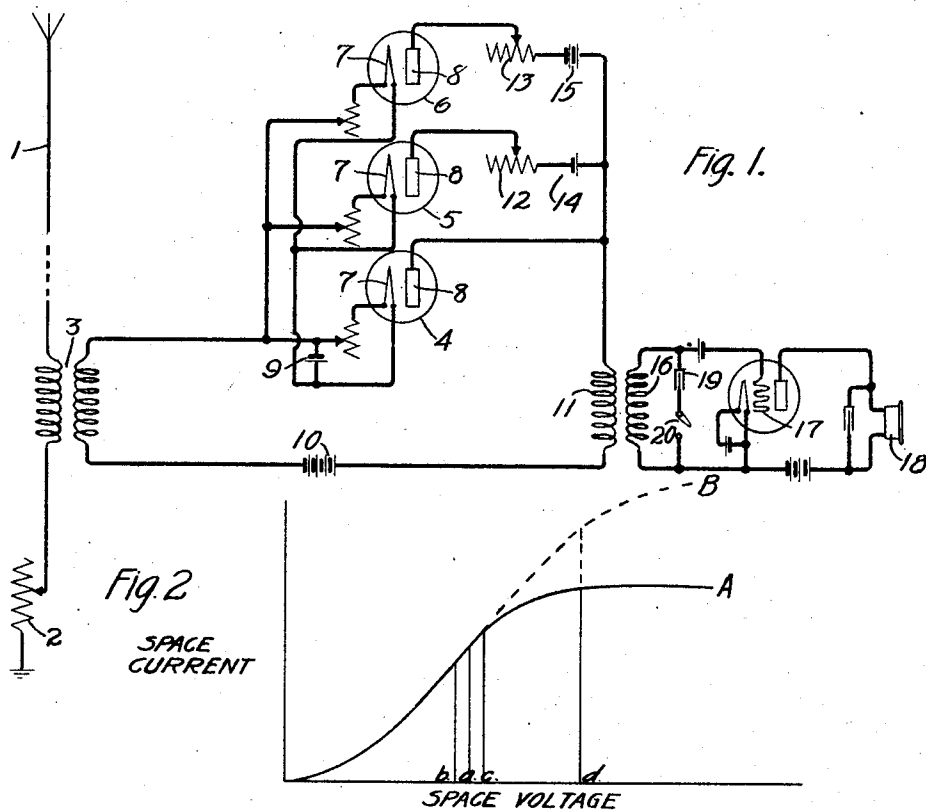
May 7, 1929.

C. A. SPRAGUE

1,711,658

CURRENT CONTROLLING AND STATIC REDUCING SYSTEM

Original Filed May 2, 1919 4 Sheets-Sheet 1



Inventor
Clarence A. Sprague.
by *E. W. Adam* Atty.

May 7, 1929.

C. A. SPRAGUE

1,711,658

CURRENT CONTROLLING AND STATIC REDUCING SYSTEM

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4 Sheets-Sheet 2

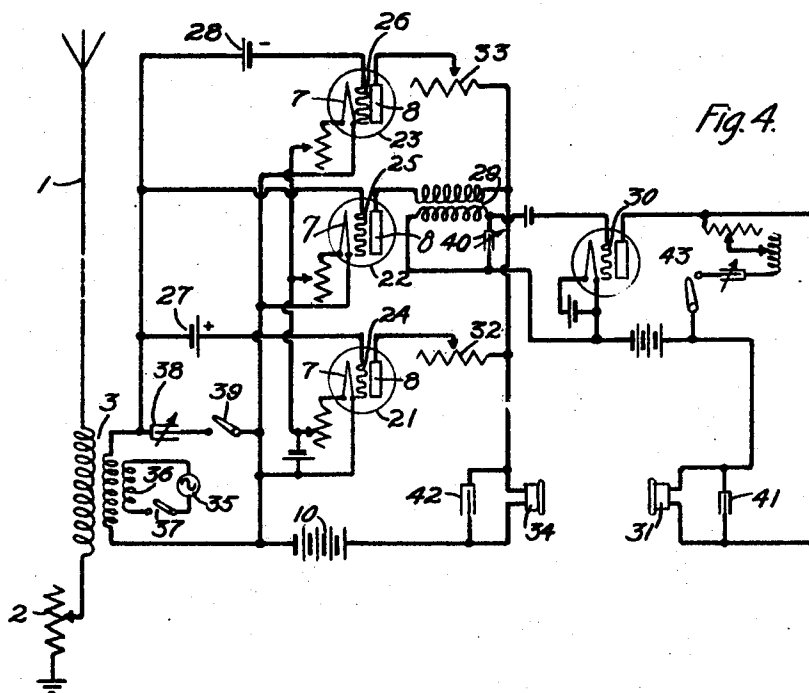


Fig. 4.

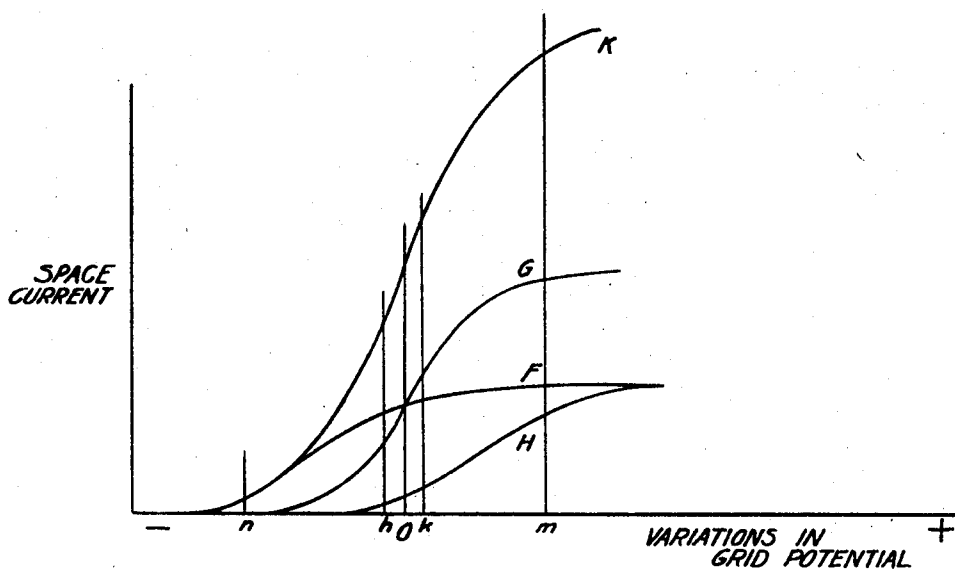


Fig. 5.

Inventor:
Clarence A. Sprague
by Edward A. Att'y.

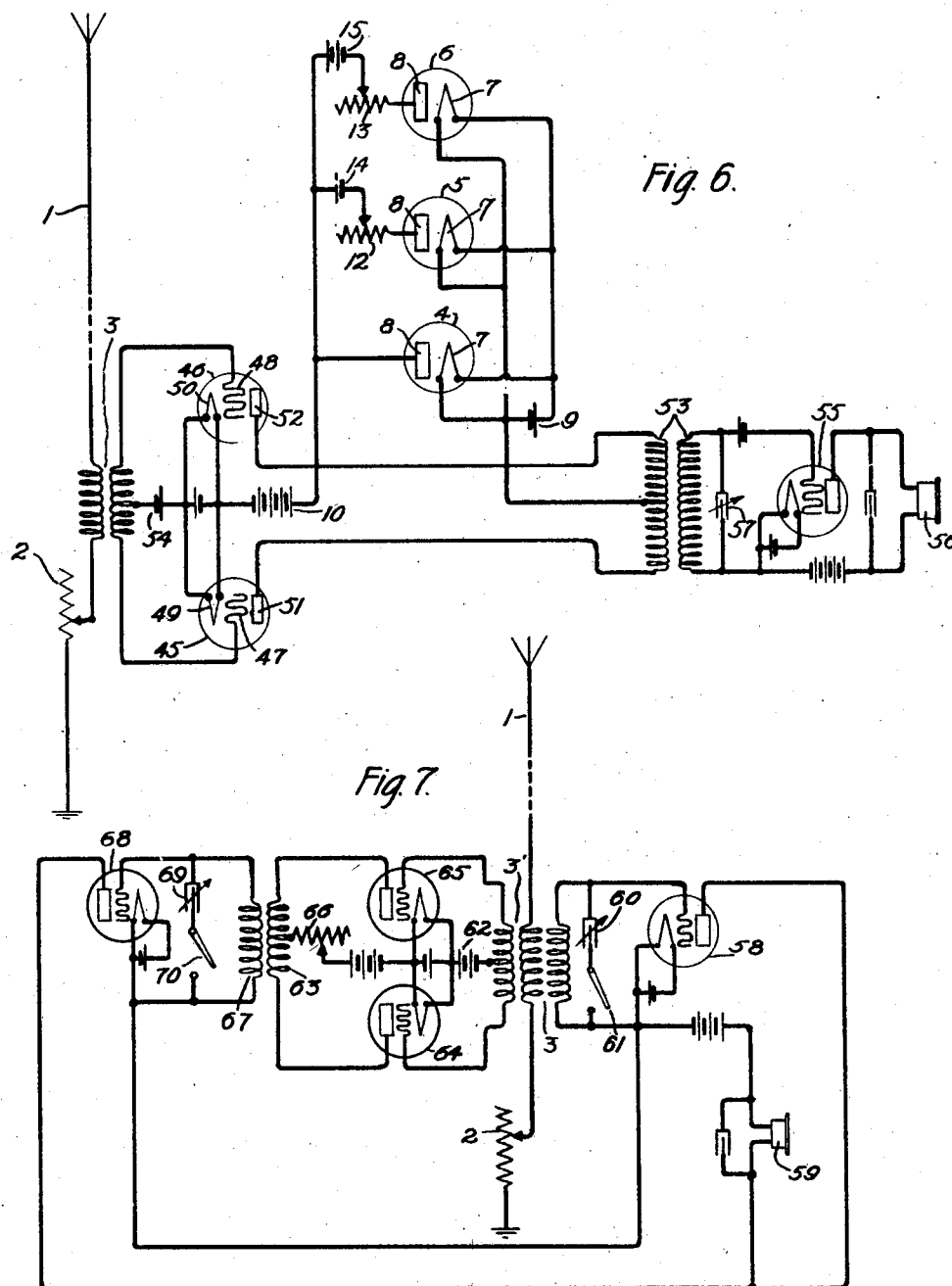
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CURRENT CONTROLLING AND STATIC REDUCING SYSTEM

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CURRENT CONTROLLING AND STATIC REDUCING SYSTEM

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4 Sheets-Sheet 4

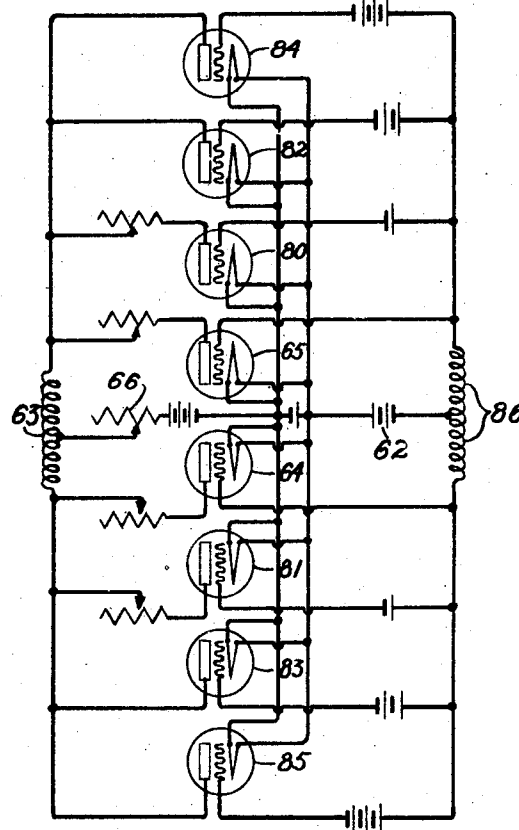


Fig. 8.

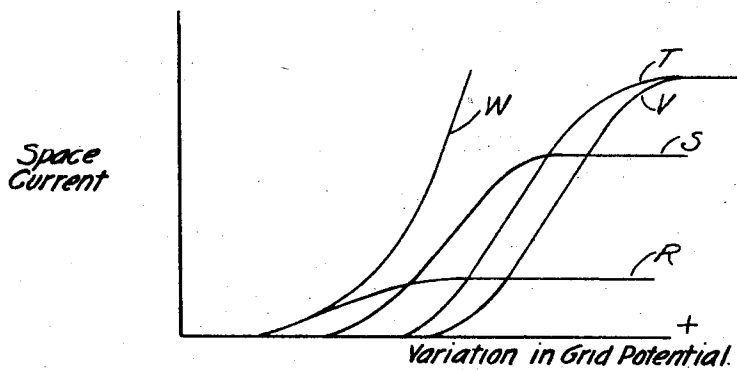


Fig. 9.

Inventor:
Clarence A. Sprague
by E. W. Adams Att'y.

Patented May 7, 1929.

1,711,658

UNITED STATES PATENT OFFICE.

CLARENCE A. SPRAGUE, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

CURRENT-CONTROLLING AND STATIC-REDUCING SYSTEM.

Original application filed May 2, 1919, Serial No. 294,328, Patent No. 1,477,017, dated December 11, 1923.
Divided and this application filed November 21, 1923. Serial No. 676,038.

This application is a division of application Serial No. 294,328, filed May 2, 1919, Patent No. 1,477,017, granted December 11, 1923.

5 The present invention in its broad aspect relates to a method and means for combining the properties of a plurality of electric discharge devices, or their equivalents, arranged in parallel relation, to secure a desired resultant property. It involves controlling the order and extent of operation of the discharge devices, which may, for example, be thermionic vacuum tube devices.

10 In a more specific aspect the invention relates to the reception of relatively weak signal energy in the presence of large electrical disturbances. It is particularly adapted to the reception of electromagnetic signal waves at radio receiving stations during atmospheric or other disturbances, but is not limited to such use, since it is applicable also, for example, to wire or cable signaling systems in which disturbing current waves are received together with the signal waves.

15 The invention is designed particularly for overcoming the disturbing effects of abnormal surges of energy of low periodicity compared with the signal currents. These relatively slow impulses of great amplitude are very troublesome and are difficult to control not only in radio signaling, but in high frequency carrier current wire systems and in systems of great capacity, such as the submarine cable. Without some correcting means for these large undesired currents, the receiving instrument or the operator's ear may be temporarily rendered insensitive or permanently injured, or at least it may be impossible to receive the signal during the persistence of the disturbances owing to its being "swamped" by the disturbing waves. Protective devices are known for preventing too large current from reaching the receiver but such devices wipe out the message as well as the excess current. It is an object of the invention to prevent too large current from reaching the receiver, but at the same time to permit the signal currents to be received.

20 A feature of the invention relates to the method of and means for attenuating currents of abnormal magnitude while permitting signal currents to be received.

Another feature of the invention relates to the control of a signal current by the abnormal current for determining one or another path for the passage of the signal currents.

Another feature of the invention relates to the modification of the signal currents by the disturbing currents whereby the signal currents persist through the attenuation of the disturbing currents.

A further feature of the invention relates to the separate treatment of the normal signal currents and the currents received during the disturbances.

25 Features concerned in securing the above-mentioned effects relate to the use of discharge devices so arranged as to function sequentially or in steps in accordance with the magnitude of the received energy, to modulate signal waves in accordance with abnormal currents, and to control attenuation of the abnormal currents; and other features of the invention will appear from the following description together with the drawings, of which Fig. 1 shows a receiving circuit arrangement according to the invention; Figs. 2 and 3 are curves explanatory of the action of the device of Fig. 1; Fig. 4 is a modified circuit arrangement of which the curves in Fig. 5 are explanatory; Figs. 6 and 7 are other forms of circuit arrangements which the invention may take, and Fig. 8 illustrates a high power modulator or detector of which the curves of Fig. 9 are explanatory.

Figs. 1 to 6 and the explanations in connection with them serve as preliminary steps in the disclosure of the invention illustrated in Fig. 7 which is a preferred form.

Referring to Fig. 1 the antenna 1 is connected through adjustable resistance 2 to earth and is coupled by coil 3 to the receiving circuits shown. Resistance 2 is preferably adjusted to a value which will render the antenna circuit non-oscillatory. 4, 5 and 6 indicate electron discharge devices and as illustrated comprise evacuated tubes containing heated filaments 7 and anodes or plates 8. The filaments are supplied with heating current from battery 9 connected through regulating resistances as shown, or by separate batteries if desired. Plate battery 10 causes a space current to flow normally be-

tween the filament and plate of discharge device 4 through output winding 11, battery 10 and the secondary winding of coupling 3. The relation between the magnitude of this space current and the potential impressed across the space between filament 7 and anode 8 for a given constant filament temperature if auxiliary tubes 5 and 6 were removed, would be indicated by the familiar characteristic curve A of Fig. 2, and this potential might be assumed to be approximately that indicated by the abscissa a so that the normal space current would be represented by the length of the ordinate drawn at a . If signal electromotive forces impressed through coupling 3 and superimposed upon that of battery 10 should cause the total space potential to vary between the limits indicated by b , c , the variations produced in the space current by the signals would be represented by the difference between the ordinates drawn at points b and c .

If a surge of current from some disturbing source should carry the space potential to some point d and maintain it there momentarily, the signal variations coming in with the disturbing current would produce no variation in space current, since the saturation point of the characteristic curve A of the discharge device would have been passed, and hence the signals would be lost during the existence of the disturbing current. Discharge device 4 will act then as a current limiting device, since for a given filament temperature no larger current can be made to flow through it than is represented by the ordinate corresponding to the horizontal portion of curve A.

Electron discharge devices 5 and 6 are substantially like discharge device 4 but are connected to the common space battery 10 through respective resistances 12, 13 and potential sources 14 and 15. As shown, source 14 is of less potential than 15 and both sources are connected so as to oppose the source 10, so that the normal space potential of discharge device 5 is less than that of discharge device 4 and that of discharge device 6 is less than either of the others. Also the amount of resistance 13 included in the circuit may be assumed to be greater than the portion of resistance 12 that is used. The action of discharge devices 5 and 6 is to permit current to flow in the common output circuit after the cut-off value of the discharge device 4 has been reached. With a space potential d for instance, a larger current results than is denoted by the curve A as indicated by the dotted curve B and the ordinate drawn at d . However, the current flowing through discharge device 5 or discharge devices 5 and 6 is attenuated by the resistances 12 or 12 and 13, and the attenuation is greater the greater the currents, as is indicated by the general form of the curve B

which may be considered the composite characteristic of the group of parallel discharge devices 4, 5 and 6 as a whole. A large surge of disturbing current is therefore greatly damped or reduced but the signals are not lost, since it may be assumed that saturation is not reached. The effect is graphically shown by the curves of Fig. 3, in which the small irregular curve indicates the received signal current. To the left of the line D conditions are normal and only a signal wave is present. To the right of the line D, however, a slowly rising irregular wave of great magnitude is represented as coming in together with the signal, the result being the large wave E with an irregular outline due to the superposition of the signal wave upon the disturbing wave. As soon as the potential exceeds the normal maximum signal potential indicated at c , the discharge device 5 begins to transmit current, however, and all such excess current is attenuated by the resistance 12, or, if both discharge devices 5 and 6 are conducting current, by the resistances 12 and 13, and the result is that the disturbing current is reduced to some such extent as is indicated by the curve E' which it is assumed represents the wave actually transmitted to the output coil 11. It is evident that the signal wave will also be attenuated but as long as the curve B continues to possess curvature, the signal currents will still be present and are transmitted through windings 11 and 16 to the input circuit of the detector 17 of familiar type and are rendered audible in the receiver 18. A tuning condenser 19 may be used or the detector circuit may be made aperiodic or detuned by opening the key 20. By thus greatly attenuating the disturbing current this circuit arrangement prevents a sudden large fluctuation of current from reaching the ear of the operator. Owing to the curvature of characteristic B, Fig. 2, the devices 4, 5 and 6 will act in a measure as a detector. The low frequency signal currents thus set up in the input circuit of detector 17 will in part reappear in the telephone receiver 18, by virtue of the repeating action of detector 17, and will, in part, act to modulate the carrier current component, the resultant current not being effective in reproducing the signal in the receiver 18. Circuit modifications in which this loss of energy does not occur will later be described.

The relative effects upon the operator's ear of the currents produced by static disturbances and those due to signals may be likened to the effect upon the eye of a powerful field of light superimposed upon which is a small weak source of light. If the strong field is very intense, the eye will be blinded and become incapable of discriminating between the different intensities. If, however, the intensities of both fields are

reduced in the same proportion, there is a certain value at which the discriminating power of the eye becomes greatest. According to the form of this invention just described, the intensity of the signal and the static are reduced in about the same proportion, with a resulting increase in the clearness of the signal. According to other forms of the invention the static energy is very greatly reduced while the available signal energy is reduced a relatively small amount or is increased.

The system of Fig. 1 which has been described in detail with reference to a distorting wave of such character as to raise the space potential above that of source 10 would need some modification to make it equally efficacious in reducing disturbances of reverse sign. Circuit arrangements will now be described which are designed to reduce a disturbing current of either polarity and in which the detecting action of the current limiting device is taken into account.

Referring to Fig. 4, in place of the two-element discharge devices 4, 5 and 6, discharge devices 21, 22 and 23 of the thermionic relay type are shown, each containing in addition to the hot filament and the anode, a third or grid electrode 24, 25 or 26 respectively. The grid 24 is provided with a polarizing potential source 27 to fix its normal potential with respect to its filament 7 and its potential is indicated as higher than that of its filament. Similarly, by a source 28, the normal potential of grid 26 is fixed negative with respect to its filament 7, while the potential of grid 25 is normally the same as that of its filament 7. Source 10 provides a normal potential difference across the space between filament 7 and anode 8 of each of the discharge devices 21, 22 and 23. If the characteristic curves of the discharge devices 21, 22 and 23 are as represented by the respective curves F, G and H, in Fig. 5, then a normal space current will flow through each discharge device in response to this normal space potential, the respective magnitudes of the space currents through the several discharge devices being indicated by the length of the ordinate intercepted on the line 0 by the respective curves F, G and H. A summation curve K obtained by adding curves F, G and H may serve as the characteristic curve of the three discharge devices 21, 22 and 23 in combination as shown. The zero given for these curves indicates the points on their characteristics corresponding to their respective fixed potentials and the abscissae indicate variations of grid potential from their respective fixed grid potentials. Incoming signal waves vary the potentials of all three grids between the limits h and k , for instance. These signal variations produce very slight changes in the plate cur-

rents through discharge devices 21 and 23 as shown by the relatively flat portions of their characteristics F and H respectively, that are operated over between these limits, as determined by the potential sources 27 and 28 respectively. However, the variations of plate current through discharge device 22, due to changes in its grid potential between these limits h and k are considerable, as shown by the curve G, and the resultant curve K shows that in the comparatively linear region of the curve K between limits h and k the variations in the space current are very nearly proportional to variations in grid potential and the discharge device 22 is acting as an amplifier. These variations of plate potential as determined by the signal waves are transmitted through the coupled windings 29 into the input circuit of a detector 30 of familiar type and are rendered audible in the receiver 31. Thus the normal signal waves picked up by antenna 1 are amplified by discharge device 22 in the ordinary manner, detected by detector 30 of some suitable form, and received at 31 practically without any effect due to discharge devices 21 and 23. However, if a large disturbing wave carries the grid potential variation to such excessive value as either that indicated at m on the one hand or n on the other hand, one of the discharge devices 21 or 23 comes into play. It will be noted that the characteristics F and H of discharge devices 21 and 23 respectively, are not so steep as the curve G and that the saturation region for these two discharge devices is reached relatively more suddenly than in the case of discharge device 22. This may be due to the effect of the large external resistances 32 and 33 and not to inherent differences in the devices themselves. The large disturbing wave, assumed to have varied the grid potential to the extent indicated first by m , brings the discharge device 22 up to the point of its saturation as seen from curve G, and hence practically no current variations due to the signal are transmitted through coupling 29. The discharge device 21 is also saturated and therefore the signal variations are not transmitted by it. Discharge device 23, however, is operating on a curved portion of its characteristic H and is acting as a detector, rendering the signal variations audible in the receiver 34. In this case under the condition assumed, discharge devices 21 and 22 are acting as current limiting devices permitting only current within predetermined limits to pass, while discharge device 23 detects the signal variations and the variable currents which it transmits are attenuated by the resistance 33 before they reach receiver 34. A disturbance in the opposite direction to the extent indicated by n would cause discharge devices 22 and 23 to act as current

limiters, and discharge device 21 would now act as a detector for signal variations. The resultant attenuating effect is perhaps more clearly brought out by the summation curve K which shows that between the limits h and h' , including the signal variations as before pointed out, the principal action is that of amplification, indicated by the substantially linear portion of the characteristic between these limits, but that beyond these limits in either direction the curve begins to fall off and the total current transmitted bears an increasingly smaller ratio to the incoming currents, but detection of the signals still continues by virtue of the curvature still possessed by the characteristic. When working over certain small ranges of curve K, signals may be audible in both receivers. The phase shifting means 43 may then be adjusted to obtain the proper phase relations.

A generator 35 of carrier or other high frequency may, if desired, be coupled to the circuit through coil 36 shown inductively related to windings 3, for the purpose of increasing the strength of the signal or otherwise rendering it more easily readable. A key 37 is provided in the circuit of the generator 35. Also a tuning condenser 38 may be thrown into or out of circuit across the secondary of windings 3 by key 39. It may be found desirable to render this tuned circuit non-oscillatory by the insertion of suitable resistance. A tuning condenser 40 is shown in circuit with the secondary of transformer 29. The small condensers 41 and 42 are shown respectively in shunt to receivers 31 and 34 to by-pass the high frequency current components. The direct current from battery 10 may in any case be shunted past the indicating instrument by choke coils in the well-known manner.

The devices thus far described are designed to reduce the effect of disturbing currents, while still permitting the signal currents to be received but the signal currents are somewhat attenuated by the current reducing means. Means will now be shown and described for reducing the disturbing currents while still transmitting the signal currents strongly. This is accomplished in the particular means shown by causing the lower frequency disturbing currents of large magnitude to control amplification of the signal currents, after which both kinds of currents are attenuated. Referring first to Fig. 6, the secondary of the antenna coupling 3 is connected to the input of a balanced amplifier commonly known as the "push-pull" type. This comprises two discharge devices 45 and 46, the respective grids of which are connected each to a terminal of the secondary of coil 3, while their respective filaments 49 and 50 are connected together and to the midpoint of the said sec-

ondary winding. A given induced potential in said secondary will therefore raise the potential of one grid relative to its filament and will lower the potential of the other grid by an equal amount. The respective anodes or plates 51 and 52 are connected to the extremities of the primary winding of output coil 53 and source 10 of space current is connected to the common filament connection and through a combination of discharge devices to the midpoint of said primary winding. The combination of discharge devices in the space current circuit as shown is the same as that of Fig. 1 and the identity of the various parts may be recognized by the same reference characters as are used in Fig. 1. The action of this combination of discharge devices as described in connection with Fig. 1 and 2 is to limit the current in their common circuit, not by cutting it off definitely at a particular saturation value but at a varying rate somewhat as indicated by the dotted curve B of Fig. 2, so that the signal current variations upon the disturbing waves are not lost. The normal potential of grids 47 and 48 is fixed preferably negative by the source of potential 54 so that either device 45 or 46 normally operates over that portion of its characteristic near the transition from the lower horizontal portion to the substantially linear upwardly sloping portion. An incoming signal wave will render one grid, say 47, at any given instant, more negative than normally and since the impedance of this discharge space is already practically a maximum, due to its large normal negative potential, there will be substantially no change in its output current. The same wave will at the same instant make the potential of grid 48 less negative and therefore the impedance of its discharge space becomes lower, and an output wave, depending upon the extent to which the grid potential is changed, will result. For an incoming wave of alternating current then the discharge devices 45 and 46 alternately conduct current under control of the input waves. The transmission of space current under control of signal current, while it may be regulated to be normally adequate for the reception of signals, is less favorable than if either discharge device 45 or 46 were operating over a more nearly linear and central portion of its characteristic. This more favorable condition is produced in one or the other discharge device 45 or 46 by a sufficiently large disturbing wave of relatively low frequency, since the potential of one or the other grid will be raised momentarily. The corresponding lowering of the potential of the other grid will cause no further increase in the already practically maximum impedance of its discharge space, and transmission of signal current will be through the discharge de-

vice which has a momentarily higher grid potential than normal. In other words, the signal currents are modulated in accordance with the lower frequency disturbing waves, and the signals become stronger the stronger is the disturbing current. As in the case of the arrangement of Fig. 1 the discharge device 4 transmits the normal signal currents, but larger currents than normal begin to find their way through the discharge devices 5 and 6 and become attenuated by the resistances 12 and 13 so that all variable currents of abnormally large amplitude in the common output of the discharge devices 45 and 46 are reduced before they reach the output windings 53 through which they are impressed upon the detector 55 of familiar type by which they are rendered audible in the receiver 56. The signal currents by having been previously boosted may still be as strong as normal, although they have been attenuated together with the disturbing currents.

It will be noted that in the arrangements shown, sharply tuned oscillatory circuits are avoided throughout the path of the received waves until after the waves have passed the current limiting and attenuating means, so that the possibility of shock-excitation of a resonating circuit by a sudden disturbance, whereby an aperiodic impulse is converted into a series of oscillations in the resonating circuit, is avoided. After the currents have been attenuated there is less probability of this effect and a tuning condenser in the detector circuit may be advantageous in selectively transmitting only the signal currents. Condensers 19, Fig. 1, 40 Fig. 4 and 57 Fig. 6 are indicated to be used for this purpose if desired. Any suitable form of wave filter may, of course, be used in place of a single tuned circuit.

Referring now to Fig. 7 the antenna coupling 3 is connected to the input circuit of a detector 58 of familiar type by which the signals are rendered audible in receiver 59. A tuning condenser 60 may be included around the coil winding by closing key 61 if desired. A coupling 3' is also shown, the secondary of which is connected to the input terminals of an amplifier of the "push-pull" type similar in general to that of Fig. 6. This push-pull amplifier differs from that of Fig. 6 mainly by having impressed upon the grids of the discharge devices 64 and 65 a large negative potential from battery 62. It is well known that under this condition the electrons emitted by the filament, when heated, will be forced back thereon and hence no current will flow in the plate circuit. This condition will be unaffected by small potential variations impressed on the grid by normal signals received by the antenna system.

The negative potential of the grids of

devices 64 and 65 is so adjusted that the normal currents are transmitted by the detector 58 and the disturbing currents, if of such large value as to exceed the cut-off value of the detector 58 which value may be suitably predetermined, will change the potential of the grids 64 and 65 of the "push-pull" amplifier sufficiently to enable one or the other side of said amplifier to transmit the signal current. The larger the disturbing current within reasonable limits, the greater will be the amplification of the signal currents as explained in connection with Fig. 6 and the signal currents are thus so augmented that the signals are still strong after the currents have passed the large attenuating resistance 66 in the output of the amplifier. By means of windings 63 and 67 the output waves are impressed on the input circuit of detector 85 by which they are rendered audible in receiver 59. A tuning condenser 69 is shown which may be connected across the coil 67 by closing the key 70 if desired.

Fig. 8 discloses a modulator similar to that of Fig. 7 with the addition of tubes 81 to 85 having the required grid potentials and output resistances to give the operating characteristics shown in Fig. 9, the characteristics of tubes 65, 80, 82 and 84 being respectively the same as those of tubes 64, 81, 83 and 85. The source of electromotive force 62 is of such value, as in Fig. 7, as to normally prevent flow of space current. The two groups of tubes therefore act alternately as the impressed electromotive force reverses in direction. The operating characteristics of the tubes of either group beginning with 64 or 65 are shown at R, S, T and V respectively, Fig. 9, and W is the characteristic of the combination. It will be noted that the curve W may be made substantially parabolic over a relatively very wide operating range and that this modulating system is therefore well adapted for powerful currents. The system may also be used as a detector, and with proper feed-back circuits, will function as a power oscillator. The necessary coupling may be obtained by inductively relating coils 63 to coils 86, for example.

In some of the modifications described above two telephone receivers are disclosed. Ordinarily these may be combined in a single instrument, as in Fig. 7, if desired. In place of telephone receivers, any other type of indicating or recording instrument may be employed. The inventions herein disclosed are well adapted to photographic or tape recording systems or other systems in which a visual record is obtained, as the amplitude of the static or other interfering waves is reduced to a point where a record can always be obtained without obliterating the signal.

While the invention has been illustrated and described with particular reference to a receiving circuit for electromagnetic waves, it is not to be limited to such a system since it is evident that the antenna 1 may be equally well considered as the terminal of a wire line. Also the particular discharge devices illustrated are not to be considered as limiting the invention nor are the relations set out in the various curves that have been given to be considered as limiting the invention but merely as illustrative of principles involved and as aids to a disclosure of the invention. Nor is the invention to be limited in other respects by the specific embodiments shown as a whole or to the particular details, but only by the scope of the appended claims.

What is claimed is:

1. The method of signaling in the presence of a disturbing current which comprises automatically increasing the amplification of the signal current as the disturbing current increases and attenuating the resultant current.

2. The method of receiving signal currents in the presence of abnormal currents which comprises automatically reinforcing said signal currents as the strength of the abnormal currents increases and then causing all said currents to be attenuated.

3. The method of maintaining signal currents in the presence of large abnormal currents which comprises automatically reinforcing said signal currents as the magnitude of said abnormal currents increases.

4. The method of receiving signals by space discharge devices, each including a control electrode having different values of polarizing potentials applied thereto, to produce different degrees of amplification, which method comprises applying such a polarizing potential to one of said devices as to produce one degree of amplification of received signals in the absence of disturbing energy, and applying polarizing potentials to others of said devices such that under control of received disturbing energy a higher degree of amplification for the received signals is effected.

5. In a signal receiving circuit, a signal

energy absorber, a receiver and two parallel current paths between said energy absorber and said receiver, one of said paths containing a detector and the other of said paths containing a detector, an amplifier and an attenuator, and means whereby the elements in said second path become operative only when the energy applied thereto exceeds a fixed value.

6. In a signal receiving circuit, means for intercepting desired currents and undesired currents, means for automatically increasing the amplification of said desired currents as said undesired currents increase, means for attenuating both of said currents in accordance with their magnitude, and means for detecting and receiving said desired currents.

7. In a signal receiving system, a signal energy absorber, an amplifier coupled to said energy absorber comprising two discharge devices, each having a cathode, an anode and an impedance controlling electrode, said cathodes having a common connection and said impedance controlling electrodes being connected to said common connection in opposite sense relative to the coupling with said energy absorber, a receiver, means for connecting said receiver to said anodes, a source of potential connected to said common connection and to said means, and a current-limiting and attenuating means connected between said source of potential and said means.

8. A current limiting circuit comprising a plurality of space discharge devices, a common source of space current for said devices, an attenuator included in the space current path, means for applying to the grids of said space discharge devices a biasing potential of such value that space current is normally prevented from flowing therethrough and means for applying to said grids a potential of such value as to overcome said biasing potential whereby space current is permitted to flow through said space discharge devices.

In witness whereof, I hereunto subscribe my name this 19th day of November, A. D. 1923.

CLARENCE A. SPRAGUE.