June 10, 1930. A. C. DICKIESON 1,762,768

TRANSMISSION SYSTEM

Filed Oct. 30, 1926 3 Sheets-Sheet 1

Fig. 1

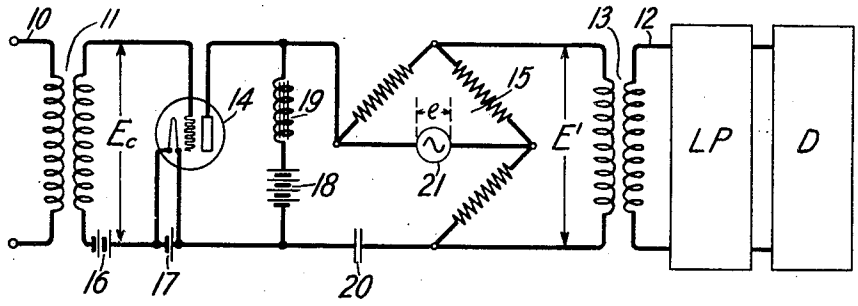


Fig. 4.

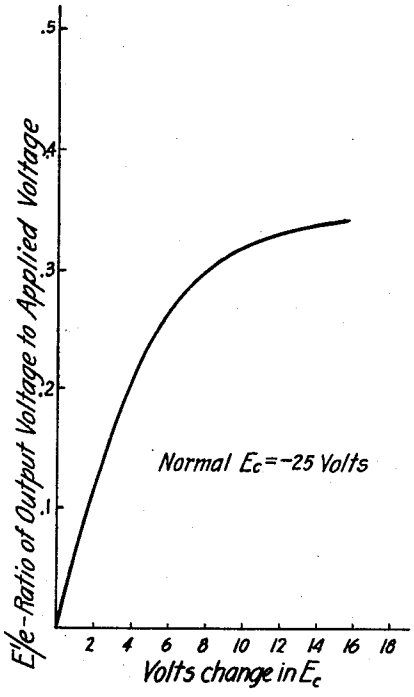
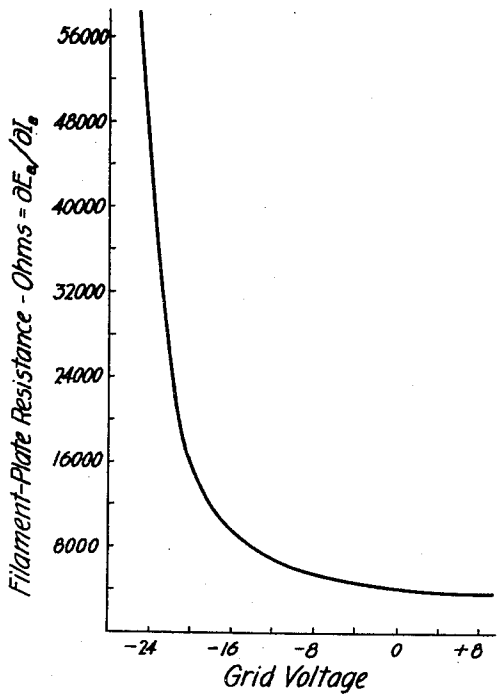


Fig. 3.



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June 10, 1930. A. C. DICKIESON 1,762,768

TRANSMISSION SYSTEM

Filed Oct. 30, 1926 3 Sheets-Sheet 2

Fig.2

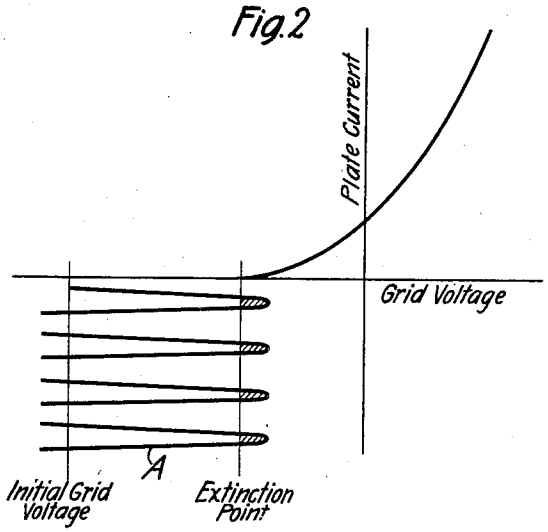
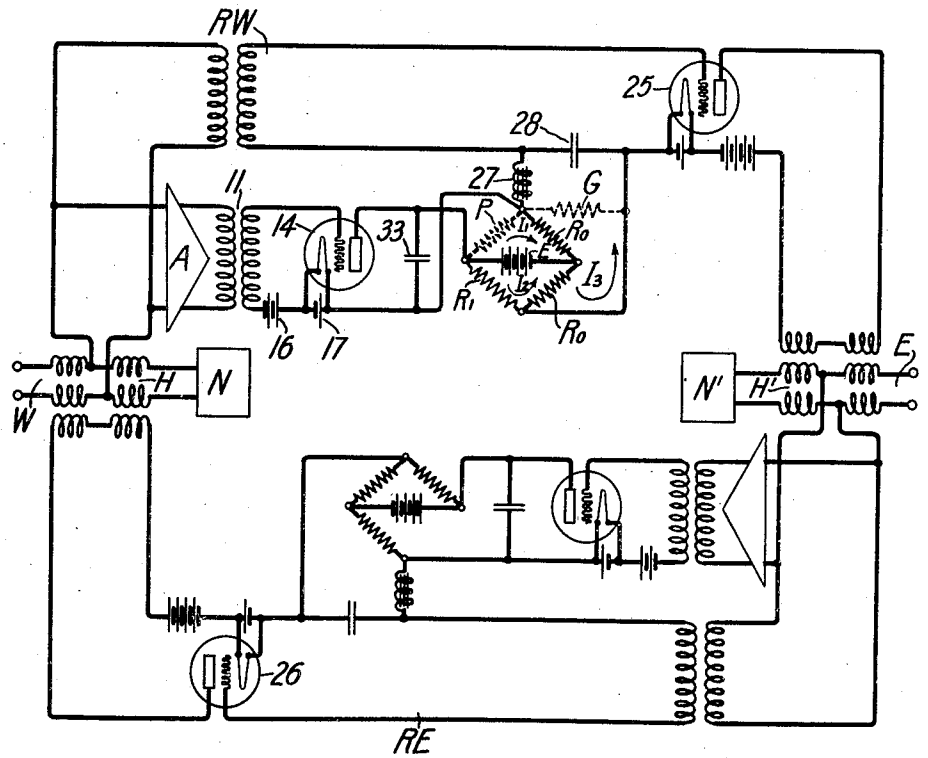


Fig.5



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June 10, 1930. A. C. DICKIESON 1,762,768

TRANSMISSION SYSTEM

Filed Oct. 30, 1926 3 Sheets-Sheet 3

Fig. 7

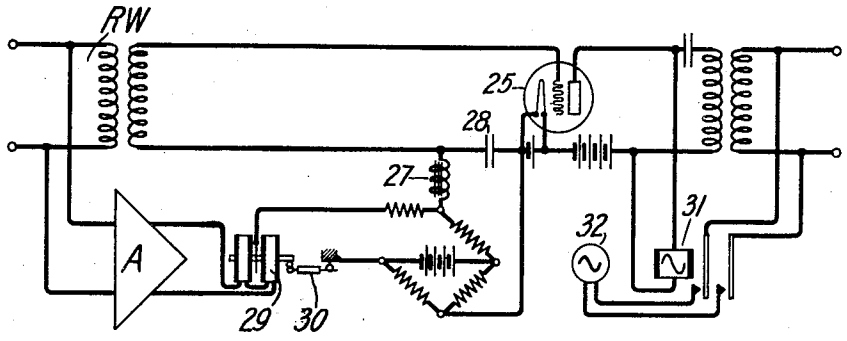
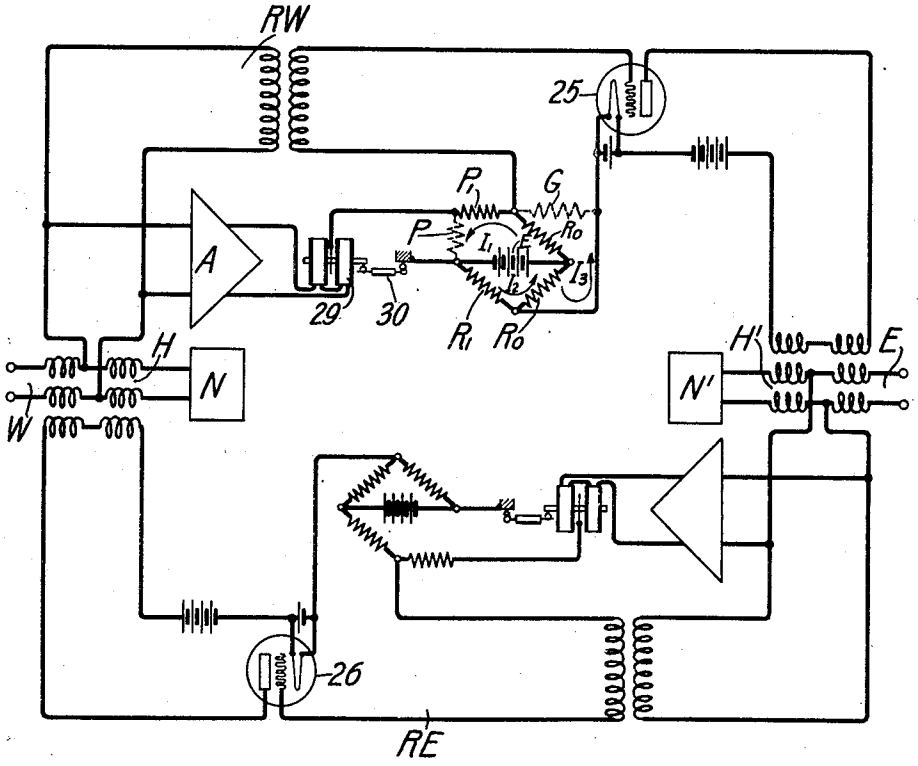


Fig. 6



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UNITED STATES PATENT OFFICE

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TRANSMISSION SYSTEM

Application filed October 30, 1926. Serial No. 145,170.

This invention relates to transmission systems and is especially applicable to electrical signaling.

An object of the invention is to increase the sensitivity and precision of electrical response circuits.

Another object of the invention is to prevent crosstalk and other extraneous noise from passing through a repeater.

A specific object of the invention is to reduce the transmission in a given direction of signals which are transmitted through a repeater in the opposite direction, thereby reducing echo effects.

In carrying out these objects there is provided a sensitive response circuit which is widely useful in the electrical arts, for example to control the application of current to an electrical circuit.

The response circuit in its preferred form comprises a space discharge tube rectifier having the usual grid, filament and plate electrodes. The grid of the tube is made so strongly negative that very little or no current flows in the plate circuit and the filament-plate resistance of the tube is therefore very high or infinite. Under such condition slight changes in the voltage impressed upon the grid of the tube produce large changes in the filament-plate resistance. Great sensitivity is thus obtained by confining the range of operation to the lowermost portion of the input voltage-output current characteristic of the tube. Moreover, it has been found that over the larger portion of this range changes in the filament-plate resistance of the tube are substantially proportional to changes in the grid potential.

According to the invention in one aspect, the plate circuit of the rectifier tube of the arrangement just described is included in one arm of a Wheatstone bridge which may be normally balanced or normally unbalanced, depending upon the purpose for which it is used, and the condition of the bridge is varied in response to changes in the grid potential of the rectifier tube.

The invention in an important aspect is the control of a space discharge tube repeater by the sensitive response circuit to render the former responsive or non-responsive to incoming signals. The plate circuit resistance of the rectifier tube is made high enough to unbalance the Wheatstone bridge when no signals are being received by the repeater. When the bridge is thus unbalanced, a negative biasing potential is impressed upon the grid of the repeater tube, which is strong enough to block this tube. When signals are received at the repeater, however, a portion of the resulting voltage is impressed upon the grid of the rectifier tube and tends to lower the resistance of its plate circuit. This action restores the bridge to a partial balance and reduces the biasing potential upon the grid of the repeater tube to the point where the repeater is operated to transmit the signals.

The invention in the aspect just mentioned is particularly applicable to two-way repeaters having two oppositely directed channels to repeat signals in two directions. Such repeaters usually rely upon a condition of balance between the transmission line sections and artificial balancing circuits to prevent currents which are transmitted through one channel from leaking back through the oppositely directed channel. It is very difficult to maintain this condition of balance, and as a result there are heard echoes which lag slightly behind the original voice currents and produce an unpleasant effect upon the subscriber's ear. This condition of unbalance may cause voice currents to circulate around the repeater, producing singing and tending to distort the amplified signals. Another example of echoes which are particularly troublesome on long transmission lines is that produced by currents meeting an impedance irregularity in traversing the line and being reflected back to the original transmitting station. The reflected currents are amplified in the repeater and appear as echoes in the talking subscriber's own receiver after a time interval which depends upon the electrical characteristics of the line traversed.

Heretofore the undesirable effects caused by echoes in such repeaters or on the line beyond the repeaters have been reduced by disabling one repeater channel whenever signals are being transmitted through the oppo

sitely directed channel. In the case of echoes due to unbalance, the leakage currents are merely dissipated in the idle channel. For the purpose of overcoming echoes caused by reflection beyond the repeater each channel is sometimes equipped with a time delay circuit to render the channel operative a certain time after currents have ceased to flow in the opposite channel. In order to prevent reflected currents from passing back through the repeater to the transmitting station, it is necessary to time the delay circuits of each repeater with great care, depending upon the length of the line over which reflection occurs. It is also well known that such repeaters will amplify crosstalk and other extraneous noise, as well as the ordinary voice currents. The present invention, however, provides a simple and efficient noise and echo suppressor which may be used with different transmission lines without special adjustment. In operation, echoes and other noise effects on the line are too weak to render this repeater operative, the signaling currents being sufficiently strong to operate the repeater.

The invention will be described in connection with the accompanying drawings, in which similar reference characters designate corresponding parts in the several views, and in which:

Fig. 1 is a diagrammatic illustration of a sensitive response circuit embodying the invention;

Figs. 2, 3 and 4 show curves used in describing the operation of the response circuit of Fig. 1;

Fig. 5 is a diagrammatic illustration of a two-way repeater employing the noise and echo suppressor of the invention;

Fig. 6 is a similar view of a two-way repeater employing a modified noise and echo suppressor; and

Fig. 7 is a diagrammatic illustration of a circuit arranged to repeat speech and ringing currents.

The sensitive response circuit shown in Fig. 1 is coupled to an incoming circuit 10 by means of a transformer 11, and is coupled to an outgoing circuit 12 by means of a transformer 13. The response circuit includes a three-electrode space discharge tube rectifier 14 having its input circuit connected to the secondary winding of the transformer 11 and its output circuit forming one arm of a Wheatstone bridge 15. The rectifier 14 is provided with the usual sources of energy 16, 17 and 18 to properly polarize the grid electrode, to heat the cathode, and to furnish anode-cathode current, respectively. Space current from the source 18 is supplied to the rectifier through a choke coil 19. A condenser 20 prevents this current from flowing through the bridge.

The Wheatstone bridge includes a source of sustained oscillations 21 adapted to impress current on the outgoing circuit 12 only when the bridge is unbalanced. The constants of the bridge are so chosen that the bridge is balanced when a predetermined voltage is impressed upon the incoming circuit 10, so that no current from the source 21 will be impressed upon the outgoing circuit 12 at such time. In balancing the bridge, the grid or control electrode of the rectifier tube 14 is made so strongly negative that large changes in the filament-plate resistance result from minute changes in the grid potential. Accordingly, when an increased voltage is impressed upon the grid circuit of the tube through the transformer 11, a substantial change is produced in the filament-plate resistance and the bridge becomes unbalanced.

In the simple application of the invention shown in Fig. 1, the sensitive response circuit may be utilized for testing purposes. A source of waves to be tested, say of 5,000 cycles frequency, may be connected to the circuit 10 in any suitable manner. The source of oscillations 21 may be arranged to produce waves of, say 200 cycles frequency. When a predetermined voltage is impressed upon the circuit 10 the bridge 15 is balanced and no current flows from the source 21 through the transformer 13. When the voltage impressed upon the circuit 10 increases, however, the filament-plate resistance of the rectifier tube 14 decreases, as hereinafter described, and the Wheatstone bridge is unbalanced, permitting current of 200 cycles frequency to flow through the transformer 13. The current which is thus impressed upon the outgoing circuit 12 is selectively transmitted through the low pass filter LP and impressed upon the detector circuit D, which may contain a galvanometer. The low pass filter LP suppresses currents of all frequencies higher than those produced by the source 21, so that the detector D is not affected by the higher frequency currents which are present in the output circuit of the rectifier. The reading of the detector circuit D serves as an indication of the current which is impressed upon the incoming circuit 10.

The operation of the rectifier tube is illustrated by the curves of Fig. 2, in which the ordinates represent the plate current and the abscissæ represent the grid voltage of the tube. As shown by these curves, the initial voltage impressed upon the grid of the rectifier tube by the source 16 is so strongly negative that no plate current flows in the output circuit of the rectifier. Under such condition, the rectifier tube impedance is infinite. The curve A represents variations in voltage which are impressed upon the grid of the rectifier tube through the transformer 11. Only voltage amplitudes which are strong enough to carry the grid potential to the right hand side of the line indicating th

extinction point cause plate current to flow in the output circuit of the rectifier. The shaded portions of this curve may comprise only a small percentage of the impressed wave and still produce a large change in the impedance of the rectifier tube.

The operation of the sensitive response circuit is further illustrated by the curve of Fig. 3 in which the ordinates represent the filament-plate resistance of the rectifier tube and the abscissæ represent the grid voltage. It will be seen from this curve that the filament-plate resistance of the rectifier tube changes from 4,000 ohms at zero grid potential to about 60,000 ohms at minus 25 volts grid potential. If the three simple resistance arms of the Wheatstone bridge shown in Fig. 1 are given a large value, such as 60,000 ohms apiece, and the grid battery 16 is made so strongly negative that the bridge is balanced, then no current flows from the source 21 through the transformer 13 but a small increase in the potential which is impressed upon the grid of the rectifier tube through the transformer 11 will produce a relatively large change in the filament-plate resistance of the tube, thus throwing the bridge off balance and permitting a large voltage to be impressed upon the transformer 13. Great sensitivity is obtained by confining the operation to the substantially straight portion of the characteristic curve.

Fig. 4 illustrates graphically the change produced in the output voltage E′ across the primary winding of the transformer 13 in response to slight changes in the voltage E_c applied to the grid of the rectifier tube. The circuit of Fig. 1 is arranged to detect small changes in the voltage E_c applied to the grid of the rectifier tube 14. The value of the negative grid biasing potential supplied by the source 16 is so chosen that the plate resistance of the rectifier tube is such as to balance the Wheatstone bridge. In the curve of Fig. 4 the normal negative biasing potential is 25 volts. When the bridge is balanced the voltage E′ is equal to zero. If the potential impressed upon the grid of the rectifier is varied, a change is also produced in the filament-plate resistance, unbalancing the bridge and causing the voltage E′ to increase. In other words, as the voltage E_c is increased a larger percentage of the voltage e is impressed upon the primary winding of transformer 13. This change may be read from the curve of Fig. 4. The total voltage impressed upon the grid of the rectifier tube may be very large, but still a change as small as .1 volt will produce a 100% change in the voltage E′. The sensitive response circuit may also be used for other purposes in the electrical arts.

In Fig. 5 the sensitive response circuit is utilized to reduce echoes and singing effects in a two-way telephone repeater, and also to prevent crosstalk and other extraneous noise from passing through the repeater. The repeater comprises two one-way repeating channels RW and RE which are connected to transmission line sections W and E by means of hybrid coils H and H′ and associated balancing networks N and N′. The channel RW includes a three-electrode space discharge tube amplifier 25 and the channel RE includes a similar amplifier 26.

Voice currents which are received from the line section W pass through the hybrid coil H into the channel RW where they are amplified by the amplifier 25 and impressed through hybrid coil H′ upon line section E. Similarly, voice currents received from the line section E pass through hybrid coil H′ into the channel RE and after being amplified in the amplifier 26 are transmitted through hybrid coil H to line section W.

The undesirable noise and echo effects mentioned above are overcome by means of this invention by rendering the space discharge tube amplifiers 25 and 26 operative only in response to voice currents of predetermined strength which are received from the line sections W and E, respectively. The undesirable echoes, crosstalk and other noise effects which, of course, are below the transmission level of the voice currents, are ineffectual to operate the repeater. Each of the channels RW and RE is provided with a branch circuit for controlling the operation of the repeater, but since these circuits are identical, only the circuit associated with the channel RW will be described in detail.

The branch circuit includes the sensitive response circuit, described above, which is coupled by means of the transformer 11 to the output of an amplifier A which has its input circuit connected across the conductors of the channel RW at a point between the hybrid coil H and the amplifier 25. The Wheatstone bridge includes a battery E which supplies space current to the rectifier tube 14 and is also arranged to supply a negative biasing potential to the grid of the amplifier 25 through a choke coil 27. The condenser 28 prevents this battery from being short-circuited. The constants of the circuit are so chosen that the bridge is normally unbalanced and under such condition the biasing potential impressed upon the grid of the amplifier tube 25 from the battery E is so strong that no current flows in the output circuit of this tube. The circuit is so arranged that incoming currents above a predetermined transmission level which are impressed upon the input circuit of the rectifier 14 will tend to balance the bridge and reduce the negative biasing potential upon the grid of the amplifier tube 25 to the point where this tube will be operative to amplify the incoming signals. The condenser 33 provides a low impedance path for the alternating cur-

rents in the output of the rectifier tube. A margin is determined upon between the incoming voice currents and the undesired crosstalk, echoes and other noise, that is, the voice currents must exceed a certain minimum transmission level before they can render the repeater operative. Hence incoming currents, which are too weak to effect the required change in the plate resistance of the rectifier tube 14 will not be transmitted through the amplifier 25.

In describing the operation of the repeater, the plate circuit of the rectifier 14 which is included in the Wheatstone bridge may be represented by the resistance P shown in dotted lines, and the grid circuit of the repeater tube 25 may be represented by a resistance G. For the sake of simplicity it is assumed that the resistance arms R_0 and R_1 are equal and of a value which depends upon the desired value of the filament-plate resistance P. By applying Kirchoff's laws to these circuits the following equations are obtained:

$$E=I_1P+I_1R_0 \quad (1)$$
$$E=I_2R_1+I_2R_0 \quad (2)$$
$$I_1R_0-I_2R_0+2I_3R_0+I_3G=0 \quad (3)$$

The term I_3G is equal to the voltage impressed upon the grid of the repeater tube 25, that is, the grid biasing potential, which may be termed E_{gf}. When the grid of the repeater tube is negative, or non-conducting, the value of G is practically infinite and I_3 is negligible. Therefore, approximately, $2I_3R_0=0$. Substituting in equation (3) and rearranging,

$$E_{gf}=R_0(I_2-I_1) \quad (4)$$

The Wheatstone bridge is balanced when I_2 equals I_1, which occurs when P equals R_1, and at such time E_{gf} equals zero. That is, no voltage is impressed upon the grid of the repeater tube 25 at such time. If P is large compared with R_1, (corresponding to the condition of no input current impressed on the rectifier tube), then I_2 is large compared with I_1. In such case E_{gf} is practically equal to I_2R_0, and substantially half of the voltage E is impressed upon the grid of the repeater tube as a negative grid bias. This last is the condition of the circuit when no current is being impressed upon the input circuit of the rectifier 14. However, when voice currents are impressed upon the grid of the rectifier, the filament-plate resistance P decreases in value, tending to approach the limiting value $P=R_1$. Thus I_1 increases in value and I_2-I_1 decreases. As a result of this action the negative grid biasing potential E_{gf} decreases in value until it reaches the normal operating grid potential for the tube 25. The constants of the circuit are so chosen that P never equals R_1 and hence E_{gf} never reaches zero but approaches the correct grid potential for this tube as the voltage impressed upon the rectifier tube increases.

The repeater circuit shown in Fig. 6 is similar to that shown in Fig. 5 except that the sensitive response circuit comprises a voice operated relay 29 having a contact device 30, this relay being of the type disclosed in U. S. Patent No. 1,579,887 to E. J. Pratt, issued April 6, 1926. This specific bridge circuit is disclosed and claimed in my copending application Serial No. 145,171, filed October 30, 1926. The contact device 30 is included with the resistance P_1 in one arm of the Wheatstone bridge, the contact resistance being represented by the dotted line P. The contact resistance characteristics are such that the resistance remains substantially constant for input voltages within a certain definite range, while above this range the resistance increases rapidly. Applying Kirchoff's laws to these circuits, and assuming the resistance arms to be equal, the following equations are obtained:

$$E=I_1R_0+I_1(P+P_1) \quad (5)$$
$$E=I_2R_0+I_2R_1 \quad (6)$$
$$I_2R_0-I_1R_0+2I_3R_0+I_3G=0 \quad (7)$$

As before, let E_{gf} represent the voltage impressed upon the grid of the repeater tube 25. Then, when G is infinite and the term $2I_3R_0$ is equal to zero.

$$E_{gf}=R_0(I_1-I_2) \quad (8)$$

When no voice currents are impressed upon the windings of relay 29 the contacts are closed and P equals zero. The resistance P_1 is chosen smaller than R_1 so that I_1 is large compared with I_2. That is, a large part of the voltage E is impressed upon the grid of the repeater tube 25 as a biasing potential. When voice currents are impressed on this relay and it begins to operate the resistance $(P+P_1)$ increases and tends to approach the limiting value R_1. Then I_1 decreases and E_{gf} also decreases until it reaches the normal operating grid bias.

Fig. 7 shows a simple embodiment of the invention in which a repeater is arranged to repeat ringing currents as well as speech currents. For the sake of simplicity only the apparatus associated with the channel RW is illustrated. The incoming speech currents are repeated in the manner described above in connection with Fig. 6. The ringing currents comprise 1000 cycle currents interrupted at the rate of 20 cycles per second, such as are commonly employed for ringing purposes in low frequency telephone systems. During quiescent periods when no speech or ringing currents are received in the channel RW, the Wheatstone bridge is unbalanced and no space current flows in the output circuit of the amplifier 25. When the interrupted 1000 cycle ringing current is received in the channel RW the relay 29 is operated and the po-

tential on the grid of the amplifier 25 is reduced in the manner described above, so that space current flows in the output circuit of the amplifier. During the 20 cycle interruptions in the ringing current, however, the relay 29 does not operate and hence no space current flows in the output circuit of the amplifier 25. As a result of this continued action the space current alternately rises and then falls to zero in response to the interrupted ringing currents, thereby producing a 20 cycle current in the output circuit. This current actuates an alternating current relay 31, which is connected in the output circuit of the amplifier and tuned to this frequency. The operation of the relay 31 connects a source of interrupted ringing currents 32 to the outgoing circuit. If desired, a slow releasing relay or other suitable device may be associated with the relay 31 to prevent the possibility of having this relay operate in response to interrupted voice currents.

The invention is also capable of many other modifications and adaptations which differ in detail from those herein shown and described but which are included within the scope of the appended claims.

What is claimed is:

1. A sensitive response circuit comprising a space discharge tube having an anode, a cathode and a grid, a Wheatstone bridge having an arm containing the cathode-anode resistance of said tube, a source of periodically varying potential connected between two opposite terminals of said bridge, and means for impressing a negative biasing potential upon said grid such that small variations in the grid potential produce substantially maximum changes in said resistance.

2. A sensitive response circuit comprising a space discharge tube having an anode, cathode and grid, a Wheatstone bridge having an arm containing the cathode-anode resistance of said tube, a source of potential connected between two opposite terminals of said bridge, a circuit in shunt to said cathode-anode resistance containing a second source of potential and a high impedance, means for preventing current from said second source from flowing in the other arms of said Wheatstone bridge and means for impressing a biasing potential upon said grid so strongly negative that small variations in grid potential produce large changes in said cathode-anode resistance.

3. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, means for impressing a large biasing potential upon said grid to block said amplifier, and means responsive to waves above a certain amplitude to reduce said biasing potential to render said amplifier operative.

4. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, a source of negative biasing potential for said grid, means for rendering a large part of said potential effective to block said amplifier, and means responsive to waves above a certain amplitude to reduce the potential impressed upon said grid.

5. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier for repeating said waves, means comprising a source of biasing voltage for blocking said amplifier, a rectifier for producing a direct current voltage in response to incoming waves, and means to oppose said voltage to the biasing voltage to unblock said amplifier.

6. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, means for impressing a large biasing potential upon said grid to block said amplifier, and a rectifier responsive to incoming waves to reduce said biasing potential to render said amplifier operative.

7. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, a Wheatstone bridge including a source of negative biasing potential effective to bias said grid, and means responsive to incoming waves for controlling the resistance of said bridge, the resistance changes of said bridge varying the biasing potential impressed upon said grid.

8. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, a Wheatstone bridge including a source of negative biasing potential effective to bias said grid, and a rectifier responsive to incoming waves for controlling the resistance of said bridge, the resistance changes of said bridge varying the biasing potential impressed upon said grid.

9. A transmission system comprising a circuit over which waves are transmitted, a space discharge amplifier including a grid for repeating said waves, a Wheatstone bridge including a source of negative biasing potential effective to bias said grid, a space discharge device having an anode, a cathode and a grid and having its cathode-anode resistance in one arm of said bridge, and means for impressing incoming waves upon said device said waves acting to vary said resistance, the resistance variations operating to vary the biasing potential impressed upon the grid of said amplifier.

10. A repeating device having an input-output characteristic which is curved in part and substantially straight in part, a source of current in the output circuit of said re-

peater, a source of potential associated with the input circuit of said repeater for normally blocking it to prevent flow of current through said repeater from said output source, a source of waves to be repeated, and means responsive to said waves to unblock said repeater and cause it to repeat said waves without substantial distortion by utilizing the substantially straight portion of the input-output characteristic.

11. A space discharge repeater comprising an output circuit having a source of space current, and an input circuit, said repeater having an input-output characteristic which is in part substantially straight and in part curved, a source of sets of waves of different amplitude respectively, means for impressing all of said waves upon said repeater, a source of potential for normally blocking the flow of current in said output circuit, said source being of such magnitude that said set of waves of lower amplitude does not unblock said repeater, and means responsive to said set of waves of greater amplitude but not to said set of waves of lesser amplitude for unblocking said repeater.

12. A transmission system comprising two line sections over which signals are transmitted in both directions, a two-way repeater including two space discharge amplifiers having grid electrodes for repeating signals between said line sections, means for impressing a large biasing potential upon said grid electrodes to block said amplifiers, and means associated with each amplifier and responsive to incoming signals above a certain amplitude to reduce said grid potential to render said amplifier operative.

13. A transmission system comprising two line sections over which signals are transmitted in both directions, a two-way repeater including two space discharge amplifiers each having an anode, a cathode and a grid for repeating signals between said line sections, a Wheatstone bridge associated with each amplifier and including a source of negative biasing potential for the grid thereof, a space discharge device associated with each bridge having an anode, a cathode and a grid and having its cathode-anode resistance forming an arm of said bridge, and means for impressing incoming signals upon each of said devices to vary the resistance of its plate circuit and thereby vary the biasing potential impressed upon the grid of the associated amplifier.

14. A transmission system comprising incoming and outgoing lines over which speech and ringing currents are transmitted, a space discharge amplifier having an anode, a cathode and a grid, an input circuit for said amplifier, including said grid and said cathode and connected to said incoming line and an output circuit for said amplifier including said anode and said cathode and connected to said outgoing line, means for impressing a large negative biasing potential upon said grid to block said amplifier, means responsive to said speech and ringing currents to reduce said negative biasing potential to render said amplifier operative, a source of ringing current, and a relay in said output circuit operated in response to incoming ringing currents to connect said source to said outgoing line.

In witness whereof, I hereunto subscribe my name this 21st day of October, A. D. 1926.

ALTON C. DICKIESON.