Sept. 28, 1943. E. W. KENEFAKE 2,330,593

HIGH FREQUENCY COMMUNICATION SYSTEM

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Fig. 1a.

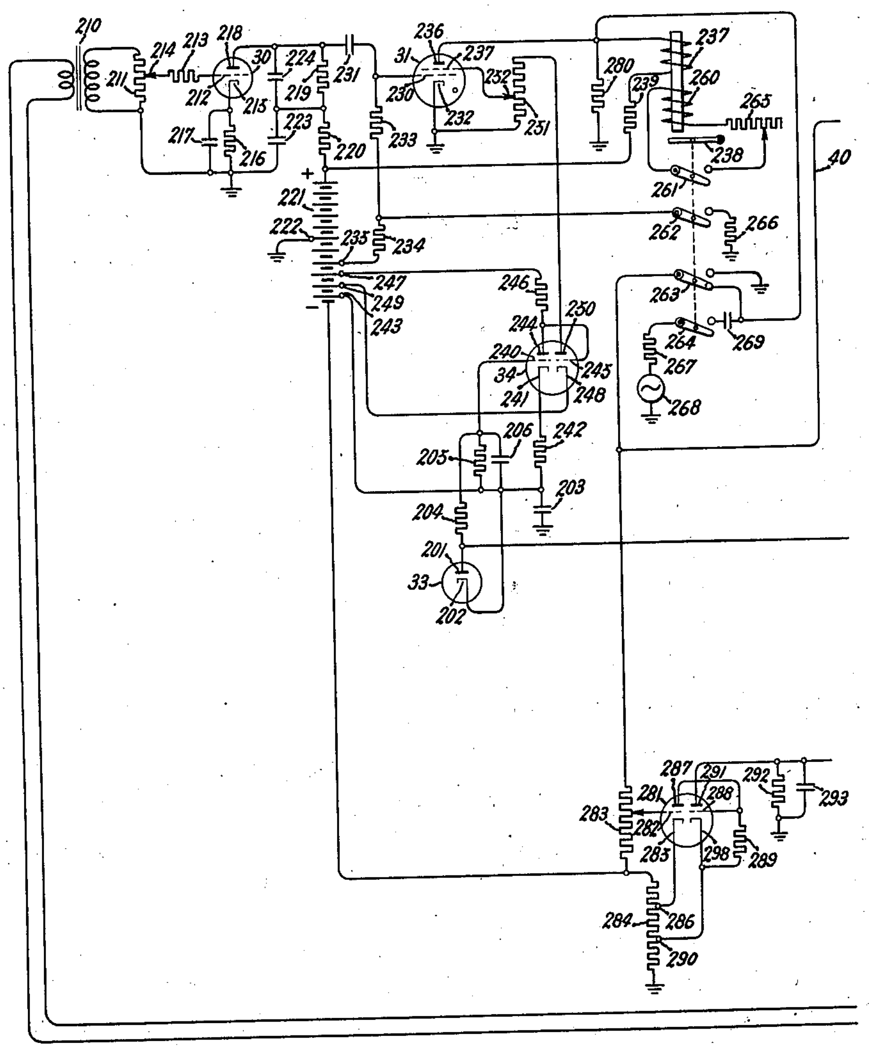

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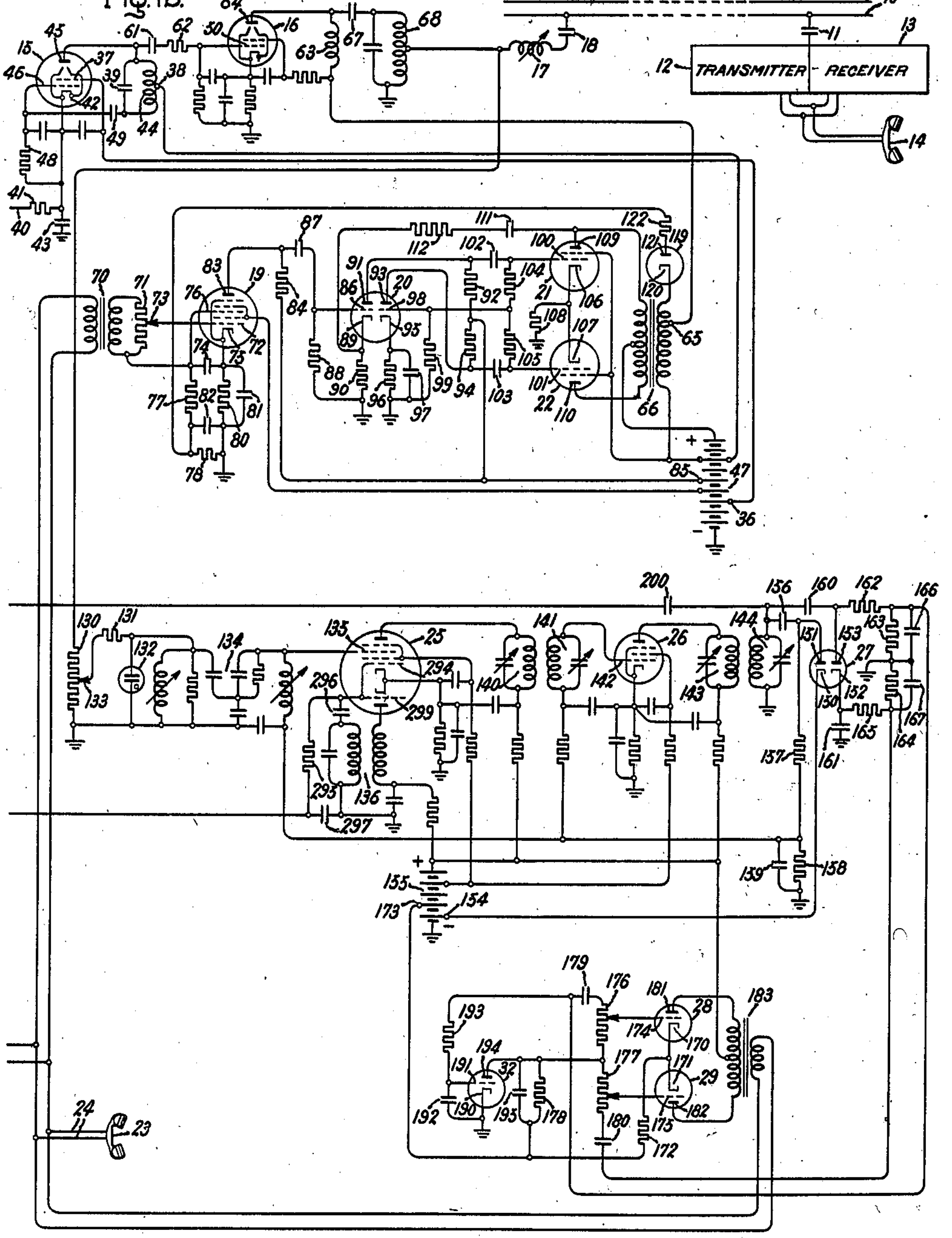
Fig. 1b.



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HIGH FREQUENCY COMMUNICATION SYSTEM

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Application July 11, 1942, Serial No. 450,499

10 Claims. (Cl. 179—1)

This invention relates to high frequency communication apparatus, and more particularly to that type of such apparatus, called duplex equipment, in which the transmission and reception of signals is accomplished at the same carrier frequency.

Duplex high frequency communication equipment is frequently connected to telephone lines to transmit and receive signals over such lines. If the input of the high frequency transmitter and the output of the high frequency receiver are both connected to such a telephone line, some means must be provided to prevent oscillations caused by the transfer of energy from the output of the receiver to the input of the transmitter and from the output of the transmitter to the input of the receiver. Hybrid coils are sometimes used for this purpose, between receiver output and transmitter input, and sometimes an arrangement is provided whereby the telephone line may be switched either to the transmitter or to the receiver.

It is an object of my invention to provide a new and simplified high frequency communication system of such nature in which such a telephone line may be connected permanently both to the transmitter input and to the receiver output without the use of hybrid coils or a switching arrangement.

According to my invention a switching arrangement is provided whereby the transmitter is rendered operative only when signals are transmitted over the telephone line and the receiver is at the same time rendered inoperative so as to prevent oscillations by reason of the connection between the transmitter input and receiver output. The apparatus is also arranged to render the receiver operative and the transmitter inoperative when high frequency signals are received by the receiver, similarly to prevent such oscillations. It is a further object of my invention to provide improved and simplified means for performing such switching in proper sequence and in reduced time such that no noticeable loss of signals occurs due to such switching.

It is an additional object of my invention to provide such an improved and simplified high frequency communication system which is easily connected to telephone lines and which is especially adapted for use in providing carrier current communication over high voltage power transmission lines.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings in which Figs. *1a* and *1b* illustrate schematically an arrangement embodying my invention. These figures are so arranged that the two drawings may be placed side by side, with Fig. *1a* at the left of Fig. *1b*, so that the whole forms a single system with several interconnections between the figures.

In Fig. *1b* a high voltage power transmission line **10** is illustrated as connected at a particular station through a coupling capacitor **11** to a carrier current transmitter represented by rectangle **12** and receiver represented by rectangle **13**, this transmitter and receiver being arranged respectively to transmit signals from and receive signals for a telephone hand set **14**. Signals from the hand set **14** are caused to modulate a desired characteristic, such as the intensity, of a carrier wave in transmitter **12**, which carrier wave is impressed on the transmission line **10** at that station through condenser **11**, for reception at another station. Similarly, signals from such other station are impressed by coupling condenser **11** on receiver **13** and demodulated to be reproduced by the hand set **14**. The coupling condenser **11**, transmitter **12**, receiver **13** and hand set **14** represent equipment similar to that at such other station. The remaining detailed portions of Figs. *1a* and *1b* represent such equipment at such other station along the power line **10**.

In such detailed portions of Fig. *1b*, the transmitter includes an electron discharge device **15**, which acts as a master oscillator, and a second such device **16**, which acts as a power amplifier for the carrier wave, the output of the device **16** being transferred through a tuning inductance **17** and coupling condenser **18** to the power line **10**. The transmitter also includes electron discharge amplifier devices **19**, **20**, **21** and **22** for amplifying signals from a telephone hand set **23** and connected telephone line **24**, and for modulating the intensity of oscillations in the device **16** in accordance with such signals.

The receiver in Fig. *1b* includes an electron discharge device **25**, acting as a frequency converter, an electron discharge device **26**, acting as an intermediate frequency amplifier, a double diode rectifier **27** for demodulating carrier waves, received from the power line **10** through coupling condenser 18 and tuning inductance 17 and amplified through devices 25 and 26. The receiver also includes signal amplifier devices 28 and 29 which, under certain conditions, amplify signals detected by the detector device 27 and transmit such amplified signals through the telephone line 24 to the hand set 23.

The transmitter and receiver, so described, are so arranged that they never operate simultaneously. The carrier wave generated by the transmitter therefore is never demodulated by the receiver, and the demodulated carrier intensity variations fed from the output of devices 28 and 29 through the telephone line connections to the input of discharge device 19, so as to modulate the carrier wave intensity in the same sense as the change of intensity which was detected by device 27, thus resulting in continuous oscillation of the entire system. Control means, provided to prevent such oscillation, is effective to prevent the transmitter and receiver from operating simultaneously. This control means is also arranged so as to be capable of operating with sufficient speed in response to the transmission or reception of signals that no substantial part of the beginning of such transmission or reception is lost.

In Fig. 1*a* the electron discharge amplifier device 30 amplifies signals from the hand set 23 and energizes a vapor discharge device represented at 31 so as to initiate operation of the master oscillator device 15 and to prevent operation of the frequency converter device 25. Details of the manner in which this action is accomplished are set forth hereinafter.

When signals are not present in the system from the hand set 23, the master oscillator device 15 is inoperative and the frequency converter 25 is operative. Under such conditions an electron discharge device 32 in the receiver is effective upon the reception of a signal by the receiver to make the amplifier devices 28 and 29 operative, these devices being normally inoperative, to transmit such received signal to the hand set 23. Such received signal is simultaneously detected by a diode rectifier 33 in Fig. 1*a* and is amplified by a continuous potential amplifier device 34 to prevent the vapor discharge device 31 from operating. In consequence, reception of signals by the receiver is effective to prevent operation of the transmitter, and at the same time opens up the channel from the receiver to the hand set 23.

The master oscillator of the transmitter illustrated in Fig. 1*b*, which includes the discharge device 15, is arranged to be rendered operative or inoperative by switching means in Fig. 1*a*. This switching means is connected between ground and a conductor 40, a cathode biasing resistance 41 being connected between the conductor 40 and the cathode 42 of device 15. A bypassing condenser 43 is connected between the cathode 42 and ground, to maintain cathode 42 at ground potential for high frequency currents.

The master oscillator circuit in Fig. 1*b* includes an inductance 44 which has one terminal connected to the anode 45 of the oscillator discharge device 15, and the other terminal coupled through a suitable coupling condenser 49 to the control electrode 46 of device 15. A tuning condenser 39 is connected in shunt to the inductance 44, thereby forming a resonant circuit 39, 44 tuned to the frequency at which the oscillator operates. An intermediate tap 38 of the inductance 44 is connected to a positive voltage tap of a source 47 of operating potential, whose negative terminal is connected to ground. A grid leak resistance 48 is connected between the control electrode 46 and cathode 42 of device 15.

Whenever conductor 40 is connected to ground, the tuned circuit 39, 44 is thus arranged so as to maintain alternating potentials of opposite phase and of the desired frequency on the anode 45 and control electrode 46 of device 15. The above mentioned switching means connected to conductor 40 is arranged, when it does not connect conductor 40 to ground to impress a positive potential thereon of such magnitude as to make the cathode 42 positive in potential with respect to ground by an amount at least within ten volts of the positive potential applied to the second, or screen, electrode 37 of device 15. This electrode 37 is connected to a suitable tap 36 of source 47 of substantially less positive potential than the tap to which the anode 45 is connected.

When such a positive potential is impressed on the cathode 42 and correspondingly on the control electrode 46 to which cathode 42 is connected by resistance 48, oscillations smoothly die out as the potential of the cathode 42 becomes more positive, such action taking place within a time determined by the sizes of resistance 41 and condenser 43.

For optimum oscillation of an oscillator, the screen electrode and anode of the discharge device are supplied with positive potentials having a more or less fixed relation therebetween. By the arrangement described above, in which the cathode 42 is made less negative with respect to the screen electrode 37 and anode 45 of device 15, this relation between screen electrode voltage and anode voltage of the discharge device is substantially undisturbed, while the oscillation intensity is smoothly decreased by the smooth decreasing of anode voltage and mutual transconductance of the discharge device.

It is of much value to provide such smooth decrease in oscillation intensity of the discharge device 15 whenever positive potential is applied to the conductor 40, to reduce the carrier frequency surges impressed on the power line 10 and consequently on all carrier current receivers connected thereto. Abrupt stoppage of the oscillations produced by device 15 would be produced if the negative bias potential between control electrode 46 and cathode 42 were increased, even if this increase took place very slowly, which abrupt stoppage is avoided by changing the relation between the voltage of cathode 42 and the voltages of the screen electrode 37 and anode 45 as described.

Oscillations produced by the device 15 in the tuned circuit 39, 44 are impressed on the control electrode 50 of the amplifier device 16 through a serially connected condenser 61 and resistance 62. The device 16 is suitably connected to amplify such oscillations, thereby producing amplified oscillations across the inductance 63, connected between the anode 64 of device 16 and a tap 65 on the secondary of the transformer 66, to be described hereinafter. One terminal of the secondary of transformer 66 is connected to the positive tap of the source 47 to which tap 38 of inductance 44 is connected, whereby operating current is supplied to the device 16.

Amplified oscillations appearing across the inductance 63 are coupled through a condenser 67 to a tuned circuit 68, from which such oscillations are transmitted through the tuning inductance 17 and coupling condenser 18 to the power line 10.

The intensity of oscillations from the oscillating discharge device 15 is modulated in the amplifier device 16 in accordance with signals from the hand set 23 by reason of the fact that such signals, after amplification through the discharge devices 19, 20, 21 and 22 are impressed on the transformer 66, through the secondary of which discharge current for the device 16 flows. The telephone line 24 connected to the hand set 23 is connected across the primary of a transformer 70, across the secondary of which a voltage dividing resistance 71 is connected. The first control electrode 72 of the device 19 is connected to an adjustable tap 73 on the voltage dividing resistance 71, and one terminal of the resistance 71 is connected through a by-passing condenser 74 to the cathode 75 of device 19.

The same terminal of the resistance 71 is also connected to the third, or gain control, electrode 76 of the device 19, and through two serially connected resistances 77 and 78 to ground. The cathode 75 is connected through a biasing resistance 80 to ground; a by-passing condenser 81 being connected in shunt to the resistance 80. A by-passing condenser 82 is connected in shunt to the resistance 78 to prevent voltage changes on resistance 78 from occurring rapidly. When voltage changes occur across the resistance 78, the gain of the device 19 is varied by reason of the fact that the average bias potential on the control electrodes 72 and 76 is changed.

Discharge current for the device 19 is supplied to the anode 83 thereof through a resistance 84 from a suitable tap 85 on the source 47 of operating potential. Voltage across resistance 84 is impressed on the control electrode 86 of device 20 through a coupling condenser 87, electrode 86 being connected to ground through a resistance 88. The cathode 89 of device 20 is connected to ground through a resistance 90, the flow of discharge current through such resistance providing suitable operating bias potential for the control electrode 86.

Discharge current for the anode 91 of device 20 is supplied through a resistance 92 from the tap 85 of source 47. Similarly, discharge current for the other anode 93 of device 20 is supplied thereto through a resistance 94 from the tap 85. The other cathode 95 of device 20 is connected to ground through a biasing resistance 96 by-passed by a suitable condenser 97, the control electrode 98 which cooperates with the anode 93 and cathode 95 being connected to ground through a suitable resistance 99.

The discharge devices 21 and 22 are connected in push-pull relation, their respective control electrodes 100 and 101 being coupled respectively to the anodes 91 and 93 of device 20 through condensers 102 and 103. The control electrodes 100 and 101 are respectively connected to the control electrode 98 of device 20 through resistances 104 and 105. The respective cathodes 106 and 107 of the devices 21 and 22 are connected together and to ground through a suitable biasing resistance 108. The anodes 109 and 110 are connected to the respective terminals of the primary of transformer 66, the center tap of such primary being connected to the positive terminal of source 47 thereby to supply discharge current for the operation of the devices 21 and 22.

So connected the amplifier acts to amplify signals from the hand set 23 and to modulate the discharge current supplied from source 47 to the carrier wave amplifier 16 in accordance therewith. To increase the fidelity of such amplification, a resistance 112 is coupled through a coupling condenser 111 between the anode 109 of device 21 and the cathode 89 of device 20. The resistance 112 is made as small as possible without causing oscillation in the amplifier, in order to produce a maximum amount of degeneration from the output of the push-pull stage including devices 21 and 22 to the input of the device 20. Such degeneration is well known to increase the fidelity of amplification of an amplifier.

In order to limit the amount of modulation of discharge current supplied to the device 16 below a predetermined value such that this discharge current for the device 16 never approaches zero, the cathode 120 of a rectifier 119 is connected to that terminal of the secondary of transformer 66 opposite the terminal which is connected to the source 47 of operating potential. The anode 121 of the rectifier 119 is connected through a resistance 122 to a point between the resistances 77 and 78, described above in connection with the device 19. The resistance 122 and the condenser 82 together form a low pass filter circuit, so that when the rectifier 119 passes current, such current being passed only during alterate half cycles, a continuous potential appears across the resistance 78.

This modulation control circuit is described and claimed in the copending application of George M. Brown, for Modulation control systems, Serial No. 346,947, filed July 23, 1940, and assigned to the same assignee as the present application. Its operation depends on the fact that the continuous potential from the source 47 is impressed with equal intensity on the cathode 120 of the rectifier 119 and the anode 64 of the device 16, while the amplified signal potential is impressed on the cathode 120 with greater intensity than on the anode 64, on account of the autotransformer action of the secondary of transformer 66. Accordingly, when the peak intensity of the amplified signals reaches a predetermined percentage of the continuous potential, the rectifier 119 conducts and reduces the gain of the discharge device 19.

The transmitter described is effective, when the conductor 40 is grounded, to generate carrier waves which are transmitted over the power line 10, and to modulate such carrier waves in accordance with signals from the hand set 23. When the transmitter is inoperative, that is, when the conductor 40 is not grounded, carrier waves may be received over the power line 10 and demodulated by the receiver, the demodulated signals being supplied to the hand set 23.

Such carrier waves coming from a distant station over the power line 10 and through the coupling condenser 18 and tuning inductance 17, are impressed across a voltage dividing resistance 130, to which the receiver is connected. A resistance 131 and a vapor discharge device 132 are connected serially between an adjustable tap 133 of the resistance 130 and ground. The vapor discharge device 132 is of the type through which a discharge current passes only after a voltage greater than a critical value has been applied to the electrodes, and which has very low resistance once such discharge current passes. The device 132 acts to prevent large carrier wave voltages, as from the power amplifier device 16, from being impressed on the frequency converter device 25.

Carrier voltage across the device 132 is impressed through a doubly tuned circuit 134 between the third or signal control electrode 135 of the converter device 25 and ground. The converter device 25 is arranged, in well known fashion, to generate, in conjunction with suitable tuning and coupling circuits 136, a local oscillation, and to heterodyne such local oscillation with the signal wave on the control electrode 135 and thereby produce a wave of intermediate frequency. For example, it has been found desirable in certain instances, where the wave impressed on the tuned circuit 134 may be within the range from 50 to 150 kilocycles, to use a local oscillator circuit 136 tunable between 225 and 325 kilocycles and a fixed intermediate frequency of 175 kilocycles. Coupled circuits 140 and 141, tuned to this fixed frequency, are arranged to transfer the output of converter device 25 to the control electrode 142 of device 26. Additional fixed tuned circuits 143 and 144 are arranged to transfer the amplified oscillations of such fixed frequency from device 26 to the rectifier, or detector device 27.

The detector 27 has two separate diodes, respectively including cathode 150 and anode 151 and cathode 152 and anode 153, which perform two separate functions. The first diode including cathode 150 and anode 151 rectifies the amplified carrier wave from tuned circuit 144, when the intensity of that wave is above a predetermined value, and produces a continuous potential for automatic volume control purposes. The other diode including cathode 152 and anode 153 rectifies the carrier wave from the tuned circuit 144 to produce audible signals.

In the first of these diodes, the cathode 150 is maintained at a positive potential with respect to ground by a connection from the cathode 150 to a positive voltage tap 154 on a source 155 of potential, whose negative terminal is grounded. The anode 151 is coupled by a condenser 156 to one terminal of the tuned circuit 144, the other terminal of circuit 144 being grounded. The anode 151 is connected through two serially connected resistances 157 and 158 to ground, the resistance 158 being by-passed for high frequency currents by condenser 159.

The resistance-condenser combination 157, 158, 159 serves as a low pass filter, so that voltage variations across resistance 158 correspond only to variations in the average carrier wave intensity. The control electrodes 135 and 142, which are connected respectively through tuned circuits 134 and 141, are connected through such circuits to ground through the resistance 158. When the carrier wave in the tuned circuit 144 is sufficiently intense to cause the anode 151 and cathode 150 to conduct current, a negative voltage with respect to ground is developed across the resistance 158, which increases the negative bias potential on the control electrodes 135 and 142 with respect to their respective cathodes, so that the gain of the discharge devices 25 and 26 is reduced.

In order that the other diode in the rectifier 27 shall function to detect audible signals modulated upon the carrier wave from tuned circuit 144, the anode 153 is coupled to the ungrounded terminal of the tuned circuit 144 through a condenser 160, and the cathode 152 is coupled to ground through a similar condenser 161. Four resistances 162, 163, 164 and 165 are serially connected in that order between the anode 153 and cathode 152. Each of the resistances 163 and 164 is by-passed for currents of carrier frequency by condensers 166 and 167, respectively, and a point between these two resistances 163 and 164 is connected to ground. Audible signals appear across the resistances 163 and 164 in push-pull, or balanced, relation.

The balanced signal voltages across the resistances 163 and 164 are amplified through devices 28 and 29, which are connected in push-pull or balanced relation. The cathodes 170 and 171 of the devices 28 and 29 are connected together, and through a resistance 172 to a positive voltage tap 173 on the source 155. The respective control electrodes 174 and 175 of the devices 28 and 29 are connected to adjustable taps on voltage dividing resistances 176 and 177. One terminal of each of the resistances 176 and 177 is connected through a resistance 178 to the tap 173 on the source 155 of potential. The remaining terminal of each of the resistances 176 and 177 is connected respectively through coupling condensers 179 and 180 to a point between resistances 162 and 163 and a point between resistances 164 and 165, thereby impressing the detected signal voltages in push-pull relation between the control electrodes 174 and 175.

The anodes 181 and 182 of the devices 28 and 29 are connected to opposite terminals of the primary of a transformer 183, the center tap of the primary being connected to the positive terminal of the source 155. The secondary of transformer 183 is connected to telephone line 24 to transfer signals amplified through the devices 28 and 29 to the hand set 23, where they are reproduced as sound.

The device 32, which is arranged to prevent the transmission of energy through the devices 28 and 29 to the hand set 23 when no carrier wave is received by the receiver, is operated in accordance with the average potential developed across the resistance 163 in the diode detector circuit of the receiver. To this end, the cathode 190 of the device 32 is connected to ground, and the control electrode 191 is connected to ground through a condenser 192, and through a resistance 193 to a point between resistances 162 and 163. The anode 194 of the device 132 is connected to a point between resistances 176, 177 and 178, and is thus supplied with discharge current from the tap 173 of source 155 of operating potential. A condenser 195 is connected in shunt to resistance 178 for a purpose to be explained in detail hereinafter.

When a carrier wave is received by the receiver, a continuous potential appears across the resistance 163, such that the point between resistances 162 and 163 is negative with respect to ground. This negative potential appears on the control electrode 191 of the device 32, which is so arranged that its discharge current is substantally cut off by the presence of this negative potential on its control electrode 191 with respect to the ground potential of its cathode 190. Although the discharge current of device 32 is cut off at a speed determined by resistance 193 and condenser 192, the potential of anode 194 returns to the positive potential of tap 173 of source 155 at a speed determined by the resistance 178 and condenser 195. This speed is adjusted in a manner to be described hereinafter.

When the discharge current of device 32 is thus substantially cut off, substantially no potential drop exists across resistance 178, and the circuit between the control electrodes 174 and 175 of devices 28 and 29 and cathodes 170 and 171 thereof includes no differences of potential, except that across the resistance 172 occasioned by the flow of the discharge current of devices 28 and 29 therethrough. This potential across the resistance 172 is adjusted to a value such as to provide a suitable operating bias for the control electrodes 174 and 175.

When the receiver is not receiving a carrier wave, the potential across resistance 163 is reduced substantially, and the potential of control electrode 191 accordingly approaches the potential of cathode 190 of discharge device 32. Consequently, discharge device 32 passes discharge current and a potential drop appears across the resistance 178 at a speed determined by the anode to cathode resistance of the device 32 and by the size of condenser 195. That is, the speed with which voltage appears across the condenser 195 is determined primarily by the resistance between the anode 194 and cathode 190 of device 32, while the speed with which this voltage disappears when the device 32 is cut off is determined primarily by the size of resistance 178.

According to my invention, voltage should be built up across the condenser 195 to silence the output of devices 28 and 29 in the hand set 23 more rapidly than this voltage is allowed to disappear. In one case, for example, a device 32 was used whose anode-cathode resistance was of such a value, and a condenser 195 was used of such size; that, when voltage disappeared from resistance 163, sufficient voltage was built up across condenser 195 to silence the devices 28 and 29 in about three milliseconds.

The resistance 178 was made sufficiently large that it took about six milliseconds after reception of a carrier wave for the voltage to disappear from condenser 195 sufficiently to allow devices 28 and 29 to reproduce signals in the hand set 23. This delay in allowing the devices 28 and 29 to reproduce signals is desirable in order to allow transients in the distant transmitter, in the power line, and in the receiver circuits to die out before energizing the hand set 23 from the receiver. Such transients are caused by the extremely rapid switching utilized in transmitters and associated equipment according to my invention. The six milliseconds delay in energizing the hand set 23 from the receiver, added to the inevitable delay in starting the transmitter in response to signals to be transmitted is sufficiently short that the loss of even the beginning of the first syllable at the beginning of a transmission is avoided.

The condenser 192 in conjunction with the resistance 193 serves to prevent very rapid changes in the conductivity of device 32, which might be caused by noise pulses appearing across the resistance 163 and lasting only for very short times. The low pass filter including resistance 193 and condenser 192 serves to prevent any voltage change on the control electrode 191 in response to such voltages of short duration, and thus to prevent false operation of the noise suppression circuit including the device 32 in response to such short voltage pulses.

In addition to the above described means for silencing the output of the receiver in the absence of the received carrier, additional means is provided to prevent operation of the transmitter while a carrier wave is being received by the receiver. When a carrier wave is received by the receiver so that a voltage of intermediate frequency appears across the tuned circuit 144, this voltage is impressed across the rectifier device 33 in Fig. 1*a* through a coupling condenser 200 connected between the ungrounded terminal of tuned circuit 144 and the anode 201 of discharge device 33, the cathode 202 of device 33 being connected to ground by a condenser 203. A circuit for unidirectional current is provided between the anode 201 and cathode 202 through a pair of serially connected resistances 204 and 205 connected between such anode and cathode. The resistance 205 is shunted by a condenser 206 whose reactance is low at the intermediate frequency to which tuned circuit 143 is resonant, but whose reactance is high at frequencies at which the intensity of the intermediate frequency carrier wave changes. Consequently such intermediate frequency carrier waves are rectified in the device 33 and a unidirectional potential appears across the resistance 205 within a short time after the reception of carrier waves by the receiver, this time being, for example, in the order of 1 millisecond or less. This unidirectional voltage across the resistance 205 is utilized to prevent operation of the transmitter, which operation might otherwise be caused by signals from the hand set 23 impressed on the transmitter, or by received signals from the receiver.

The apparatus which initiates operation of the transmitter in response to signals from the hand set 23, and which is blocked by voltage across the resistance 205, includes a transformer 210, the primary of which is energized through telephone line 24 by signals from the hand set 23. That is, the primary of transformer 210 is connected in parallel with the primaries of transformers 70 and 183, all three primaries being connected to the telephone line 24. A voltage dividing resistance 211 is connected in shunt to the secondary of the transformer 210 and one end thereof is grounded. The control electrode 212 of discharge device 30 is connected through a resistance 213 to an adjustable tap 214 of the resistance 211, and the cathode 215 is connected through a shunt combination of resistance 216 and capacity 217 to ground. The anode 218 of the device 30 is connected through a pair of serially connected resistances 219 and 220 to the positive terminal of a source 221 of operating potential, an intermediate tap 222 of which is ground. A point between resistances 219 and 220 is connected to ground through a condenser 223 to maintain such point at ground potential for signal frequency currents. Another condenser 224 is connected in shunt to resistance 219 to decrease the intensity of higher frequency components of signals amplified through the device 30.

So connected, the device 30 acts to amplify most efficiently middle frequency components of signals impressed on the transformer 210, such middle frequency components being, for example, of the order of 2500 cycles.

The principal reason for using condenser 224 is to prevent the production of parasitic oscillations by the device 30, or the amplification of high frequency energy which may be picked up from the transmitter mounted in close proximity, and also to reduce the transmission of high frequency noise components through device 30. In one particular case the device 30 was a 6SQ7, the condenser 224 was 0.001 microfarad and resistance 219 was 100,000 ohms.

The signal frequency voltages developed across resistance 219 by the amplifier 30 are impressed on the control electrode 230 of the vapor discharge device 31 through a coupling condenser 231. The cathode 232 of the device 31 is grounded, and the control electrode 230 is connected through two serially connected resistances 233 and 234 to a suitable tap 235 of the source 221 at a negative potential with respect to the tap 222 and ground. The negative potential between the tap 222 and 235 is sufficient, when no signal is applied to the control electrode 230, to maintain the device 31 nonconductive. Discharge current is supplied to the anode 236 of the device 31 through the actuating winding 237 of a relay having an armature 238, and through a resistance 239 from the positive terminal of the source 221.

Signals amplified by device 30 which appear across the resistance 219 are impressed through the coupling condenser 231 on the control electrode 230 with sufficient intensity to decrease its negative potential during a portion of each cycle sufficiently so that the device 31 becomes conductive.

The condenser 231 and resistance 233 are so proportioned that signals of all frequencies from the hand set 23 are impressed on the control electrode 230 of device 31 with substantially equal intensities. This is to insure that the transmitter shall be started with equal speed, whether a message be started with a high frequency syllable, such as one including a sibilant, or a low frequency syllable, such as one of the vowel sounds. It is well known that low frequency sound signals in general contain much more energy than high frequency sound signals. The condenser 231 is therefore made small in capacity so that such low frequency sound signals are not transmitted to the control electrodes 230 in larger relative intensity than high frequency sound signals. In the case discussed above in connection with the condenser 224 and resistance 219, it was found desirable to make the condenser 231 of 0.001 microfarad and the resistance 233 of 250,000 ohms. The device 31 was a type 2051 gas tetrode. With such values, transmission of signals from resistance 219 to the control electrode 230 of device 31 was reduced in increasing amounts at frequencies below 800 cycles.

The device 31 has a second control electrode 237 which, during normal operation of the device 31, may be maintained near the potential of the cathode 232, but which, when it is made sufficiently negative with respect to the cathode 232, prevents discharge current from flowing in the device 31 even though the control electrode 230 is made positive. That is, whenever either of the control electrodes 230 or 237 is maintained sufficiently negative with respect to the cathode 232, discharge current cannot be initiated in the device 31.

Means is provided to prevent the initiation of the flow of discharge current in device 31 by maintaining the control electrode 237 negative with respect to cathode 232 whenever a signal is received by the receiver. As explained previously, whenever a signal is received by the receiver, a unidirectional potential appears across the resistance 205. This potential across resistance 205 is amplified through the continuous potential amplifier device 34 and, after amplification, maintains the control electrode 237 negative with respect to cathode 232, whenever a unidirectional potential exists across resistance 205.

The continuous potential amplifier device 34 may, as illustrated, include two triode amplifier sections, and may, for example, be a 6C8G twin triode, the control electrode 240 of one section being connected ot a point between resistances 204 and 205. The cathode 241 of this triode section is connected through a resistance 242 to the cathode 202 of rectifier device 33, and to a tap 243 on the source 221 at a potential with respect to tap 222 and ground, which potential is considerably more negative than that of the tap 235. The anode 244 of this triode section is connected to the control electrode 245 of the other triode section, and is also connected through a resistance 246 to a tap 247 on the source 221 of potential more negative with respect to ground than the potential of tap 235, but substantially less negative than the potential of tap 243 to which the cathode 241 is connected.

The cathode 248 of the other triode section is connected to a tap 249 on the source 221 whose negative potential is intermediate in value the negative potentials of the taps 247 and 243. The anode 250 of this other triode section of the device 34 is connected through a voltage dividing resistance 251 to ground. The control electrode 237 of the vapor discharge device 31 is connected to an adjustable tap 252 on the voltage dividing resistance 251.

In operation, the continuous potential amplifier is supplied with discharge current from the source 221. When substantially no voltage exists across the resistance 205, in the absence of a signal in the carrier wave receiver, the control electrode 240 is at a minimum negative bias potential with respect to the cathode 241, so that a maximum discharge current flows through the anode 244. The size of resistance 246 and the potentials of the taps 247, 249 and 243 with respect to each other and with respect to ground are so adjusted that the control electrode 245 is sufficiently negative with respect to the cathode 248 that substantially no discharge current flows in the anode 250, and consequently the control electrode 237 of the vapor discharge device 31 remains substantially at the potential of the grounded cathode 232. Thus, whenever a signal is impressed on transformer 210 from the hand set 23, making the control electrode 230 positive with respect to cathode 232, the discharge device 31 is caused to carry discharge current and initiate operation of the transmitter, and is not prevented by a negative potential on control electrode 237.

Whenever the carrier wave receiver is receiving a signal and a continuous potential exists across the resistance 205, the control electrode 240 becomes more negative with respect to the cathode 241 and reduces the discharge current in the anode 244. The potential of control electrode 245 then becomes less negative with respect to the cathode 248 and discharge current flows in the anode 250. Since the potential of the cathode 248 is fixed at a negative value with respect to ground, the potential of the anode 250 when discharge current flows therein becomes negative with respect to ground and the voltage dividing resistance 251 consequently impresses a negative potential on the control electrode 237. The intensity of this negative potential on the control electrode 237 may be adjusted by the adjustable tap 252, so as to prevent discharge current from flowing in the vapor discharge device 31 even though the control electrode 230 becomes positive with respect to cathode 232.

Under some conditions of operation it may be desired to break in on a message from a distant station, even though the operator at the distant station is still operating his transmitter, and the receiver is still receiving a carrier wave so that the control electrode 237 of vapor discharge device 31 is still negative in potential. If this type of operation be desired, the negative potential impressed on the control electrode 237 of vapor discharge device 31 may be reduced by suitable adjustment of the tap 252 of voltage dividing resistance 251, so that, when a particularly intense signal is applied to control electrode 230 through the hand set 23, the control electrode 230 will be made sufficiently positive with respect to cathode 232 as to overcome the effect of the negative potential on control electrode 237, thereby making the vapor discharge device 31 pass discharge current, even though the receiver is at the time receiving a signal. The adjustable tap 252 on the resistance 251 allows the control equipment to be adjusted, therefore, in either manner, so that the transmitter can never be operated when the receiver is operating, or alternatively so that the transmitter can be operated by shouting or whistling into the hand set 23 even when the receiver is operating.

Such adjustment of the adjustable tap 252 of the voltage dividing resistance 251 may also be made where it is desired to force the transmitter into operation in the presence of received noise of high intensity. Under certain circumstances, random noise voltages and the like may be received by the receiver and detected by the rectifier device 33 so as to apply a negative bias potential on the control electrode 237 of the vapor discharge device 31. Obviously, it is desirable in the presence of such high noise voltages, to reduce the negative potential applied to control electrode 237 to such a value that the transmitter can be turned on by whistling or shouting in the hand set 23.

The vapor discharge device 31 and the relay including operating coil 237 and armature 238 are so connected and arranged, together with the master oscillator device 15, that, immediately after the vapor discharge device 31 begins to carry current, the master oscillator device 15 produces oscillations, and the relay maintains the oscillator device 15 in operation for a predetermined time after the cessation of discharge current in vapor discharge device 31. The relay is also arranged so that it is operated in response to the flow of discharge current in the vapor discharge device 31 with minimum time delay, and is further arranged to reduce the negative bias potential on the control electrode 230 of device 31 so as to make it easier for signals from the hand set 23 to maintain the device 31 conductive after it has once become conductive. The relay is also arranged to apply an alternating potential to the anode 236 of vapor discharge device 31 after it has become conductive, so that, during alternate half cycles of the applied alternating potential, the control electrodes 230 and 237 may stop the flow of discharge current whenever a suitable negative potential is applied thereto. The vapor discharge device 31 and relay together are arranged to block the operation of the carrier wave receiver even before the oscillator device 15 is made to operate.

In order that the relay shall open a predetermined time after the vapor discharge device 31 stops passing current, a coil 260 is provided, in inductive relation with the operating coil 237. Four switches 261, 262, 263 and 264 are provided, operated by the armature 238. The coil 260, normally open switch 261, and an adjustable resistance 265 are connected in series, so that, when the operating coil 237 is deenergized, current tends to continue flowing in the coil 260 and resistance 265, thereby maintaining the armature 238 in operated position for a time determined by the adjustment of resistance 265. A delay of about 150 to 300 milliseconds may be provided between the deenergization of operating coil 237 and the opening of switches 261, 262, 263 and 264.

Switch 262 of the relay is arranged to reduce the negative bias potential on control electrode 230 of vapor discharge device 31, so that signals from the hand set 23 may easily maintain the device 31 conductive after it has once been rendered conductive. For this purpose the switch 262 and a resistance 266 are connected serially between ground and a point between the resistances 233 and 234. Resistances 234 and 266 act as a voltage dividing resistance, so that, when switch 262 is closed, only a portion of the negative potential between tap 235 of the source 221 and ground is applied to the control electrode 230.

Switch 264 of the relay is arranged to apply an alternating potential to the anode 236 of vapor discharge device 31 when the relay is energized, so that the vapor discharge device 31 may be rendered nonconductive if either of the control electrodes 230 or 237 assumes a negative potential with respect to cathode 232. For this purpose a resistance 267 and a source 268 of alternating potential are connected serially between the switch 264 and ground, and a coupling condenser 269 is connected between switch 264 and the anode 236 of discharge device 31.

Switch 263 of the relay is arranged so that in the deenergized position of the relay conductor 40 of Fig. 1b is connected through switch 263 to the anode 236 of vapor discharge device 31. As explained previously, whenever conductor 40 is maintained at ground potential, the oscillating discharge device 15 produces carrier frequency oscillations. Connection of the conductor 40 through switch 263 to the anode 236 of device 31 is also effective, when device 31 is nonconductive, to maintain the cathode 42 and electrode 46 of oscillating device 15 at a positive potential, whose magnitude was explained previously, with respect to ground, by reason of the connection through the operating coil 237 and resistance 239 to the positive terminal of source 221. As pointed out thus previously, whenever cathode 42 of oscillating device 15 is at such a suitable positive potential, the oscillating device 15 is effectively prevented from producing oscillations.

Switch 263 of the relay is also arranged so as to connect conductor 40 directly to ground whenever the relay is in its energized position. By such connection, it is necessary for the vapor discharge device 31 to carry the discharge current of oscillating device 15 only for a short time immediately after the vapor discharge device 31 is first made conductive. Also, the oscillating device 15 by this direct connection to ground is maintained in operation so long as the relay is in its energized position, which persists for a predetermined time after the vapor discharge device 31 becomes nonconductive by reason of the action of coil 260 of the relay and switch 261 and resistance 265. This delay in turning off the carrier wave generator of the transmitter is desirable so that the transmitter does not turn off between syllables or between words of a message, but turns off only when a message is finished. It is generally found that a delay in turning off the carrier wave generator of the transmitter of 150 to 300 milliseconds, as mentioned previously, is sufficient for this purpose.

It is desirable that the relay including switch 263 operate as fast as possible, preferably within 8 milliseconds after its energization, in order that the cathode 42 of the master oscillator discharge device 15 shall be connected directly to ground through switch 263 before the noise suppression circuit of the distant receiver shall energize the hand set 14 at that receiver. If these time relations are not observed, and the noise suppression circuit in receiver 13 opens the channel to hand set 14 before the relay including switch 263 operates, the operation of switch 263 causes the master oscillator device 15 to stop operation for an instant as the switch 263 passes between its contacts.

In order to provide fast operation of the relay, a higher voltage than necessary to operate the relay is applied to its operating coil 237 from source 221, and the steady current after operation of the relay is limited by resistance 239. Also, a resistance 280 is connected between the anode 236 of vapor discharge device 31 and ground, so that, when device 31 is not conductive, a small current flows through the operating coil 237 of the relay, which current is not quite sufficient to operate the relay or even to maintain it operated. By providing this initial current to the operating winding 237 of the relay and by impressing a voltage across the winding greater than that necessary to operate it, very fast operation may be attained. As pointed out above, it is desired that the relay shall be operated to its energized position before the noise suppression circuit in the distant receiver 13 shall energize the hand set 14.

In addition to the previously described control arrangement, another continuous potential amplifier device 281 is provided which is responsive to changes of potential on the conductor 40 for rendering the converter device 25 in the receiver operative or inoperative. The device 281 may conveniently be a type 6C8G twin triode unit similar to the device 34. The control electrode 282 of one section of the device 281 is connected to the adjustable tap of a voltage dividing resistance 283, which is connected between the conductor 40 and the negative terminal of the source 221. Another voltage dividing resistance 284 is connected between the negative terminal of source 221 and ground, the cathode 285 of the first section of the twin triode device 281 being connected to a tap 286 on the resistance 284. The anode 287 of this section is connected to the control electrode 288 of the other triode section of device 281, and is also connected through a resistance 289 to another tap 290 on resistance 284 which is less negative in potential than the tap 286. The cathode 298 of this other triode section of device 281 is also connected to the tap 290, and the anode 291 of this other triode section is connected through a resistance 292, shunted by a condenser 293, to ground.

The twin triode device 281 and its associated connections as thus described are so adjusted that when the potential of the anode 236 of vapor discharge device 31 plus the negative potential with respect to ground of source 221 are impressed across resistance 283, substantially no potential exists across the resistance 292. Also, when the conductor 40 is connected to ground, either through the vapor discharge device 31, when it is conductive, or through the switch 263 directly to ground, a potential appears across the resistance 292 such that the anode 291 of the second triode unit in device 281 becomes negative with respect to ground.

In order to block the operation of the converter device 25 of the receiver in response to negative voltage developed across the resistance 292, this negative voltage is applied to the control electrodes 294 and 299 of device 25, these two control electrodes being connected together and to the anode 291 of the second triode section of device 281 through a grid resistance 295. The control electrodes 294 and 299 are coupled to the tuned circuit 136 of the oscillator section through a coupling condenser 296. That terminal of the resistance 295 opposite the control electrode 294 is connected to ground at the converter device 25 through a by-passing condenser 297 which is small with respect to the condenser 293. The condenser 297 should have a reactance which is low at the frequency of operation of the tuned circuit 136.

The time within which a negative voltage is built up across the condenser 293 depends on the size of the condensers 293 and 297 and the anode to cathode resistance of the second triode section of device 281 including the anode 291 and cathode 298. It is desirable that the time of charging this condenser 293 to a sufficiently negative potential to prevent the operation of converter device 25 be small, as for example 2 milliseconds.

Of course, as the connections for device 281 are illustrated, the voltage dividing resistance 284 also contributes to the time constant of the circuit including the condenser 293. If the power delivering capability of the source 221 be made relatively small, so that the voltage dividing resistance 284 must be relatively large, it may be that the resistance 284 is larger than the anode-to-cathode resistance of one section of the device 281. In any case the charging time of the condenser 293 should be small, and preferably 2 milliseconds or less.

In a particular case where the source 221 delivered about 150 volts negative potential with respect to ground, and the voltage dividing resistance 284 was of the order of 50,000 to 75,000 ohms, the device 281 being a 6C8G twin triode unit, the condenser 293 was made 0.1 microfarad. The condenser 297 was much smaller than condenser 293, condenser 296 was about 200 micro-microfarads, and resistance 295 was about 100,000 ohms.

It is desired that, after the conductor 40 has been disconnected from ground and returned to a positive potential, the converter device 25 shall remain inoperative for a relatively long period, in the order of 25 to 50 milliseconds. In order to accomplish this the resistance 292 must be relatively large, so that the condenser 293 discharges therethrough relatively slowly. In the particular case described, this resistance 292 was 1 megohm.

It was found that the oscillator section of the converter device 25 would operate properly, even with this high resistance 292 in its control electrode cathode circuit, provided the condenser 296 be sufficiently small. If the condenser 296 be too large, blocking of the oscillator section results, producing a kind of superregenerative action or an audible blocking. The necessity for making condenser 296 small can be avoided by using a smaller resistance 284 as the voltage divider, so that the negative potentials of the taps 286 and 290 are more nearly fixed, whereby the condenser 293 may be made larger and its charge time still remain small, with the result that the resistance 292 may be made smaller, thereby reducing the possibility of superregenerative blocking action in the oscillator section of converter device 25.

The blocking of the receiver is brought about by impressing a large negative bias potential on the control grid of the oscillator section of the frequency converter device 25 as well as on the control grid of the mixer, or heterodyne, section of the frequency converter device 25. By providing this negative blocking potential on both of these control electrodes, the possibility of the production of intermediate frequency potentials is made small, and the possibility of any carrier wave reaching the detector device 27 is minimized.

As described, there are four different control arrangements, each of which performs two control operations. Control means is provided which responds to signals from the hand set 23 to start and stop the generation of a carrier wave. Control means is provided, responsive to signals from the hand set 23, to make operative or inoperative the frequency converter device 25 in the receiver. Control means is provided responsive to signals received in the receiver for preventing or allowing the first control means to control generation of a carrier wave in response to signals from the hand set 23. Finally, control means is provided responsive to signals received in the receiver for transferring such signals from the receiver to the hand set 23.

The eight operating times of these four control means are so correlated as to make it possible to connect the hand set 23 directly with the transformers 70 and 183 without producing oscillation between the transmitter and receiver. There are two conditions under which the entire apparatus at a particular station is used, one condition being that of the transmission of a message, and the other condition being that of reception of a message. Under each such condition two sets of operating times are involved, one occurring at the beginning of the message and another at the end of the message. In each case an operation is performed both on the transmitter and on the receiver to make one operative and the other inoperative, or, at the end of a message, to put the receiver into condition to receive a signal.

The operating sequences of the entire apparatus may now be described. When the apparatus is in standby condition, and a sound impinges on hand set 23 of sufficient intensity to cause transmission, this sound is amplified through amplifier device 30 and causes vapor discharge device 31 to become conductive. Within a very short time and before relay 237, 260 operates to close any of its contacts the continuous potential amplifier device 281 produces a large negative bias potential on the control electrodes 294 and 299 of the frequency converter device 25 in the receiver, to prevent operation of the receiver. Shortly, and as soon as possible thereafter, the potential of the cathode 42 of oscillating discharge device 15 reaches a value such that oscillations are generated, and are modulated in the carrier wave amplifier device 64 in accordance with the signals from the hand set 23 which initiated operations. As pointed out previously, the receiver may, for example, be rendered inoperative in response to signals from hand set 23 in about 2 milliseconds, and the transmitter may be made to generate oscillations to be modulated in accordance with such signals in about 3 milliseconds.

So long as signals continue to be impressed from the hand set 23 upon the vapor discharge device 31 to maintain it conductive, transmission continues. Transmission of the carrier wave also continues in the absence of such signals, so long as such signals from the hand set 23 are not absent for more than the time required after deenergization of the operating coil 237 for the relay to move to its unoperated position. As pointed out previously, the relay operates after about eight milliseconds and it may be adjusted so that it remains in its operated position for 150 to 300 milliseconds after the vapor discharge device 31 becomes nonconductive. Thus, if signals from the hand set 23 are not interrupted for periods longer than 150 to 300 milliseconds, the relay does not move to its unoperated position, and the transmission of carrier waves is continued. At the end of the message, a period occurs without signals from hand set 23 whose duration is greater than the period required for the relay to move to its unoperated position, and at the end of that time transmission of the carrier wave is discontinued.

When transmission of the carrier wave is discontinued, the continuous potential amplifier device 281 allows the condenser 293 to discharge through resistance 292, and eventually the frequency converter device 25 becomes operative again. The device 25 may, for example, become operative within 25 or 30 milliseconds after the transmission of the carrier wave discontinues.

If, during the reception of a message or noise, the transmitter be started by shouting or whistling into the hand set 23 as explained previously, the frequency converter device 25 in the receiver is first blocked and then the oscillating device 15 is caused to begin the transmission of a carrier wave. Under no condition can the receiver be operative when a carrier wave is being transmitted. There is therefore no possibility of oscillation through the transmitter and receiver even though both are connected directly to telephone line 24.

Upon the reception of a carrier wave over the power line 10, as from a distant station including the hand set 14, the receiver first energizes the rectifier device 33 in the control apparatus of Fig. 1*a*, and, through the continuous potential amplifier device 34, blocks the vapor discharge device 31 from becoming conductive. Thereafter, the noise suppression arrangement in the receiver including the discharge device 32 makes the amplifier devices 28 and 29 operative to impress received and demodulated signals on the hand set 23. The time required for the operation of the noise suppression circuit to energize the hand set 23 from received signals after reception of the carrier wave by the receiver should be in the order of 6 milliseconds in order to allow surges of various sorts in the system to die out. The continuous potential amplifier device 34 should be effective to put a bias potential on the control electrode 237 of device 31 in less time than this short period to prevent device 31 from becoming conductive. For example, after reception of the carrier wave by the receiver, a bias potential may appear on the control electrode 237 of the vapor discharge device 31 in about 1 millisecond.

The period after reception of a carrier wave by the receiver before the device 32 operates should be as short as possible, so that the time elapsing between initiation of a signal at the hand set 14 and its reception at hand set 23 is small enough to avoid losing any significant part of the beginning of a message. This time, however, should be sufficiently long to allow surges in the carrier wave transmission system and in the automatic volume control circuits of the receiver to die out substantially before the device 32 makes the amplifier devices 28 and 29 operative. In view of the desirability of allowing time for such surges to die out, it is desirable that they be initiated in minimum time. Hence, it is highly desirable that the transmitter be turned on in minimum time after the impression of a signal on the associated hand set. If, as explained previously, the transmitter is effective to transmit a modulated carrier wave in about 3 milliseconds after impression of a signal on the associated hand set, the receiver may be made to demodulate such signal and impress it on the associated hand set in about 6 milliseconds after reception of the carrier wave, this period being sufficient to allow surges to die out substantially. Under such conditions, the total time of transmission of a signal from one of such hand sets to the other is only about 9 milliseconds, which is an acceptably short time, within which no appreciable portion of the beginning of a syllable is lost.

When the receiver no longer receives a carrier wave from the distant station, the noise suppression circuit including the device 32 first operates to block the amplifier devices 28 and 29. This action may take place in about 3 milliseconds after the carrier wave is no longer received. Thereafter, for example, in about 6 milliseconds, the bias disappears from the control electrode 237 of vapor discharge device 31, thereby leaving the apparatus as a whole in its standby condition. The time within which the negative bias disappears from the control electrode 237 is determined by the sizes of resistance 205 and condenser 206. The larger the resistance 205, the longer it takes for the charge to disappear from condenser 206.

By thus arranging carrier wave transmitting and receiving apparatus according to my invention it is possible to operate it in response to signals to be transmitted to cause transmission and reception of such signals, and to operate it with sufficient speed that no significant portion of the beginning of any signal is lost. For example, the total time from the point of time when sound impinges on the hand set until such sound is reproduced by the hand set 14 in a distant station includes only the time required for the cathode 42 of the oscillating device 15 to reach its proper potential, and the time for the noise suppression circuit including the device 32 in the distant receiver 13 to energize the hand set 14 at that station.

In the example of time given where such total time is about 9 milliseconds, no appreciable portion of the beginning of a message is lost. Assuming that the average frequency of the first syllable of a message is 200 cycles, in 9 milliseconds only two cycles of the signal are lost. These first two cycles do not contribute substantially to the intelligibility of the first syllable of the message.

Furthermore, no appreciable pause between the cessation of transmission from one station and the beginning of transmission from the distant station is necessary because, after the cessation of transmission at one station, the carrier wave is turned off in from 150 to 300 milliseconds, long before the operator at the distant station realizes that the message is ended. Conversation can therefore be carried on over this system as over an ordinary telephone system, with the exception that a message from a distant station normally is not interrupted.

It should be noted that adjustable tap 252 of the voltage dividing resistance 251, which determines the intensity of negative bias potential on the control electrode 237 of the vapor discharge device 31, should never be adjusted so that this bias potential is smaller than a certain critical value. That is, this bias potential on the control electrode 237 of the vapor discharge device 31 should be at least large enough to prevent the discharge device 31 from becoming conductive in response to received signals reproduced in the hand set 23, and therefore impressed on the transformer 210. If the bias produced by such received signals on the control electrode 237 through the agency of the rectifier device 33 and continuous potential amplifier 34 be smaller than this critical value, these same signals impressed on transformer 210 as well as on hand set 23 are impressed on control electrode 230 of device 31 in sufficient intensity to make the device 31 conductive. Under such conditions the receiver continues operation and the transmitter starts, thereby producing an oscillating circuit through both transmitter and receiver to block the operation of the entire system.

The high speed starting of the transmitter is accomplished by connecting the cathode 42 of the oscillating device 15 to ground directly through the vapor discharge device 31 until the relay operates to connect that cathode to ground through the switch 263. This high speed operation is made possible by the even higher speed operation of the continuous potential amplifier 281 which blocks the receiver by rendering the frequency converter device 25 inoperative whenever the discharge device 31 becomes conductive.

The high speed operation of the receiver is accomplished by the high speed operation of the noise suppression circuit including device 32, which is possible because the amplifier stage on which the noise suppression circuit operates is balanced with respect to ground, and therefore does not reproduce the rapid grid bias potential changes caused by device 32 in making operative or inoperative the amplifier devices 28 and 29. This high speed operation is also aided by the rapid operation of the rectifier device 33 and continuous potential amplifier device 34 in preventing operation of the vapor discharge device 31.

Although I have described my invention as applied to a carrier current transmission system in which the carrier wave is transmitted over a power line 10, it is equally applicable to a radio transmission system including a radio transmitter and a radio receiver connected to the same antenna or to adjacent antennas. In fact, my invention may be employed with any signalling system in which messages must be transmitted between two or more stations, and in which it is undesirable to have the signal transmitter and signal receiver connected to the message channel simultaneously.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. The combination in a signalling system of a signal transmission channel, a signal transmitter and signal receiver at each of two spaced points along said channel, means responsive to signals in one of said signal transmitters for rendering inoperative the associated signal receiver and for subsequently connecting said signal transmitter to said channel in a time sufficiently short that no appreciable part of said signal is lost, means associated with the other of said signal receivers for detecting the presence of a signal in said channel and for rendering the associated signal transmitter inoperative and subsequently causing said signal receiver to reproduce said signal after a period sufficiently short that no appreciable part of the beginning of said signal is lost and sufficiently long that disturbances in said system are substantially attenuated before said receiver reproduces said signal.

2. The combination in a signalling system of a signal transmission channel, a signal transmitter and signal receiver at each of two spaced points along said channel, each signal transmitter and the associated receiver being connected to signal conductors over which signals are impressed on said transmitter and upon which signals are impressed by said receiver, means responsive to a signal on said signal conductors associated with one of said signal transmitters and receivers for rendering said receiver inoperative and subsequently connecting said transmitter to said channel within a time sufficiently short that no appreciable part of said signal is lost, means associated with the other of said receivers for detecting a signal in said channel and for preventing the operation of the associated transmitter and subsequently connecting said receiver to said channel to reproduce said signal on the associated signal conductors within a period sufficiently short that no appreciable part of the beginning of said signal is lost and sufficiently long that undesirable transients in said channel are substantially attenuated before said signal appears on said last mentioned signal conductors, said signal responsive means and signal detecting means being arranged to operate said transmitters and receivers in such a sequence that the common interconnections with said signal conductors are not effective to produce undesirable operation.

3. In a signal system the combination of a vapor discharge device having a control electrode, a source of signals, means for impressing a bias potential on said control electrode to prevent said discharge device from conducting, a source of continuous potential arranged to supply discharge current to said discharge device, means for impressing signals from said first source on said control electrode to render said device conductive whenever the intensity of said signals exceeds said bias potential, and means responsive to conduction of said discharge device for impressing upon the discharge path thereof an alternating potential whose peak intensity exceeds the continuous potential of said second source, whereby, upon the cessation of signals from said signal source, the bias potential on said control electrode is effective to render said discharge device nonconductive.

4. In a signal system the combination of a vapor discharge device having a control electrode, a source of signals, means for impressing a bias potential on said control electrode to prevent said discharge device from conducting, a source of continuous potential arranged to supply discharge current to said discharge device, means for impressing signals from said first source on said control electrode to render said device conductive whenever the intensity of said signals exceeds said bias potential, means for reducing said bias potential on said control electrode in response to conduction of said discharge device to make said signals more effective in rendering said device conductive, and means responsive to conduction of said discharge device for impressing upon the discharge path thereof an alternating potential whose peak intensity exceeds the continuous potential of said second source, whereby, upon the cessation of signals from said signal source, the bias potential on said control electrode is effective to render said discharge device nonconductive.

5. The combination in a signalling system having a signal transmission channel and a signal transmitter, of means for connecting said transmitter to said channel in response to signals from a signal source, said means comprising a vapor discharge device arranged to connect said transmitter to said channel when current flows through its discharge path and having a control electrode, and a relay arranged to connect said transmitter to said channel in the operated position, means for impressing a negative bias potential on said control electrode to maintain said discharge device nonconductive and for impressing signals from said source on said control electrode to render said device conductive in the presence of said signals, means for operating said relay in response to conduction of said discharge device, and means for maintaining said relay operated for a substantial time after said device becomes nonconductive in the absense of signals.

6. In a signal transmission system the combination of a signal transmitter and receiver, a signal transmission channel, a source of signals, a vapor discharge device having two control electrodes, means for impressing signals from said signal source on one of said control electrodes to make said discharge device conductive, means responsive to conduction of said discharge device for operating said transmitter to transmit signals from said source through said channel, and means responsive to signals received by said receiver through said channel for impressing a bias potential on the other of said control electrodes to prevent said device from becoming conductive to operate such transmitter and make said receiver inoperative in the presence of signals simultaneously from said transmitter and channel.

7. The combination in a signal system of a signal transmitter and receiver, a signal transmission line, means responsive to a signal from said transmitter for rendering said receiver inoperative and subsequently connecting said transmitter to said channel, and means responsive to a signal in said channel for rendering said first means ineffective to connect said transmitter to said channel and for subsequently making said receiver effective to reproduce said signal in a period sufficiently short that no appreciable part of the beginning of said signal is lost, said last means comprising a balanced amplifier in said receiver arranged to reproduce signals from said receiver, and means responsive to a received signal for adjusting a common bias potential for said balanced amplifier to render said amplifier operative to reproduce said signal, whereby high speed adjustment of said bias potential is not re-

produced in the output of said balanced amplifier.

8. A signal transmission system having a signal channel and a signal transmitter including an oscillating discharge device, said device having an anode, a cathode and a control electrode, said anode and control electrode being connected to opposite terminals of a tuned circuit of which an intermediate tap is maintained at fixed potential, means for impressing a positive potential on said anode, and means for reducing the potential of said cathode to initiate oscillation in said device and tuned circuit and for substantially uniformly increasing the potential of said cathode with respect to said anode to decrease uniformly the intensity of oscillations of said device and tuned circuit, said increase in potential of said cathode being effective to reduce such oscillations to small intensity before extinction.

9. A signal transmission system having a signal channel and a signal transmitter connected thereto and including an oscillating discharge device, said device having an anode, a cathode, a control electrode and a screen electrode, said anode and control electrode being connected to opposite terminals of a tuned circuit of which an intermediate tap is maintained at a fixed potential, means for impressing positive potentials on said anode and screen electrode in such intensities as to provide optimum conditions for oscillation of said device and tuned circuit when the potential of said cathode with respect to said anode is decreased, means for decreasing the potential of said cathode with respect to said anode to initiate oscillation in said device and tuned circuit, and means for increasing the potential of said cathode with respect to said screen electrode and anode at a substantially uniform rate to reduce the intensity of oscillations in said device and tuned circuit substantially uniformly to a low intensity before the extinction of such oscillations.

10. A signal transmission system comprising a signal transmitter and a signal receiver connected to the same signal transmission channel, said receiver being of the superheterodyne type and including a frequency converter having a local oscillator and a mixer, said local oscillator and mixer each including an electron discharge device having a control electrode, a source of signals, means responsive to signals from said source for impressing a negative bias potential on both of said control electrodes to block operation of said receiver and for subsequently initiating operation of said transmitter to transmit such signals through said channel.

EDWIN W. KENEFAKE.