TWO-WAY CARRIER WAVE SIGNAL TRANSMISSION SYSTEM

Filed Dec. 30, 1944 2 Sheets-Sheet 1

FIG. 1

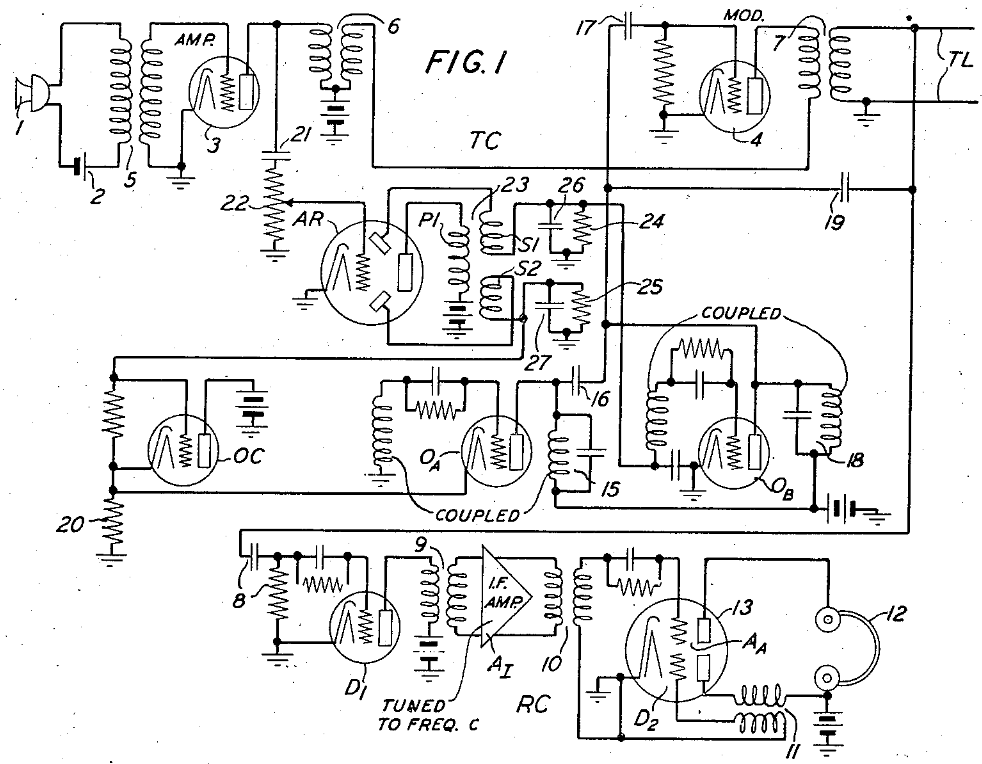

FIG. 2

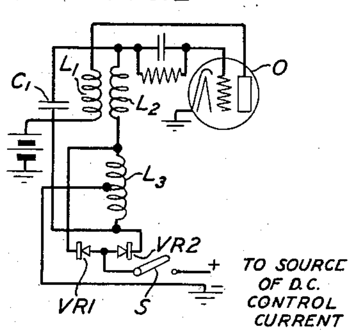

FIG. 3

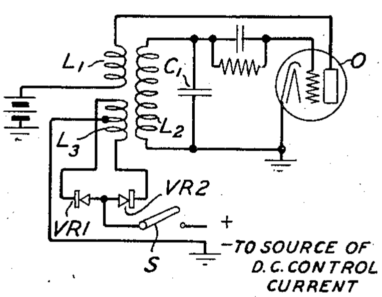

FIG. 4

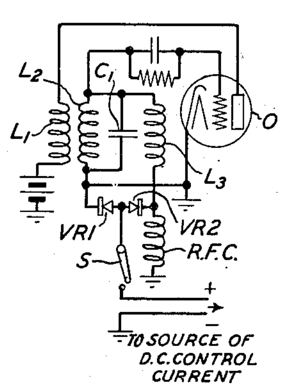

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FIG. 5

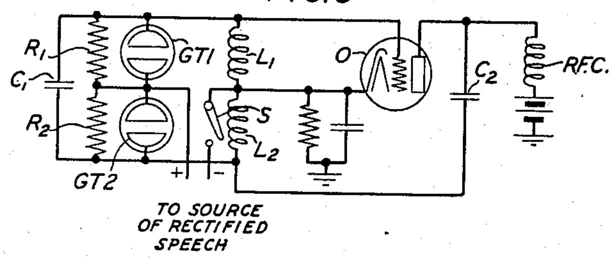


FIG. 6

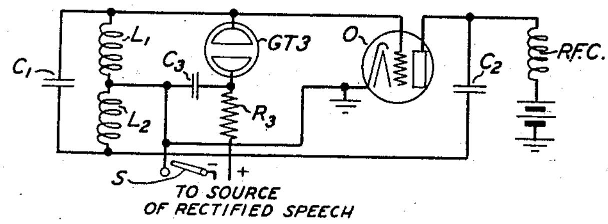


FIG. 7

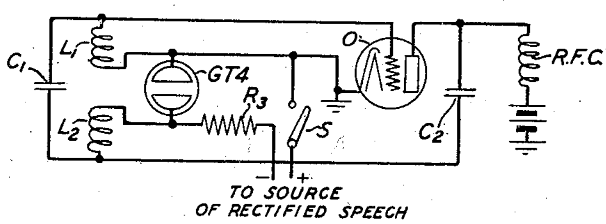


FIG. 8

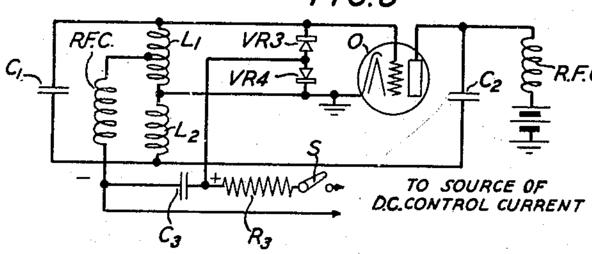
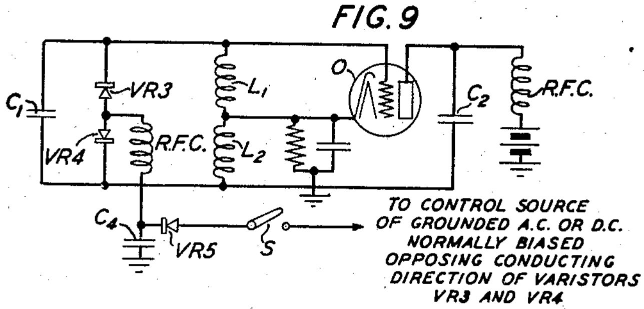


FIG. 9



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UNITED STATES PATENT OFFICE

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TWO-WAY CARRIER WAVE SIGNAL TRANSMISSION SYSTEM

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Application December 30, 1944, Serial No. 570,591

11 Claims. (Cl. 179—1)

The invention relates to a two-way carrier wave signal transmission system and to the signal-controlled oscillator and switching apparatus employed in such a system.

An object of the invention is to provide efficient two-way operation of a carrier wave signal transmission system with a relatively small amount of transmission apparatus, while minimizing signal distortion due to the switching operations required to change the direction of signal transmission.

Another object is to effectively silence the signal receiver during the operation of the signal transmitter at a subscriber's station of a two-way carrier telephone system.

Other objects are to switch the frequency of an oscillator from one value to another, to enable an inoperative oscillator or to disable an operative one, under control of signaling currents in such manner as to minimize switching transients.

These objects are attained in accordance with one embodiment of the invention in a two-way carrier telephone system employing at each of the subscribers' stations connected by a two-way transmission line, which may be a high voltage power line, a signal receiver of the superheterodyne type and an oscillator circuit adapted for producing carrier waves of different frequencies utilized respectively for transmitting outgoing telephone signals over the line, and for aiding in the detection of incoming telephone signals from the signal-modulated carrier waves received over the line.

Each station is normally conditioned for listening, and in that condition the oscillator circuit is arranged to supply a wave of suitable frequency to beat in the first detector of the superheterodyne receiver with the signal-modulated carrier received over the line, so as to produce a combination wave of the frequency to which the following intermediate frequency receiving amplifier is tuned, and to detect the incoming telephone signals from the amplified intermediate frequency wave and to amplify these signals in the following second detector and audio amplifier in the usual manner. A voice operated switching device is responsive to outgoing telephonic signals generated at the station to change the frequency of the carrier oscillator to that desired for the transmitting condition, the resulting carrier frequency, which is selected to be outside the range of amplification of the receiver so as to silence the latter during signal transmitting intervals, being combined in the modulator of the signal transmitter with the outgoing signals to provide a signal-modulated carrier which is transmitted over the line.

Among the features of the invention are various signal-controlled switching arrangements including vacuum tubes, copper oxide varistors or gaseous tubes, for enabling or disabling a vacuum tube oscillator, or for changing its oscillation frequency from one value to another, without the production of objectionable switching transients.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 shows schematically a subscriber's station of a two-way carrier telephone system, embodying the invention; and

Figs. 2 to 9 show schematically alternative signal-controlled switching arrangements for controlling an oscillator which may be employed in the system of the invention shown in Fig. 1.

Fig. 1 shows one of a plurality of similar subscriber's stations of a two-way carrier telephone system, including a signal transmitter TC and a signal receiver RC of the superheterodyne type, associated with a two-way transmission line TL connecting these stations. The transmitter TC includes a telephone transmitter 1 with its associated energizing battery 2, and the amplifying vacuum tubes 3 and 4 operating respectively as a transmitting amplifier and a plate circuit transmitting modulator. The grid circuit of the amplifier tube 3 is coupled to the telephone transmitter 1 through transformer 5, and its plate circuit is coupled through transformer 6 to the plate circuit of modulator tube 5. The plate circuit of the modulator tube 4 is coupled by output transformer 7 to the two-way transmission line TL leading to other subscribers' stations. A single tube, for example, an RCA 6F8G tube, may be substituted for the separate amplifier and modulator tubes 3 and 4 shown.

The receiver RC is of conventional superheterodyne or double detection type including a first vacuum tube detector stage D_1 having its grid circuit connected through the resistance-condenser coupling circuit 8 across the line TL on the output side of transformer 7; an intermediate frequency amplifier A_I, tuned to an intermediate frequency C, which may be, for example, 175 kilocycles, having its input coupled through transformer 9 to the plate circuit of the detector tube D_1; a second vacuum tube detector or rectifier stage D_2 having its grid circuit coupled through transformer 10 to the output of the intermediate frequency amplifier A_I; a vacuum tube audio amplifier stage A_A having its grid circuit coupled by transformer 11 to the plate circuit of the detector stage D_2; and a telephone receiver 12 connected in the plate circuit of the audio amplifier stage A_A. The second detector D_2 and the audio amplifier A_A may be included in a single tube 13 as indicated; for example, an RCA 6F8c may be used.

A carrier wave of frequency A, for example, 300 kilocycles, for the outgoing speech waves is supplied by the oscillator O_A comprising a single vacuum tube having inductively coupled plate and grid circuits and a coil-condenser frequency determining circuit 15 in its plate circuit, as indicated. The output of the oscillator O_A is connected through the series condensers 16 and 17 to the grid circuit of the modulator tube 4 in the transmitter TC. A similar vacuum tube oscillator O_B having inductively coupled plate and grid circuits and a coil-condenser frequency determining circuit 18 in its plate circuit, provides a carrier wave of the frequency B, for example, 475 kilocycles.

The carrier oscillators O_A and O_B are controlled to provide two-way operation of the station under control of the oscillator control vacuum tube OC and the amplifier-rectifier vacuum tube AR, which may be an RCA 75-type tube, in the following manner:

In the normal receiving condition of the station, when no outgoing speech energy is being applied to the transmitter TC, the oscillator O_B is normally oscillating at the frequency B (475 kilocycles) since its grid is not biased to prevent such operation, the only bias being received from its own oscillating circuit. The carrier wave of frequency B from O_B is applied through the condenser 19 and the condenser of coupling circuit 8 in series to the control grid circuit of the first detector stage D_1 of the superheterodyne receiver RC, and beats in that detector with the incoming speech modulated carrier of frequency A (300 kilocycles) received over the line TL from a talking subscriber at another station, and also impressed by coupling circuit 8 on that detector's grid circuit, to provide a combination wave in the detector output of the intermediate frequency C (175 kilocycles) to which the following intermediate frequency amplifier A_I is tuned. This intermediate frequency wave is amplified by the amplifier A_I, and the modulating speech frequencies are demodulated from the amplified wave in the second detector stage D_2, are amplified by the following audio amplifier A_A and are heard in the associated telephone receiver 12. The oscillator O_B continues to oscillate at the frequency B until the subscriber at the station starts to talk, and until this occurs the oscillator O_A is maintained in a non-oscillating condition by the biasing voltage drop across the large (100,000-ohm) resistor 20 in series with its cathode provided by the plate current of the oscillator control tube OC flowing through that resistor.

When the subscriber at the station starts to talk, his speech current generated in telephone transmitter 1 is impressed by transformer 5 on the amplifier 3. A portion of the amplified speech energy in the output of amplifier 3 is applied through transformer 6 to the plate circuit of the modulator tube 4, and another portion is impressed through condenser 21 and potentiometer 22 on the control grid circuit of the three-electrode amplifier portion of the tube AR. The amplified speech waves in the plate circuit of the amplifier of tube AR passes through the primary winding P1 of transformer 23 and are induced in the secondary windings S1 and S2 of that transformer. The currents from these two secondary windings are rectified through the diode elements in the rectifier portion of the tube AR. The resultant rectified currents respectively pass through one of the two resistors 24 and 25, respectively shunted by the condensers 26 and 27, associated with these respective windings and the respective diode plates of the tube AR, making the upper terminals of these resistors have a negative potential with respect to ground, which may be adjusted to a desired value by proper adjustment of the potentiometer 22 in the input of the tube AR. The negative potential of the resistor 25 associated with the secondary winding S2 of transformer 23 is applied directly to the grid circuit of the oscillator control tube OC, biasing that tube to cut-off. The resultant reduction to zero of the plate current of that tube, flowing through the cathode resistor 20 of the oscillator tube O_A, will remove the normal negative bias on the latter tube provided by the voltage drop across that resistor, alowing O_A to oscillate at the frequency A (300 cycles). At the same time, the negative potential from the resistor 24 associated with the secondary winding S1 of transformer 23 is applied directly to the grid of the oscillator tube O_B to bias that tube to cut-off, preventing the latter from oscillating. Thus, the frequency of the carrier oscillator arrangement at the station is switched from the frequency B to the frequency A as soon as voice energy is applied to the transmitter TC, and, in the absence of applied voice energy, the reverse process takes place, the carrier frequency being switched from A to B. The selected values of the condensers 26 and 27 associated with the resistors 24 and 25 will determine the speed at which the switching takes place, as well as the degree of hangover of the switching circuit between speech syllables. The values of these condensers would be made such that there is sufficient holdover of frequency A so that normal pauses between syllables of a word will not result in the reversion of the carrier produced at the station to the frequency B, such as will occur at the station when the subscriber thereat stops talking.

While speech energy continues to be applied to the telephone transmitter 1 of the transmitter TC, the oscillator O_A continues to oscillate to supply the carrier of frequency A (300 cycles) to the grid circuit of the modulator 4, which carrier will be modulated in that modulator by the speech energy applied to the plate circuit of the tube to provide a speech modulated carrier of the frequency A (300 kilocycles) which is impressed by transformer 7 on the line TL, and is transmitted thereover to the other subscribers' stations. When the station has been changed from a listening to a talking condition in the manner which has been described, the frequency A (300 cycles) of the signal-modulated carrier wave apearing on the line at the input to the receiver RC is so far away from the intermediate frequency C (175 cycles) to which the receiver of the station is tuned that it will not be amplified in the receiver, and the telephone receiver 12 of the station will be silenced.

When the subscribers at two connected stations both talk at once, each will cause the oscillator at his station to be switched to frequency A and the receiver at each station will be effectively blocked because there will be no local carrier of frequency B to beat in the receiver with the incoming signal-modulated carrier. Thus, the system will be inoperative.

The switching of the station from the receiving to the transmitting condition, and vice versa, in the manner which has been described avoids changing the static characteristics of the vacuum tubes in the transmission paths, and, as the carrier frequency is shifted so quickly, the switching operation will not result in the production of undesirable large "starting" and "stopping" transients tending to produce clicks or other distortion in the transmitted speech. Such switching transients would be attained in systems in which the required switching involves the introduction in or removal of considerable losses from the signal transmission paths, or making changes in the gain of these paths by biasing the grids of vacuum tubes negatively so as to switch substantial amounts of energy in the anode circuits of these tubes, especially when the system is operating at a frequency not greatly removed from the voice transmission. The switching arrangement of the invention has certain other advantages, such as a selectively tuned high gain receiver and non-critical switching circuits.

To cut down the number of tubes employed in the system of the invention, it may be desirable to use a single double triode tube in place of the separate oscillator tubes O_A and O_B, for example, an RCA 6C8 tube; and also a single double triode tube to replace the detector tube D_1 in the receiver RC and the oscillator control tube OC, for example, an RCA 6E8c tube.

Figs. 2 to 9 show alternative arrangements which may be employed for switching the frequency of a vacuum tube oscillator from one value to another, or for enabling or disabling such an oscillator, without changing the static currents in the vacuum tube, so as to avoid the production of objectionable switching transients. The oscillator of each of these figures comprises a single vacuum tube O having its plate circuit inductively or capacitively coupled to its grid circuit, and having a parallel inductance coil-condenser arrangement associated with the coupled circuits for determining the frequency of oscillation.

In the circuit of Fig. 2 the coil of an inductance L_1 in the plate circuit of the oscillator tube O is inductively coupled to a coil of inductance L_2 in the grid circuit of the tube, and a third inductance coil of inductance L_3, which may or may not be inductively coupled to L_1 or L_2, is connected in a closed series circuit with the inductance coil L_2 and the condenser C_1 to form a frequency-determining or oscillating circuit for the oscillator tube. The varistors VR1 and VR2, which are preferably of the copper oxide rectifier type, are connected in series across the inductance coil L_3, and are relatively poled in such a direction that they in effect constitute an open circuit across that coil. A source of direct current, which may be rectified speech, is adapted to be connected by the switch S across the mid-point of the coil L_3 and a point between the varistors VR1 and VR2. With the switch S open, the frequency of oscillation of the oscillator is determined by the selected values of the inductances L_2 and L_3 in series and the shunt capacity C_1. When the switch S is closed to apply a direct current biasing potential poled as indicated across the inductance L_3, the impedance characteristics of the varistors VR1 and VR2 will be so changed that they effectively place a low resistance shunt across that inductance, and since this materially reduces the inductance of the oscillating circuit, the period of the oscillator will assume a higher value.

The variable oscillators of Figs. 3 and 4 differ essentially from that of Fig. 2 merely in the arrangements of the inductances and capacity of the oscillating circuit with respect to each other and the varistors, and operate in similar manner. In the circuit of Fig. 3 the capacity C_1 is connected in shunt with the grid coil L_2 only, and the coil L_3 is only inductively coupled to the coils L_1 and L_2. In the circuit of Fig. 4 the capacity C_1 is also connected in shunt with the inductance L_2 in the grid circuit of the oscillator tube, but the inductance L_3 is connected in series with the normal high impedance varistors VR1 and VR2 across the coil L_2 and shunt capacity C_1, so that the inductance L_3 is effectively removed from the oscillating circuit in the normal condition of that circuit; and the source of direct control current is adapted to be connected by the closing of the switch S directly across the varistor VR1, and across the varistor VR2 in series with the radio frequency coil R. F. C. provided to prevent shunting of oscillations from L_1 and L_2. The closing of the switch S to connect the source of direct control current across the varistors in the circuit of Fig. 4 will change the impedance of the varistors VR1 and VR2 so that they provide a low impedance connection between the lower terminals of the coils L_3 and L_2, thereby connecting these coils in parallel so as to effectively reduce the inductance in the oscillating circuit and thus increase the period of oscillation of the oscillator.

Figs. 5 to 7 show various arrangements employing cold cathode gas tubes for changing the operation characteristics of a single vacuum tube oscillator. In the arrangement of Fig. 5, with the switch S opened, the oscillator will generate a wave of a frequency determined by the inductance L_1 in series with the inductance L_2 and the shunt capacity C_1 in the oscillation circuit connected in series with the condenser C_2 in the feedback path between the plate and the control grid circuit of the oscillator tube O. The cold cathode gas tubes GT1 and GT2, shunted respectively by the resistors R_1 and R_2, are connected effectively in series with each other across this oscillating circuit, and are normally deionized so as not to interfere with the oscillation of the oscillator. When the switch S is closed to apply a direct current voltage from the associated direct current source, which may be a rectified speech source, as indicated, across the mid-point between the coils L_1 and L_2 and the mid-point between tubes GT1 and GT2, of sufficient value, say, 70 volts, to cause ionization in these tubes, a relatively low resistance shunt will be placed on the oscillating circuit effectively disabling the oscillator.

In the circuit arrangement of Fig. 6 the vacuum tube oscillator O normally oscillates at a period determined by the inductance L_1 in series with the inductance L_2 and the shunt capacitance C_1 in the oscillation circuit connected in series with the condenser C_2 in the feedback path between the plate of the tube and the grid thereof. When the switch S is closed, a source of direct current voltage of sufficient value is connected in series with the cold cathode gas tube GT3 and resistance R_3 across the inductance L_1 of the oscillating circuit, to cause ionization of the gas in that tube to provide a relatively low resistance shunt through that tube and the capacity C_3 across the inductance L_1. This will reduce the total inductance of the oscillating circuit and increase the period of oscillation of the oscillator.

In the circuit of Fig. 7 the plate of the oscillator tube O is connected to the grid thereof through the series circuit comprising the condenser C_2 and a circuit comprising the capacity C_1 shunted by the inductances L_1 and L_2 and the intermediate cold cathode gas tube GT4. With the switch S open, the gas tube GT4 is deionized so that it effectively provides an open circuit between the inductances L_1 and L_2 in the oscillating circuit and therefore the oscillator normally will not oscillate. When the switch S is closed, a source of direct current voltage, which may be rectified speech, of sufficient value, say, 70 volts, to cause ionization in the tube GT4 is applied across that tube, the resulting ionization in that tube causing the connection between the inductances L_1 and L_2 to be effectively closed. This will cause the oscillator to oscillate at a period determined by the values of the series inductances L_1 and L_2 and the shunt capacity C_1.

The oscillator circuit of Fig. 8 normally oscillates at a period determined by the values of the inductance L_1 in series with the inductance L_2 and the shunt capacity C_1 in the frequency-determining circuit connected between the plate and the grid of the oscillator tube. The copper-oxide varistors VR3 and VR4 are connected in series across the inductance L_1 in this oscillating circuit and are so poled that they provide a very high impedance path in shunt with that inductance and thus do not normally prevent oscillation of the oscillator. When the switch S is closed to connect a direct current source of biasing potential poled as indicated, through the series resistance R_3 and shunt capacity C_3 across a point between the two varistors VR3 and VR4 and the mid-point of the inductance coil L_1, these varistors will become a low impedance and will effectively short out the inductance coil L_1, thus decreasing the inductance in the oscillating circuit and causing the oscillator to oscillate at a higher frequency. The radio frequency coil R. F. C. in series with the biasing circuit is provided to prevent shunting out or suppressing oscillation by virtue of the connection of C_3 or the direct current control circuit to the mid-point of L_1.

In the oscillator circuit of Fig. 9, the two copper-oxide varistors VR3 and VR4 are connected in shunt with the oscillating circuit comprising the inductances L_1 and L_2 shunted by the capacity C_1, connected in series with condenser C_2 between the plate and grid of the oscillator 2, instead of in shunt with the inductance L_1 alone as in the circuit of Fig. 8, and a source of control voltage, which may be a grounded alternating current or a direct current source poled as shown is adapted to be connected by switch S across the mid-point between the two varistors and the mid-point between the inductances L_1 and L_2. The rectifying arrangement comprising the series copper-oxide varistor VR5 and the shunt capacity C_4 in the biasing circuit makes it possible to impress a direct current bias on the varistor when either an alternating current or direct current potential is applied at the input of the control circuit. Let us consider that an alternating current potential is impressed on this control circuit on the positive half of the cycle. The varistor VR5 will pass current and charge the condenser C_4 at a positive potential with respect to ground. This positive potential will materially reduce the impedance of the varistors VR3 and VR4 thus effectively short-circuiting the oscillating circuit and stopping the operation of the oscillator. This direct current bias will also be present during each negative half cycle of the impressed voltage because of the energy fed from the condenser C_4 during this period.

The rectifying arrangement of Fig. 9 may be applied also to any of the oscillator circuits of Figs. 2 to 8 to provide a direct current source of control potential from an alternating current source.

The variable frequency oscillator of Figs. 2, 3, 4, 6 or 8 may be substituted for the oscillator arrangement comprising the oscillator tubes O_A and O_B, the control tube OC and the associated grid biasing arrangements in the system of Fig. 1, in which case the direct current biasing potential for switching the frequency of the former oscillator from one value to another would be obtained from the output of the amplifier-rectifier AR during the period in which speech energy is applied to the transmitter TC. Also, the normally operative oscillator and associated disabling arrangement of Fig. 5 or Fig. 9 may be substituted for the normally operative oscillator O_A and associated disabling arrangement in the system of Fig. 1, and the normally disabled oscillator and associated enabling arrangement of Fig. 7 may be substituted for the normally disabled oscillator O_B, control tube OC and the associated oscillator enabling arrangement in the system of Fig. 1, the direct current control for the substituted arrangement in each case being supplied from the output of the amplifier-rectifier AR.

Various modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. In combination at a station of a two-way carrier wave signaling system, a signal transmitter including a signal modulator, a signal receiver including a signal demodulator, a common oscillator for supplying carrier waves of different frequencies to said signal modulator and said signal demodulator, respectively, for modulating therein respectively with outgoing signals to produce a signal-modulated carrier wave for transmission, and with an incoming signal-modulated carrier wave to aid in the detection of the signals therefrom during receiving intervals, said oscillator being normally conditioned to supply only the carrier of the frequency used in said receiving intervals, and a signal-operated switching device responsive to outgoing signals generated at the station to change the produced frequency of said oscillator to that used for transmitting said outgoing signals.

2. The combination of claim 1, in which said oscillator comprises one portion normally in oscillating condition to supply to said demodulator the carrier wave of the frequency used during said receiving intervals, and another normally-disabled oscillator portion, which, when operative, oscillates to supply to said modulator the carrier wave of the frequency used for transmitting outgoing signals, said signal-operated switching device being responsive to the outgoing signals generated at the station to disable the first oscillator portion and to enable said other oscillator portion during signal transmitting intervals.

3. The combination of claim 1, in which said common oscillator comprises two vacuum tube

oscillator portions each having a control grid, the grids of said oscillator portions being normally biased so that one portion is in a state of oscillation to supply a carrier of the desired frequency to said demodulator, and the other portion is disabled, said signal-operated switching device being responsive to outgoing signals generated in said transmitter to reverse the bias on the grids of said oscillator portions so that said one portion is disabled, and said other oscillator portion is enabled to supply to said modulator a carrier wave of the frequency used for transmitting said outgoing signals.

4. In combination in a two-way carrier wave telephone system, a two-way transmission line and a subscriber's station comprising a signal transmitter including a wave modulator feeding said line, a signal receiver of the superheterodyne type, including a wave detector fed from said line and a following wave amplifier tuned to a given intermediate frequency, a carrier wave source comprising one oscillator portion normally operative to transmit a carrier wave of suitable frequency to said detector to beat therein with an incoming signal-modulated carrier wave of another frequency received by said receiver from said line, so as to produce a combination wave of said intermediate frequency, and a second normally disabled oscillator portion, which, when operative, transmits to said modulator a carrier wave of a third frequency to combine therein with outgoing voice signals generated in said transmitter to produce a signal-modulated carrier wave for transmission over said line, a voice-operated switching device responsive to voice signals generated in said transmitter to disable said one oscillator portion and enable said second oscillator portion and responsive to cessation in the generation of said signals to return said station to the normal condition with said one oscillator portion operative and said second oscillator portion disabled, said third carrier frequency being outside the amplification range of said tuned intermediate frequency amplifier.

5. The combination of claim 4, in which said voice-operated switching device comprises means connected to said transmitter for amplifying and detecting a portion of the voice signals generated therein, and means responsive to the detected signals to produce biasing voltages providing the desired reversal of the operating condition of said two oscillator portions.

6. The combination of claim 4, in which each of said oscillator portions comprises a vacuum tube oscillator having a control grid, the normal disabling of said second oscillator portion is provided by a control vacuum tube having a control grid, normally operative to bias that oscillator portion against operation, said voice-operated switching device comprises an amplifier-rectifier supplied with a portion of the voice signals generated in said transmitter, and means responsive to the rectified voice output of said amplifier-rectifier to apply a disabling bias to the grid of said one oscillator portion, and a disabling bias to the grid of said control tube so as to effectively remove the disabling bias produced thereby on said second oscillator portion.

7. In combination, a vacuum tube oscillator having two different frequency determining circuit arrangements, means normally making only one of said frequency-determining arrangements effective so that said oscillator normally produces a wave output at one frequency, a source of direct current, and means responsive to the application of waves from said source to said oscillator to cause said other frequency-determining circuit arrangement only to be effective so that said oscillator produces a wave output of a different frequency.

8. In combination, a vacuum tube oscillator having a frequency-determining circuit including inductance and capacitance, variable impedance means connected across at least a portion of said inductance, the shunt impedance provided by said variable impedance means being normally so high as to constitute an effective open circuit across said inductance portion making the latter effective in said frequency-determining circuit to cause oscillation of said oscillator at a frequency determined by the total inductance and capitance in said circuit, a direct current source, and means responsive to the current from said source to change the shunting impedance of said variable impedance means to a very low value, thereby effectively removing said inductance portion from said frequency-determining circuit and causing said oscillator to oscillate at a different frequency.

9. The combination of claim 8, in which said variable impedance means across said inductance portion comprises two copper oxide varistors poled in oposition providing such a high shunt impedance that said inductance portion is effective in said frequency determining circuit, and said source applies a direct current bias to said varistor of such value and with such poling as to reduce the impedance thereof to such a low value as to effectively short-circuit said inductance portion and thus increase the frequency of oscillation of said oscillator.

10. The combination of claim 8, in which said variable impedance means comprises one or more gaseous discharge devices which are normally deionized to provide a very high shunt impedance across said inductance portion so that the latter is effective in said circuit, and are ionized in response to the direct current bias applied by said source to effectively short-circuit said inductance portion and thus change the frequency of oscillation of said oscillator.

11. The combination of claim 8, in which said variable impedance device comprises two oppositely poled copper oxide rectifiers shunting the whole inductance in said frequency-determining circuit, said rectifiers normally providing an effective open circuit across said whole inductance and thereby allowing oscillation of said oscillator at a frequency determined by the values of said inductance and capacitance, and being biased by the current from said source to reduce the impedance of said rectifiers to a very low value so as to effectively short-circuit said whole inductance and thus to stop oscillation of said oscillator.

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