Oct. 8, 1946. H. MAGNUSKI 2,408,791

RADIO COMMUNICATION SYSTEM

Filed June 21, 1943 3 Sheets-Sheet 1

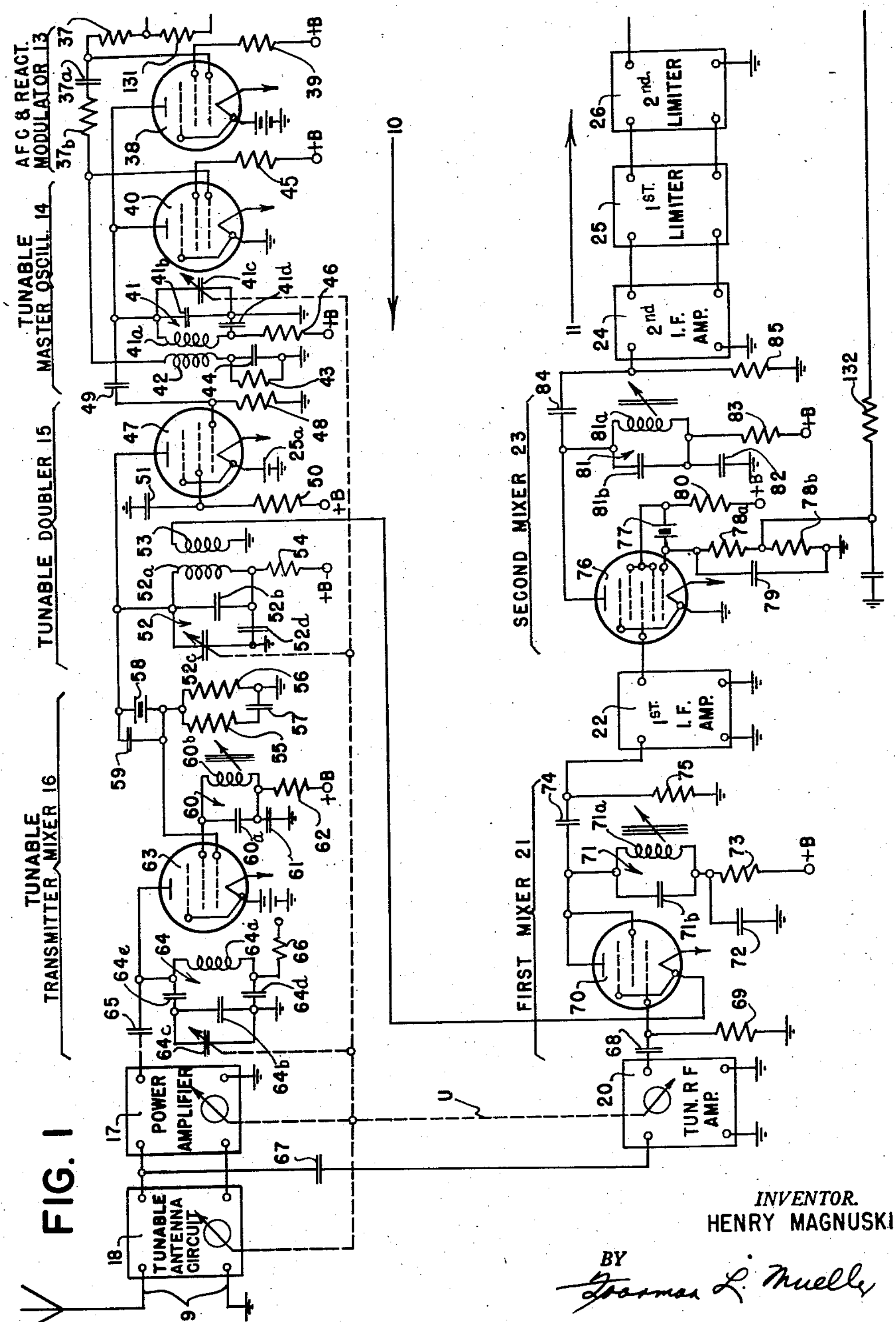

FIG. 1

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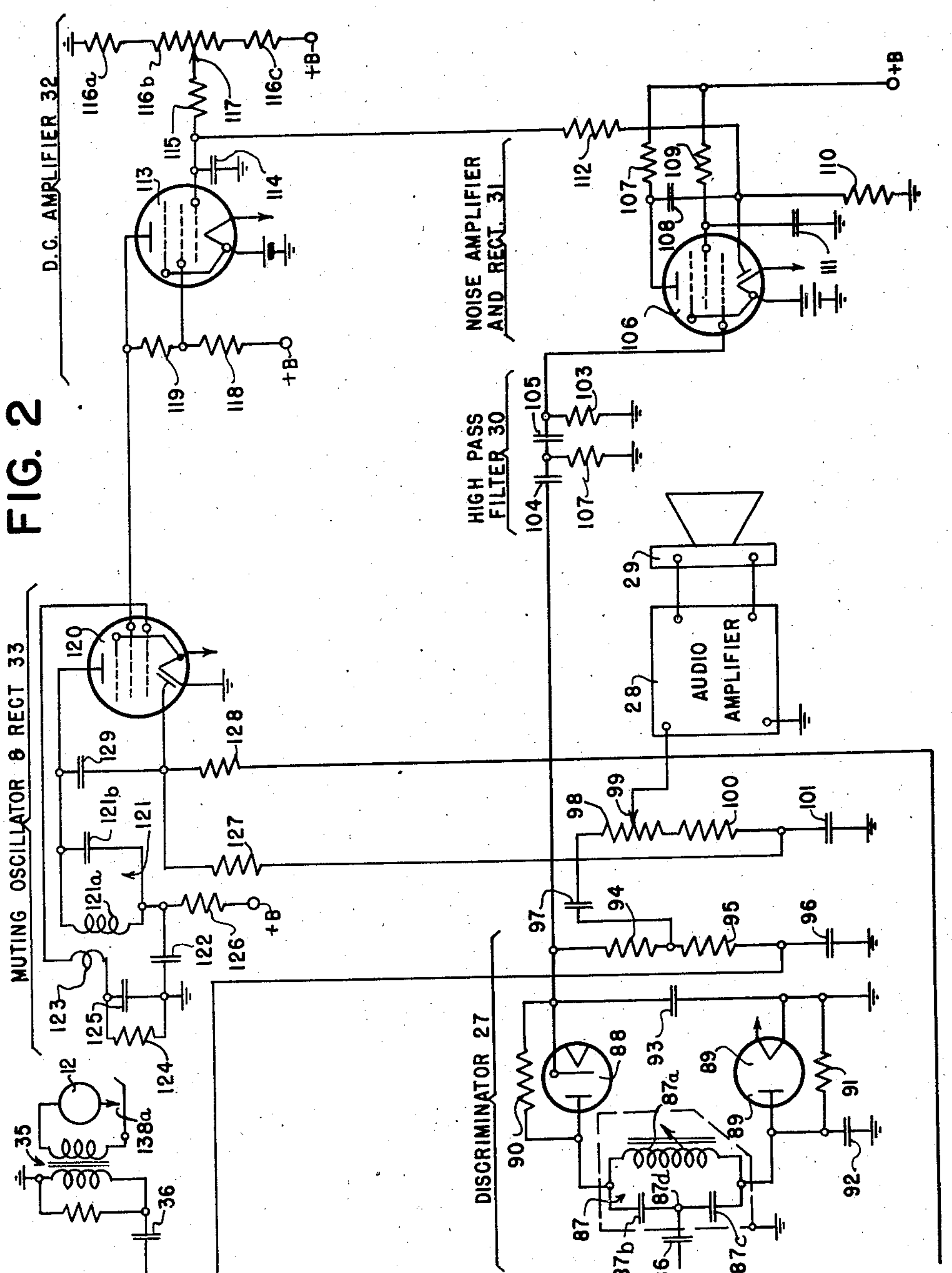
Filed June 21, 1943 3 Sheets-Sheet 2

FIG. 2



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RADIO COMMUNICATION SYSTEM

Filed June 21, 1943 3 Sheets-Sheet 3

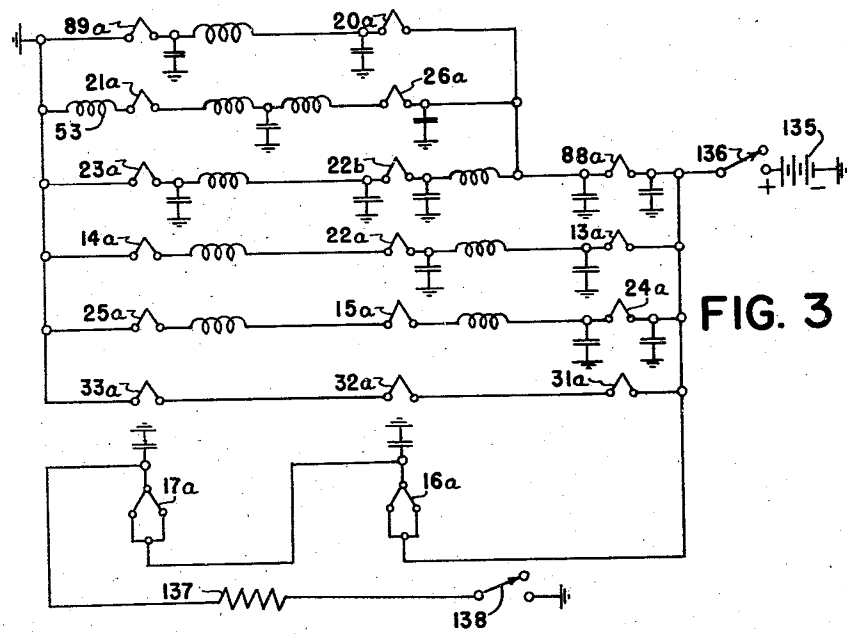

FIG. 3

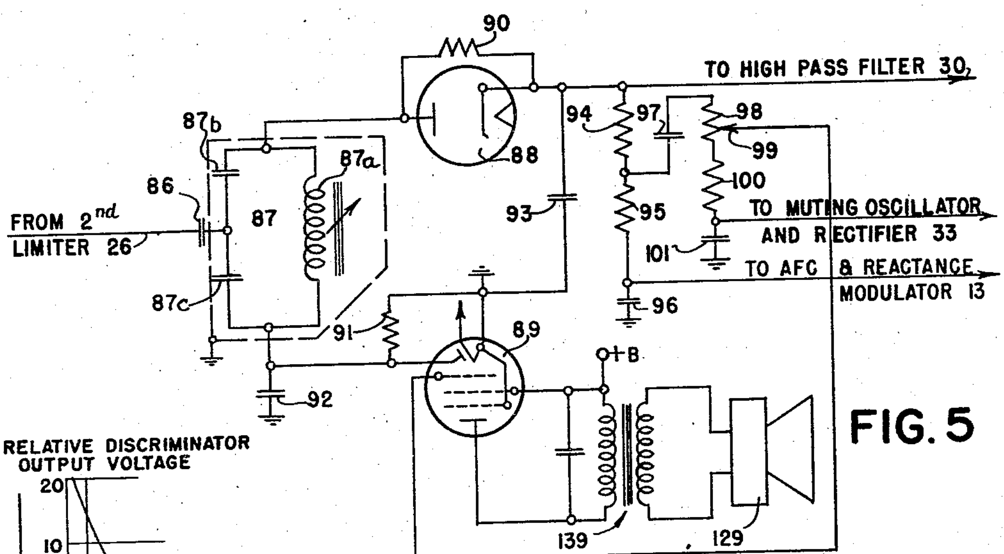

FIG. 5

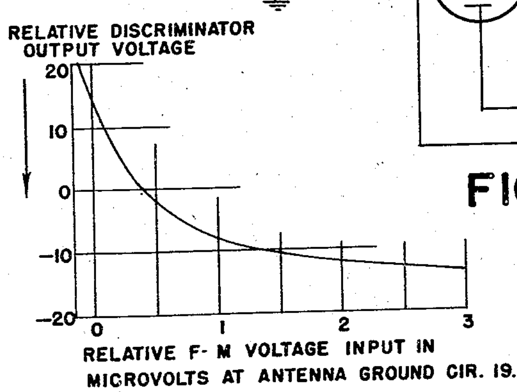

FIG. 4

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RADIO COMMUNICATION SYSTEM

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Application June 21, 1943, Serial No. 491,651

9 Claims. (Cl. 250—13)

1

The present invention relates to improvements in radio communication apparatus and more particularly to improvements in combination radio transmitter and receiver systems of the character used in police and military communication work, for example.

Complete self-contained combination transmitter and receiver units, both of the portable and fixed position types, are now extensively used in many forms of radio communication work and are especially useful in two-way police and military communication work. Such units must of necessity be rugged, light in weight, and easily manufactured in production quantities at low cost. They must also be capable of being easily and rapidly conditioned to operate either as a transmitter or as a receiver, and should be easily tunable to transmit or receive at any desired carrier frequency within an allotted frequency band. Other requirements of a unit of this type are that the unit have sufficient signal radiating power and sufficient sensitivity of reception to permit high quality two-way communication to be held over substantial distances, and that the receiving channel of the unit be capable of maintaining its sensitivity in receiving a signal carrier having a drifting carrier frequency.

In general, it is an object of the present invention to provide an improved combination radio transmitting and receiving system which meets all of the requirements outlined above in a highly satisfactory manner.

It is another object of the invention to provide a system of the frequency modulated type which meets all of the requirements outlined above.

It is a further object of the invention to provide a combined transmitting and receiving system in which portions of both the transmission and receiving channels are used both during signal transmission and signal reception, thereby to minimize the number of component parts of the system without sacrificing desirable operating features.

According to another object of the invention, a combination frequency modulated transmitting and receiving system is provided which includes a receiving channel of the superheterodyne type, and in which improved facilities are provided for utilizing one of the oscillators of the transmission channel as a local oscillator at a mixer stage of the receiving channel during signal reception.

In accordance with a further object of the invention, improved facilities are provided for utilizing a portion of the transmission channel to obtain automatic frequency control in the intermediate frequency section of the receiving channel during signal reception.

2

According to a further object of the invention, the modulator stage of the transmission channel is controlled by a variable bias derived from the receiving channel in order automatically to control the carrier frequency of a signal carrier traversing the intermediate frequency section of the receiving channel during signal reception.

It is another object of the invention to provide improved facilities whereby the system may be utilized for signal transmission and reception at the same carrier frequency without altering the tuning of any of the tunable stages of the system.

It is a further object of the invention to provide an improved radio transmitter wherein two oscillators arranged in tandem are utilized to produce for radiation a signal modulated carrier.

According to a further object of the invention, the transmission channel is provided with a mixer stage which follows the master carrier producing oscillator and utilizes a crystal oscillator having a resonant frequency equaling the center intermediate frequency of the first intermediate frequency section of the receiving channel to obtain the desired frequency of carrier radiation.

It is a still further object of the invention to provide an improved arrangement for selectively rendering the transmission and receiving channels active and inactive in a manner such that all of the facilities mentioned above are selectively, automatically and appropriately rendered active and inactive as the two channels are selectively conditioned for signal transmission and signal reception.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

Figs. 1 and 2, when laid end to end in the order named, illustrate a combined frequency modulated radio transmitting and receiving system characterized by the features of the invention briefly referred to above;

Fig. 3 diagrammatically illustrates the circuit arrangement of the cathode heaters of the electron discharge tubes included in the system shown in Figs. 1 and 2;

Fig. 4 is a graph illustrating the noise and signal response characteristics of the receiver; and

Fig. 5 is a circuit diagram illustrating a modification of the receiving equipment forming a part of the system shown in Figs. 1 and 2.

Referring now more particularly to Figs. 1 and 2 of the drawings, there is illustrated, partially in schematic form, a combination frequency modulated radio transmission and receiving system which is well adapted for use as a complete portable unit and includes a transmitting section 10 and a receiving section 11 commonly coupled to an antenna ground circuit 19 through a tunable antenna circuit 18. Briefly considered, the transmitting section 10 comprises a combination automatic frequency control and reactance modulator stage 13, a tunable master oscillator 14, a tunable frequency doubler network 15, a tunable transmitter mixer 16, a power amplifier 17, and the tunable antenna circuit 18, connected in tandem in the order named. The receiving section 11 of the system comprises the tunable antenna circuit 18, a tunable radio frequency amplifier 20, a first mixer or converter stage 21, a first intermediate frequency amplifier 22, a second mixer or converter stage 23, a second intermediate frequency amplifier 24, a first limiter 25, a second limiter 26, a frequency discriminator 27, an audio frequency amplifier 28, and a loud speaker 29, all connected in cascade in the order named. As pointed out below the system may be selectively controlled to operate either as a transmitter or a receiver and, when conditioned for operation, is set to operate as a receiver. In order to render the audio section of the receiving channel 11 inoperative to pass noise signals appearing in this channel during intervals when a desired signal is not being received, muting or squelch apparatus is provided which comprises a high pass filter network 30 coupled to the output side of the frequency discriminator 27, a noise amplifier and rectifier 31, a direct current amplifier 32 and a muting oscillator and rectifier section 33. These stages are connected in tandem in the order named, and respond to noise voltages appearing in the receiver channel to impress a blocking bias voltage upon the audio amplifier 28 in the manner explained below.

More specifically considered, the transmitting section of the system comprises a microphone 12 which is arranged to impress audio frequency voltages developed during operation thereof between the input electrodes of the combination frequency control and modulator tube 38 through a coupling network which comprises a microphone transformer 35, a condenser 36, and a resistor 37. The space current path through the tube 38 is connected in shunt with the space current path through the tube 40 of the master oscillator 14, and also shunts the tunable frequency determining circuit 41 of the master oscillator 14. This oscillator is of the conventional tuned plate circuit type, the frequency determining circuit 41 thereof comprising a fixed inductance element 41*a* which is tuned to the desired resonant frequency by means of the shunt connected fixed condenser 41*b* and an adjustable tuning condenser 41*c*. Operating potentials are supplied to the anodes of the tubes 40 and 38 through a resistor 46 and the inductance element 41, a low impedance direct current blocking condenser 41*d* being provided in the tunable circuit 41 in order to isolate this direct current path from ground. The tunable frequency determining circuit 41 of the oscillator 14 is regeneratively coupled to the input electrodes of the tube 40 by means of an inductance element 42 which is inductively coupled to the inductance element 41. It is also coupled to the input electrodes of the frequency control and modulator tube 38 by means of the inductance element 42 and a phase shifting network which includes the condenser 37*a* and the resistor 37*b*. A suitable grid condenser 44 shunted by a grid leak resistor 43 is serially included in the input circuit of the oscillator tube 14 for the purpose of maintaining the control grid of this tube at the proper operating potential with respect to the cathode of the tube.

The signal modulated carrier voltage developed across the tunable frequency determining circuit 41 is impressed between the input electrodes of a tube 47 included in the frequency doubler 15 through a network which comprises the coupling condenser 49 and a resistor 48. This tube is provided at its output side with a tunable frequency selective circuit 52, which includes a fixed inductance element 52*a* shunted by a fixed tuning condenser 52*b* and an adjustable tuning condenser 52*c*, and is tuned to a center frequency substantially twice the center resonant frequency of the frequency determining network 41 forming a part of the master oscillator stage 14. Anode current is supplied to the tube 47 through a filter resistor 54 and the inductance element 52*a*, and the usual direct current isolating condenser 52*d* is provided in the circuit 52 to isolate the anode current path from ground.

In accordance with the present invention, the carrier voltage developed through operation of the tunable master oscillator 14 and the tunable frequency doubler 15 is utilized as a heterodyning frequency source for converting a received frequency modulated radio frequency carrier into a correspondingly modulated intermediate frequency carrier in the first mixer stage 21 of the receiver channel 11. When, therefore, it is desired to utilize the system to transmit and receive signals at a fixed and preestablished carrier frequency without altering the tuning of the tunable circuits in the system incident to a change from transmission to reception, or vice versa, it is necessary to increase or decrease the output frequency of the frequency doubler 15 by an amount equal to the value of the intermediate frequency utilized in the first intermediate frequency amplifier section 22 of the receiver channel 11. Whether or not the output frequency of the doubler 15 is raised or lowered to provide the desired frequency of carrier transmission, will of course depend upon whether the doubler output frequency is above or below the particular carrier frequency at which transmission is to be effected. In the particular arrangement illustrated, a piezoelectric crystal 58 having a resonant frequency equal to the intermediate frequency utilized in the first intermediate amplifier 22 of the receiver is utilized to increase the frequency of a transmitted signal carrier above the carrier frequency appearing across the frequency selective circuit 52 by an amount equal to the intermediate frequency utilized in the first intermediate frequency amplifier 22. More specifically considered, the tunable circuit 52 is coupled to the input electrodes of the transmitter mixer tube 63 through the shunt connected crystal 58 and condenser 59. A grid leak and condenser network comprising the two resistors 55 and 56 and a condenser 57 is provided for maintaining the proper bias potential between the input electrodes of the mixer tube 63. For the purpose of driving the crystals 58 to maintain oscillation of the crystal at its resonant frequency, a tuned circuit 60 is provided which is suitably designed to resonate at the same frequency as the crystal 58 and comprises a fixed condenser 60*a* shunted by an adjustable inductance element **60b**. This network is included in the screen electrode circuit of the mixer tube **63** and also in the path comprising the resistor **62** over which the required operating potential is positively applied to the screen electrode of the tube **63**.

The mixer tube **63** is provided with a tunable frequency selective output circuit **64**, which comprises a fixed inductance element **64a** shunted by the fixed condenser **64b** and the adjustable tuning condenser **64c** through the low impedance direct current isolating condensers **64d** and **64e**. This circuit is normally maintained tuned to a frequency which is equal to twice the output frequency of the oscillator **14** plus the resonant frequency of the crystal **58**, which latter frequency equals the first intermediate frequency used in the receiver channel **11**. The output voltage appearing across the circuit **64** is impressed across the input circuit of the power amplifier **17** through a coupling network which includes the condenser **65**.

Referring now more in detail to the signal receiving channel **11** of the system, the first mixer stage **21** is illustrated as being resistance-capacitance coupled to the output circuit of the tunable radio frequency amplifier **20** through a network which includes the coupling condenser **68** and resistor **69**. As indicated above, when the system is conditioned for reception, the tunable master oscillator **14** and the tunable frequency doubler **15** are utilized as a heterodyning frequency source required to effect the desired carrier frequency conversion in the first mixer stage **21**. To this end, an inductance element **53** which is inductively coupled to the inductance element **52a** of the frequency selecting circuit **52** is included in the cathode-ground circuit of the mixer tube **70**. The output electrodes of this tube are coupled to a fixed tuned frequency selecting circuit **71** which comprises a fixed condenser **71b** shunted by an adjustable inductance element **71a** and is tuned to the desired first intermediate frequency of 4.3 megacycles, for example. Anode potential is supplied to the tube **70** over a path which includes the inductance element **71a** and a filter resistor **73** which is shunted by a by-pass condenser **72**. The tuned output circuit **71** of the tube **70** is coupled to the input electrodes of the first tube in the intermediate frequency amplifier **22** through a network which comprises the coupling condenser **74** and resistor **75**.

The output side of the first intermediate frequency amplifier **22** is coupled to the input electrodes of the mixer tube **76** provided at the second mixer or converter stage **23** in an obvious manner. This tube is provided with output electrodes which are bridged by a frequency selective circuit **81** tuned to the second intermediate frequency of 2.515 megacycles, for example, and comprising a condenser **81b** shunted by an adjustable inductance element **81a**. Anode potential is supplied to the tube **76** over a path which includes the inductance element **81a** and a filter resistor **83** shunted by a by-pass condenser **82**. The voltage appearing across the frequency selective circuit **81** is impressed across the input side of the second intermediate frequency amplifier **24** through a network which comprises the coupling condenser **84** and a resistor **85**. For the purpose of effecting the required carrier frequency conversion at the second mixer stage **23**, the mixer tube **76** is provided with an oscillator section of the Pierce type which includes a piezoelectric crystal **77** connected between the control and screen electrodes of the tube. This crystal has a resonant frequency of 6.815 megacycles which is greater than the intermediate frequency utilized in the first intermediate frequency amplifier **22** by an amount equal to the intermediate frequency utilized in the second intermediate frequency amplifier **23**. A suitable biasing network comprising the series connected resistors **78a** and **78b** shunted by the grid condenser **79** is provided between the input electrodes of the tube **76** for maintaining the proper bias voltage between these electrodes.

Noise and signal voltages appearing at the output side of the second limiter **26** are introduced into the frequency discriminator **27**. Briefly considered, this discriminator comprises a tuned circuit **87**, a pair of diode rectifier tubes **88** and **89**, the space current paths of which are respectively shunted by load resistors **90** and **91**, a radio frequency by-pass condenser **93** having substantially negligible impedance to frequencies of the order of the second intermediate frequency, and a stabilizing condenser **92**. More specifically, the resonant circuit **87** serves to tune the frequency discriminator network to a center frequency equal to the second intermediate frequency and comprises a pair of series connected condensers **87b** and **87c** which are shunted by an adjustable inductance element **87a**. Preferably the last mentioned element is of the variable permeability type being provided with an adjustable powdered ferrous metal core, the position of which may be changed to alter the inductance of the element within the desired limits. The circuit constants of the resonant circuit **87** are so chosen that the discriminator network is provided with a band pass characteristic such that all desired signal components of a frequency modulated carrier appearing in the second intermediate frequency channel **24, 25, 26** may be detected and impressed upon the input circuit of the audio amplifier **28**. The voltage appearing across the output side of the second limiter **26** is impressed upon the discriminator network **27** through a coupling condenser **86** which is connected at one side thereof to the junction point between the two condensers **87b** and **87c**. Audio frequency voltages detected through operation of the discriminator **27** appear across the condenser **93** and are impressed upon the input side of the audio frequency amplifier **28** through a coupling circuit which includes radio frequency decoupling resistor **94**, an audio frequency filter comprising the resistor **95** and condenser **96**, an audio frequency coupling condenser **97**, and a volume control voltage dividing network comprising the two resistors **98** and **100** and a direct current blocking condenser **101**. It will be understood in this regard that the proportion of the available audio frequency voltage appearing across the series connected resistors **98** and **100** which is impressed upon the input circut of the audio frequency amplifier **28**, is determined by the setting of the wiper **99** along the resistor **98**.

As will be explained more fully below, noise signals appearing in the signal transmission channel of the receiver in the absence of a received signal modulated carrier are passed through the discriminator **27** and appear as detected audio voltages across the condenser **93**. Such detected voltages are impressed across the high pass filter network **30**, and those components thereof having frequencies above the cutoff frequency of the filter network are impressed between the input electrodes of the tube **106** included in noise amplifier and rectifier 31. More specifically considered, the high pass filter 30 comprises a pair of series condensers 107 and 102 and a pair of shunt resistors 103 and 106, and is designed to pass those components of noise voltages which have frequencies above the normal signal reproducing band of the receiver. The noise amplifier section of the tube 106 works into a noise rectifier circuit which comprises the diode section of the tube and a load resistor 110. This rectifier circuit is coupled to the anode of the tube 106 through a coupling condenser 108 which is of appropriate impedance to pass any noise currents which may be transmitted through the high pass filter 30. Anode and screen potentials are supplied to the tube 106 through the resistors 107 and 109, the second of which is by-passed to ground through a condenser 111.

Rectified noise voltages appearing across the load resistor 110 are utilized to control the bias between the input electrodes of the tube 113 provided in the direct current amplifier 32. The initial or threshold bias established between the electrodes of this tube is derived from a voltage dividing network, which comprises the series connected resistors 116*a*, 116*b*, and 116*c* bridged across the available source of anode potential, and is provided with a tap 117 adjustable along the resistor 116 to impress a variable positive potential upon the control electrode of the tube 113 through the filter resistor 115. The biasing circuits connected between the input electrodes of the tube 113 are by-passed for audio frequency currents by means of a condenser 114. Screen and anode potentials are applied to the amplifier tube 113 through the resistor 118 and the resistors 116 and 119, in series, respectively.

The direct current amplifier 32 as controlled by the variable bias voltage derived from the load resistor 110, is utilized to control the starting and stopping of the muting oscillator and rectifier 33. This stage of the muting or squelch apparatus comprises a dual purpose tube 120 having an oscillator section which includes a tuned frequency determining circuit 121 connected between the output electrodes of the tube through a by-pass condenser 122. The resonant circuit 121 is fixed tuned to a particular frequency of from 200 to 300 kilocycles and comprises an inductance element 121*a* shunted by a tuning condenser 121*b*. It is regeneratively coupled to the input electrodes of the tube 120 by means of a feed back circuit which comprises an inductance element 123 inductively coupled to the inductance element 121*a* and connected in series with a parallel connected grid leak resistor 124 and condenser 125 between the control grid and cathode of the tube 120. Anode potential is supplied to the tube 120 over a path which includes the inductance element 121*a* and a resistor 126. The oscillator section of the tube 120 is coupled to the rectifying circuit of the tube through a coupling condenser 129, and the indicated rectifying circuit serially includes the diode rectifier section of the tube and the resistors 128, 132 and 76*b*. Any bias voltage appearing across the load resistors 128, 132 and 78*b* during operation of the oscillator and rectifier stage 33 is negatively applied to the control grid of the first tube in the audio frequency amplifier 28 over a path which comprises the resistor 127, the resistor 100 and the lower portion of the resistor 98.

In order to insure that the system will operate efficiently with low battery current drain, all of the tubes, with the exception of the discriminator diode 88, are of the filamentary cathode type. The diode rectifier 88 must of necessity be of the indirectly heated cathode type since the cathode thereof is, during operation of the discriminator 27, maintained at potentials substantially above the reference ground potential present upon the filamentary cathodes of the remaining tubes provided in the system. More specifically, the circuit arrangement of the cathodes provided in the various electron discharge tubes referred to above and also provided in the diagrammatically illustrated sections of the system, is shown in Fig. 3 of the drawings. In this circuit, reference characters corresponding to those used in Figs. 1 and 2, but having the differentiating subscripts *a* and *b*, are used to identify the relationship between the cathodes and the respective associated circuit sections, as shown in Figs. 1 and 2. From a consideration of the circuit arrangement shown in Fig. 3, it will be noted that the various cathodes are effectively isolated at radio and audio frequencies by means of the separating filter networks comprising the illustrated high impedance choke coils and the low impedance by-pass condensers. It will also be noted that current for energizing the various cathodes in the series-parallel circuit is supplied by a direct current source 135 through the contacts of a manually operable "on" and "off" switch 136. The cathodes 16*a* and 17*a* of the electron discharge tubes respectively provided in the mixer 16 and the power amplifier 17 are arranged to be energized in series with each other and with a suitable current limiting resistor 137 through the contacts of a manually operable "press-to-talk" switch 138. This switch is normally spring biased to its open circuit position and may be utilized in the manner explained below selectively to condition the system for signal transmission or signal reception, as desired. It is provided with a pair of normally open contacts 138*a* which are closed to connect the microphone 12 across the primary winding of the transformer 35 only when the switch is operated to condition the system for signal transmission. From an inspection of the cathode circuit arrangement, it will be apparent that this circuit has been carefully arranged to utilize the voltage drops across certain of the cathodes as bias voltages between the input electrodes of certain of the other tubes provided in the system. For example, the voltage drop appearing across the cathode 25*a* of the tube provided in the first limiter stage 25 is impressed between the filamentary cathode 15*a* of the tube 47 in the proper direction to bias this cathode positively with respect to the control grid of the tube. These bias voltages, as derived from the circuit network shown in Fig. 3, are appropriately indicated in Figs. 1 and 2 of the drawings by the illustrated battery symbols, and the relationship between the respective battery symbols and the voltage drops across certain of the cathodes shown in Fig. 3 will be readily apparent from a careful comparison of the circuit shown in Fig. 3 with that shown in Figs. 1 and 2.

Preferably, the transmitter mixer tube 63 is a pentode of the well known commercial 3A4 type, the frequency doubler tube 47 and the master oscillator tube 40 are commercial type 1T4 pentodes, the automatic frequency control and reactance modulator tube 38 and the first mixer tube 70 are commercial type 1L4 pentodes, the second mixer tube 76 is a commercial type 1R5 pentagrid converter, the two diodes 88 and 89 are of the commercial type 1A3 and 1S5, respectively, the noise amplifier and rectifier tube 106 and the muting oscillator and rectifier tube 120 are commercial type 1S5 pentodes, and the direct current amplifier tube 113 is a commercial type 1L4 pentode. Suitable screen potentials are applied to the tubes 63, 47, 40, 38 and 76 over direct current paths which respectively include the filter resistors 62, 50, 45, 39 and 80, respectively. The potential applied to the screen electrode of the muting oscillator and rectifier tube 120 is controlled in the manner more fully explained below to effect the desired starting and stopping of the oscillator section of this tube. It will be understood that the tuning elements of the various tunable circuits provided in the system are gang controlled to be operated in unison, so that frequency alignment between the various resonant frequencies thereof is maintained during each tuning operation. More specifically, the tuning element of the antenna circuit 18, the tuning element of the radio frequency amplifier 20, and the adjustable condensers 64*c*, 52*c* and 41*c*, respectively provided at the tunable stages 16, 15 and 14, are mechanically connected in the manner indicated by the dash line U, so that all of the enumerated tuning elements may be operated in unison.

Briefly to consider the operation of the system, it will be understood that when the switch 136 is operated to its closed circuit position, the cathodes of all tubes provided in the system, with the exception of the cathodes 16*a* and 17*a* of the tubes provided in the mixer 16 and the power amplifier 17, are energized from the current source 135. If now the push-to-talk switch 138 is operated to its closed circuit position, the cathodes 16*a* and 17*a* are also energized. Due to the filamentary character of the energized cathodes, they are rapidly heated to electron emitting temperatures following the energization thereof.

When the two switches 136 and 138 are thus operated, the system is conditioned for signal transmission at the particular carrier frequency established by the tuning of the five tunable stages 14, 15, 16, 17 and 18 of the transmission channel. In this regard it will be understood that when space current flow through the tube 40 is initiated, the master oscillator 14 starts to oscillate at a carrier frequency which is primarily determined by the setting of the tuning condenser 41*c* and is secondarily determined by the magnitude of the bias voltage between the control grid and cathode of the tube 38. More generally considered, if the receiving channel 11 of the system is designed to operate with a first intermediate frequency of 4.3 megacycles and signals are to be transmitted and received at a carrier frequency of 44.3 megacycles, the condenser 41*c* is so adjusted that with zero bias upon the control grid of the tube 38, the master oscillator 14 will produce a carrier voltage having a frequency of 20 megacycles and the other tunable circuits of the transmission channel 10 are adjusted accordingly. With the frequency of the signal carrier thus determined, an audio frequency voltage developed through operation of the microphone 12 is impressed through the microphone transformer 35 and the coupling condenser 36 between the control grid and cathode of the modulator tube 38. The resulting audio frequency variation of the voltage between the control grid and cathode of the tube 38 effectively changes the reactance of the tunable frequency determining circuit 41 of the master oscillator 14 at a corresponding rate. In other words, varying the voltage applied between the input electrodes of the tube 38 effectively serves to vary the tuning of the network 41 in like manner, whereby the carrier output of the oscillator 14 is reactance modulated in accordance with the audio signal voltage impressed between the input electrodes of the tube 38. This modulated carrier voltage is impressed between the input electrodes of the tube 47 of the frequency doubler 15 through the coupling condenser 49. Due to the action of the tube 47 in distorting the signal modulated carrier voltage and the action of the tunable frequency selecting circuit 52 in selecting only signal modulated carrier components having twice the frequency of the carrier voltage developed at the output side of the oscillator 14, the modulated carrier voltage appearing across the output circuit of the doubler 15 has a carrier frequency which is twice that of the oscillator carrier output frequency, i. e. 40 megacycles in the case assumed above. The signal modulated carrier voltage appearing across the frequency selecting circuit 52 is impressed between the input electrodes of the transmitter mixer tube 63 over a path which includes the coupling condenser 59 and the heterodyning piezo-electric crystal 58. As previously explained, this crystal has a resonant frequency which is equal to the first intermediate frequency used in the receiving channel 11 of the system. Accordingly, this crystal, acting in conjunction with the tuned circuit 60, functions to produce a carrier voltage which is electronically mixed in the tube 63 with the carrier frequency output across the tuned circuit 52, so that a carrier is produced at the output side of the mixer tube 63 having a frequency equal to twice the output frequency of the oscillator 14 plus the first intermediate frequency. This carrier voltage is frequency modulated in accordance with the audio frequency voltage applied to the input electrodes of the modulator tube 38. At the output side of the tube 63, this particular signal modulated carrier voltage is selected through the action of the tuned frequency selecting circuit 64 and is impressed across the input circuit of the power amplifier 17 through the coupling condenser 65. After being amplified by the amplifier 17, the voltage is transmitted through the tunable antenna circuit 18 and impressed across the antenna ground circuit 19 for radiation.

Referring now more specifically to the function performed by the tunable transmitter mixer 16, it is pointed out above that the tunable frequency selecting circuit 64 is tuned to respond only to a signal modulated carrier having a carrier frequency which is greater than twice the output carrier frequency of the oscillator 14 by an amount equal to the intermediate frequency utilized in the first intermediate frequency channel 22 of the receiver. Since the carrier voltage appearing across the tuned output circuit 52 of the frequency doubler 15 is used as a heterodyning frequency source at the first mixer stage 21 during reception and this frequency is mixed with the frequency produced by the crystal 58 to produce a frequency of carrier radiation which is equal to the sum of the two frequencies, signal reception and transmission may be held at the same carrier frequency. Thus if the crystal 58 has a resonant frequency of 4.3 megacycles, equaling the center intermediate frequency used in the first intermediate frequency section of the receiver channel 11, and the tuning elements of the tunable stages 14, 15, 16, 17, 18 and 20 are adjusted by means of the adjusting element U to a setting wherein the carrier output frequency of the oscillator 14 is 20 megacycles and the carrier output frequency of the doubler 15 is 40 megacycles, then the tunable stages 17, 18 and 20 are tuned to a carrier frequency of 44.3 megacycles. This of course means that if the tunable stages of two remotely located sets of the character illustrated are tuned for transmission and reception at the same carrier frequency, it is unnecessary to alter the settings of the tuning elements of either set when the direction of transmission between the two systems is changed. Thus, the systems of the two sets may rapidly be altered for transmission in either direction with a minimum number of manual operations on the part of the persons using the respective sets for two-way communication.

As indicated above, the desired increase in the frequency of the radiated carrier over the carrier frequency appearing at the output side of the frequency doubler 15 is provided through the action of the piezoelectric crystal 58. In considering the manner in which this crystal is driven at its resonant frequency, it is pointed out that at this resonant frequency, the upper terminal of the tuned circuit 52 is effectively at ground potential due to the low impedance of this circuit at the particular frequency in question. The resonant circuit 60 which is coupled between the cathode and screen electrode of the tube 63 is precisely tuned to the resonant frequency of the crystal 58. Due to the electronic and capacitance coupling between the upper terminal of the tuned circuit 60 and the lower terminal of the crystal 58, a sufficient driving voltage is applied across the crystal 58 through the tuned circuit 52 to maintain the oscillation of the crystal. This coupling also serves to maintain the tuned circuit 60 oscillating at its resonant frequency.

In order to condition the system for signal reception after signal transmission has been effected in the manner explained above, the push-to-talk switch 138 is released. Incident to the restoration of this spring biased switch to its normal position, the cathodes 16*a* and 17*a* of the tube 63 and the tube provided in the power amplifier 17 are deenergized in an obvious manner. Thus, the transmitter mixer stage 16 and the power amplifier stage 17 of the transmitter channel 10 are rendered inactive without in any way interrupting or otherwise affecting the operation of the preceding stages 13, 14 and 15. In this regard it is pointed out that when space current flow through the mixer tube 63 is interrupted, the operation of the oscillator section of this tube, i. e. that portion of the tube input circuit which comprises the intercoupled crystal 58 and resonant circuit 60, is arrested. Thus, no carrier voltage is produced in the transmission channel 10 having a frequency approaching the intermediate frequency used at either the first or second intermediate frequency sections of the receiving channel 11. Accordingly, the continued operation of the three stages 13, 14 and 15 of the transmission channel 11 can in no way interfere with the reception of the selected signal modulated carrier.

Assuming that the system is conditioned for signal reception in the manner explained above, and that the tunable stages of the system are appropriately tuned to the center frequency of a desired frequency modulated signal carrier, the signal carrier voltage appearing across the antenna ground circuit 19 is transmitted through the tunable circuit 18 and the coupling condenser 67 to the input side of the tunable radio frequency amplifier 20. This voltage, as amplified by the amplifier 20, is mixed with the carrier output voltage of the frequency doubler 15, which output voltage is impressed between the cathode and control grid of the tube 70 over a coupling path including the inductance element 53. It is thus converted into a signal modulated intermediate frequency carrier which is amplified through the first intermediate amplifier 22 and impressed between the input electrodes of the tube 76 provided in the second mixer stage 23.

In the second mixer stage, the intermediate frequency carrier output from the amplifier 22 is mixed with the carrier frequency produced through operation of the crystal 77 so that a beat frequency carrier, modulated with the signal voltage and of the desired second intermediate frequency, appears across the tuned output circuit 81. This modulated carrier, as selected through the action of the tuned circuit 81, is transmitted through the condenser 84 to the second intermediate frequency amplifier 24 where it is amplified and transmitted successively through the limiter stages 25 and 26 to the input side of the discriminator 27. In this discriminator the modulation components of the second intermediate frequency carrier, as represented by deviations in the carrier frequency from the established center frequency, are detected in the manner pointed out below. The detected signal voltage appears across the condenser 93, which condenser is possessed of exceedingly low impedance at the center carrier frequency and exceedingly high impedance at audio frequencies. This voltage is impressed across the voltage dividing network comprising the resistors 98 and 100 through the carrier frequency decoupling resistor 94 and the audio frequency coupling condenser 97. The portion of this voltage which appears between the wiper 99 and ground is impressed across the input circuit of the audio frequency amplifier 28 in an obvious manner. The audio frequency signal voltage as impressed across the input side of the audio frequency amplifier 28 is amplified in this amplifier and transmitted to the loud speaker 29 for reproduction.

Referring now more particularly to the operation of the discriminator 27, it will be noted that this circuit is essentially a four terminal bridge circuit two arms of which respectively include the condensers 87*b* and 87*c* of equal capacitances. A third arm of the bridge comprises the capacitive impedance of the diode 88. The fourth arm of the bridge comprises the combined capacitive impedance of the diode 89 and the condenser 92. The inductance element 87*a* is bridged between two terminals of the bridge circuit and the frequency modulated signal voltage is applied to the circuit across the other two terminals thereof. Since the load resistors 90 and 91 have impedances far in excess of the capacitive impedances of the diode legs of the bridge circuit at the frequencies involved, they may be neglected in analyzing the circuit. Again, the capacitance of the condenser 93 is so much greater than that of either diode leg of the circuit, that this condenser may also be neglected in analyzing the circuit. With this bridge circuit arrangement the voltage appearing at the output side of the discriminator is the difference between the absolute values of the voltages to ground at the upper and lower terminals of the inductance element 87*a*. From an examination of the bridge, it will be understood that if the capacitance of the condenser 87*b* equals that of the condenser 87c, which it does, and the capacitances of the two diode legs of the circuit are equal, such that the bridge is balanced, the currents respectively traversing the condensers 87b and 87c are equal so that equal voltage drops appear across these condensers. Accordingly, no difference between the voltages to ground is developed at the upper and lower terminals of the inductance element 87a, regardless of the frequency of the exciting voltage applied to the circuit. In the actual circuit, however, the capacitance of the leg which includes the diode 89 is greater than the capacitance of the leg including the diode 88 by an amount equal to the capacitance value of the condenser 92, such that the bridge is unbalanced. Accordingly during excitation of the circuit, the current traversing the condenser 87c exceeds the current traversing the condenser 87b so that a current is caused to flow through the inductance element 87a.

The magnitude of this current obviously depends upon the reactive impedance of the inductance element 87a at the particular frequency of excitation, and the direction of current flow is such that the voltage drop across the condenser 87b is enhanced and that across the condenser 87c is decreased. It will be understood, therefore, that by suitably proportioning the impedance of the inductance element 87a relative to the reactive impedance of the condensers 87b and 87c at a particular center frequency to establish a given relationship between the currents traversing the circuit elements 87a, 87b and 87c, the absolute voltages between the upper and lower terminals of the inductance element 87a and ground become equal. In their relationship to each other, however, these voltages are out of phase so that a difference voltage actually exists between the upper and lower terminals of the circuit 87. This difference voltage is, of course, equal to the vector sum of the absolute voltages from the upper and lower terminals of the inductance element 87a to ground. The particular frequency at which these absolute voltages become equal to balance the bridge represents the center frequency at which the voltage appearing at the output side of the discriminator between the cathode of the diode 88 and ground becomes zero. In this regard it is pointed out that when the bridge is balanced so that the voltages from the upper and lower terminals of the inductance element 26a to ground are equal, equal direct voltages are produced across the load resistors 90 and 91. These voltages are opposingly combined in a direct current path through the inductance element 87 so that when equal, no direct voltage appears between the cathode of the diode 88 and ground.

As the exciting voltage for the resonant circuit 87 is increased above the center frequency, due to the signal modulation thereof at an audio rate, the reactive impedances of the circuit constants change to alter the relative magnitudes of the currents traversing the circuit elements 87a, 87b and 87c, so that the voltage from the upper terminal of the inductance element 87a to ground exceeds that between the lower terminal of the inductance element 87a and ground. Accordingly, a voltage which is positive with respect to ground is produced between the cathode of the diode 88 and ground. If, on the other hand, the exciting frequency for the circuit 87 is decreased below the center frequency, the reactive impedances of the circuit constants change to alter the relative magnitudes of the currents traversing the circuit elements 87a, 87b and 87c so that the voltage between the lower terminal of the inductance element 87a and ground exceeds that between the upper terminal of the inductance element 87a and ground. As a result, an output voltage which is negative with respect to ground is produced between the cathode of the diode 88 and ground. It has been found that the extent or magnitude of the discriminator output voltage varies in accordance with the departure of the exciting frequency from the center intermediate frequency to which the discriminator network 27 is center tuned. It will be understood, therefore, that if the frequency of the carrier appearing at the output side of the limiter 26 is frequency modulated in accordance with a given audio signal, a corresponding audio frequency voltage is accurately reproduced across the condenser 93 at the output side of the discriminator 27.

To consider somewhat more fully the action of the condenser 92 in stabilizing the operation of the discriminator network 27, it may be pointed out that if the impedances of the four legs of the bridge circuit are perfectly balanced, changes in the exciting frequency will not produce the desired differences of potential between the upper and lower terminals of the inductance element 87a and ground. By providing the condenser 92 connected in the manner illustrated, however, thereby to insure that the over-all capacitance between the lower terminal of the inductance element 87a and ground exceeds that between the upper terminal of this element and ground, the desired circulating current within the resonant circuit 87 will always be produced to insure stability of circuit operation. In this regard it is pointed out that the unbalancing or stabilizing condenser 92 may be connected either between the lower terminal of the resonant circuit 87 and ground or between the upper terminal of this circuit and ground. In either case, the desired operation of the network is produced. It is noted, however, that when a condenser 92 of appropriate capacitance value is connected between the upper terminal of the circuit 87 and ground, the direction of circulating current flow within the circuit is reversed. Accordingly, the polarity of the output voltage produced across the condenser 93 incident to a given departure of the exciting frequency from the center intermediate frequency is the reverse of that which is obtained for the same frequency departure when the condenser 92 is connected between the lower terminal of the resonant circuit and ground.

If desired, one rectifying section of the improved discriminator 27 may be combined with the audio frequency amplifier 28 in the manner illustrated in Fig. 5 of the drawings, wherein reference characters corresponding to those used in Fig. 2 identify the same circuit elements. From an examination of the Fig. 5 arrangement, it will be seen that the diode section of the tube 89 is utilized as one of the rectifying paths of the discriminator, and that the cathode, anode and three grids of the tube are used to amplify the audio frequency voltage which is developed between the wiper 99 and ground during reception of a selected signal. This audio voltage is transmitted to the loud speaker 29 for reproduction through a coupling transformer 139. The manner in which the audio section of the tube is blocked under the control of the muting oscillator 33 and mode of operation of the discriminator 27 are exactly the same as explained herein with reference to the system shown in Figs. 1 and 2. In fact, the circuit of Fig. 5 may be directly substituted for the discriminator 27 and the audio frequency amplifier 28 in the system of Figs. 1 and 2 to perform in the same manner, when the indicated connections are made between this circuit and the limiter 26, the high pass filter 30, the transmitter mixer 16, the muting oscillator and rectifier 33, and the modulator stage 13.

Automatic frequency control

As previously indicated, provisions including the discriminator 27 and the modulator stage 13 of the transmission channel 10, are made in accordance with the present invention for automatically adjusting the output frequency of the frequency doubler 15 so that the difference between this frequency and the center frequency of a selected carrier is held at a substantialy constant value which substantially equals the center intermediate frequency to which the resonant circuits of the first intermediate frequency section of the receiving chanel 11 are tuned. The purpose of this arrangement is to correct for any drift in the output frequency of the oscillator 14 or in the center frequency of the received signal carrier. In this regard, it is noted that regardless of the settings of the tuning elements provided in the tunable stages 18 and 20 of the receiving channel 11, these stages are broadly tuned to the center carrier frequency which corresponds to the settings of the tuning elements, so that irrespective of any drift in the center frequency of the received carrier all modulation components of the received signal are passed through these stages of the receiving channel. In a similar manner, the fixed tuned stages of the first and second intermediate frequency sections of the channel 11 are somewhat broadly tuned in order to permit, within limits, deviations in the center carrier frequencies appearing therein without cutting off the modulation components of the frequency modulated carriers which are transmitted therethrough. It will be understood, therefore, that by providing the improved automatic frequency control arrangement described below, any drift in the output frequency of the oscillator 14 or in the center frequency of a received signal carrier is substantially corrected in so far as the intermediate frequency sections of the receiving channel and the discriminator 27 are concerned.

Briefly to consider the manner in which the output frequency of the oscillator 14 is automatically controlled, it may be assumed that the center frequency of the received signal carrier starts to drift to a value higher than the center frequency to which the resonant circuits of the tunable stages 18 and 20 are tuned, or that while this center carrier frequency remains constant, the output frequency of the oscillator 14 starts to drift from an established value to a lower value. As the frequency drift starts and regardless of where it originates, the center frequency of the carrier transmitted through the first intermediate frequency amplifier 22 increases to produce a corresponding decrease in the center frequency of the carrier transmited through the second intermediate frequency stages 24, 25 and 26. As will be apparent from the above explanation, this departure in the exciting frequency of the tuned circuit 87 from the center frequency to which this circuit is tuned, causes a bias voltage, which is negative with respect to ground, to be produced between the cathode of the diode 88 and ground. This bias voltage is negatively applied to the control grid of the modulator tube 38 over a path which includes the radio frequency decoupling resistor 94, the audio frequency decoupling resistor 95 and the filter resistors 131 and 37. At this point it is noted that the audio frequency filter comprising the decoupling resistor 95 and the by-pass condenser 96 prevents the audio frequency components of the voltage appearing at the output side of the discriminator 27 from being impressed between the input electrodes of the modulator tube 38. This filter also prevents audio frequency voltages developed during signal transmission by the microphone 12 from being impressed upon the input side of the audio frequency amplifier 28 through the coupling condenser 97.

As the bias applied to the tube 38 increases, the magnitude of the out of phase current component traversing the space current path of the modulator tube 38 and the tuned circuit 41 changes so that the frequency of the voltage developed by the master oscillator 14 increases. As this frequency increases, that appearing at the output side of the doubler 15 obviously changes in like manner to decrease the center frequency of the signal carrier traversing the first intermediate frequency section and increase the center frequency of the signal carrier traversing the scond intermediate section of the receiving channel 11. The resulting increase in the center excitation frequency of the resonant circuit 87 produces a corresponding decrease in the rate of increase of the negative bias voltage applied between the control grid and cathode of the modulator tube 38. As the bias applied to the tube 38 continues to increase at a constantly decreasing rate the center frequencies of the signal carriers traversing the first and second intermediate frequency sections of the receiving channel 11 change in like manner until the two factors become balanced. It will be understood, therefore, that when the received carrier frequency is stabilized at a particular above-normal value, the bias voltage applied to the modulator tube 38 is likewise stabilized at a particular value. Moreover, if the circuit constants of the system are properly chosen, this bias voltage will in each instance be stabilized at a value such that the center frequencies of the signal carriers traversing the first and second intermediate sections of the receiving channel 11 will be held at values which closely approximate the center frequencies at which these sections of the receiving channel and the discriminator 27 are designed to operate.

If the center frequency of a selected signal carrier drifts to a value below the center frequency to which the stages 18 and 20 are tuned, or the output frequency of the oscillator 14 drifts from its established value to a higher value, the center frequencies of the signal carriers traversing the first and second intermediate frequency sections of the receiving channel 11 are decreased and increased respectively. As a result, a positive bias voltage appears at the output side of the discriminator 27 which is applied to the tube 38 to produce a decrease in the output frequency of the oscillator 14. The center frequencies of the signal carriers traversing the intermediate frequency sections of the receiving channel are increased and decreased accordingly. Thus, the frequency correcting action proceeds in the exact manner explained above until a point of stability is reached at which the center frequency of the signal carrier voltage impressed upon the discriminator network 27 closely approximates the center frequency to which the resonant circuit 87 is tuned.

Operation of the muting apparatus

Referring now more particularly to the manner in which the audio section of the receiving channel 11 is muted or squelched during periods when the system is conditioned for operation but is not being used either for signal transmission or reception, it may be pointed out that at all times when the system is conditioned for reception but is not receiving a desired signal, noise signal voltages appear in those stages of the receiver channel which precede the discriminator 27. These voltages are transmitted through the intermediate frequency and mixer stages of the channel 11 and are detected by the discriminator 27 to appear as audio frequency voltages at the output side of the discriminator. They may be produced as a result of thermal agitation within the tubes provided in the receiving channel, shot effects, extraneous noise voltages appearing across the antenna-ground circuit 19, or by physical shock to the circuit elements provided in the receiving channel. Regardless of the origin thereof, however, the noise signals are manifested as audio frequency voltages across the output side of the discriminator which, in the absence of the muting apparatus provided in the system, would be passed through the audio frequency amplifier 28 to the loud speaker 29 for reproduction.

More specifically considered, the noise response of the receiver is graphically illustrated in Fig. 4 of the drawings, wherein the noise voltage appearing across the condenser 93 is plotted as a function of the selected signal carrier input voltage appearing across the antenna-ground circuit 19. From a consideration of this curve, it will be noted that when no signal carrier is being received, the noise voltage appearing at the output side of the discriminator 27 is high and that the magnitude of this voltage is sharply reduced in response to the application of a selected signal carrier to the antenna-ground circuit 19. The decrease in the level of the noise voltage which accompanies the transmission of a selected signal through the receiving channel 11, is largely effected in the amplitude limiters 25 and 26.

To consider the action of the muting apparatus, it is pointed out that the noise voltage appearing between the cathode of the diode 88 and ground at the output side of the discriminator 27 is impressed upon the input side of the high pass filter 30. This filter acts to pass only those components of the noise voltage having frequencies above the normal signal reproducing band of the receiver. For example, this filter may be designed to pass frequencies above 20 kilocycles. The noise voltage appearing across the output side of the filter 30 is impressed between the input electrodes of the noise amplifier and rectifier tube 106 and appears in amplified form across the coupling condenser 108 and the diode section of the tube 106 in series. Due to the rectifying action of the diode section of the tube 106, a direct voltage is produced across the load resistor 110 which varies in magnitude in accordance with the magnitude of the noise voltage impressed between the input electrodes of the tube 106. This direct voltage i. e. that across the resistor 110, is negatively applied to the control grid of the direct voltage amplifier tube 113 through the resistor 112 in opposition to the fixed bias voltage normally positively applied to the control grid of the tube 113 through the resistor 115. The negative voltage appearing across the resistor 110 so greatly predominates over that positively applied to the control grid of the tube 113 that this tube is biased beyond its space current cutoff point. Accordingly, the voltage drops across the two resistors 118 and 119 are sharply decreased to very low values, with the result that the full voltage of the available source of anode current is positively applied to the screen electrode of the oscillator and rectifier tube 33. The application of this voltage to the screen electrode of the tube 120 initiates the operation of the oscillator section of this tube, so that an oscillatory voltage is developed across the series connected coupling condenser 129 and the space current path between the diode electrodes of the tube. Due to the action of the diode section of the tube 120 in rectifying the oscillatory voltage, a direct bias voltage is produced across the diode load circuit comprising the series resistors 128, 132 and 78*b*. This bias voltage is negatively applied to the control grid of the first tube provided in the audio frequency amplifier 28, over a path which includes the resistors 127 and 100 and the encircuited portion of the resistor 98. The magnitude thereof is sufficient to bias the first audio frequency amplifier tube beyond cutoff, whereby the noise signals are prevented from being transmitted through the audio channel of the receiver to the loud speaker 29 for reproduction.

As will be apparent from further consideration of the curve shown in Fig. 4 of the drawings, when a selected signal carrier of substantial magnitude appears across the antenna ground circuit 19, the limiters 25 and 26 function sharply to decrease the noise voltage developed at the output side of the discriminator 27. This produces a corresponding decrease in the bias voltage developed across the load resistor 110. When the negative bias applied to the control grid of the tube 113 is thus reduced to a low value, the current flow through the resistors 118 and 119 and the space current path of the tube 113 is sharply increased to produce a corresponding increase in the voltage drops across the two identified resistors. As a result, the voltage which is positively applied to the screen electrode of the oscillator and rectifier tube 33 through the two resistors 118 and 119 is sharply decreased to a value such that operation of the oscillator section of this tube cannot continue. When the production of an oscillatory voltage across the space current path of the tube 120 is thus arrested, the negative bias voltage across the rectifier load circuit resistors 128, 132 and 78*b* is reduced to zero, permitting the normal negative bias voltage as developed across the resistor 78*b* to be impressed upon the control electrode of the first tube provided in the audio frequency amplifier 28. When this amplifier tube is thus unblocked or biased to a normal value, the audio section of the receiving channel is rendered operative to amplify the audio frequency components of the received signal and to transmit the same to the loud speaker 29 for reproduction.

From the foregoing explanation it will be understood that normally, i. e. when the system is conditioned for signal reception, the noise signals appearing in the receiving channel 11 are utilized to completely block the audio section of the receiving channel against the transmission of noise signals to the loud speaker 29. More specifically, the component circuit elements of the muting apparatus should be so chosen that in the absence of a desired signal, the negative bias voltage developed at the upper terminal of the resistor 128 is approximately 20 volts. To this end, from 40 to 50 volts must be positively applied to the screen electrode of the oscillator and rectifier tube 33 when a tube of the commercial 1S5 type is employed in the oscillator and rectifier stage 33. Further, the component circuit elements of the muting apparatus should be such that when a selected frequency modulated carrier is received having a magnitude exceeding a predetermined low value, the voltage positively applied to the screen electrode of the tube 120 is dropped to approximately 20 volts such that operation of the oscillator section of the tube 120 is arrested. In the absence of an oscillatory voltage between the anode and cathode of this tube, the only negative bias voltage applied to the control grid of the first tube in the audio frequency amplifier 28 is that developed across the grid leak resistor 78*b*, which voltage is of the order of one volt.

When the apparatus is designed to have the characteristics just described, the audio channel of the receiver will at all times remain blocked during periods when a selected signal is not being received and will be automatically unblocked when a selected signal is transmitted through the receiving channel of the system to the discriminator 27 for detection. In this regard it will be understood that since the high pass filter 30 will only pass frequencies outside of the normal signal reproducing frequency band of the receiving channel, the muting apparatus is not responsive to the audio frequency components of a received signal carrier and thus this apparatus is prevented from blocking the audio section of the receiving channel against the transmission of detected signal voltages to the loud speaker 29.

Blocking the receiving channel during transmission

In considering the manner in which the receiving channel 11 is blocked against reproduction of the signal components of the modulated carrier radiated during operation of the transmission channel 11, it is pointed out that the equipment is deliberately designed and is physically so arranged that a relatively large amount of stray capacitance coupling exists between the circuit elements provided in the input and output circuits of the first mixer 21, and the electrodes of the crystal 58 and the circuit conductors connecting these electrodes with the input electrodes of the tube 63 and the terminals of the tuned circuit 52. More specifically, the electrodes of the crystal 58, the elements of the tuned circuit 60 and the circuit elements forming the input circuit for the mixer tube 70 are unshielded; and the control grid of the tube 70 is spaced approximately one inch from the circuit conductor which connects the control grid of the tube 63, the lower electrode of the condenser 59 and the lower electrode of the crystal 58. With this arrangement and during signal transmission, when the crystal 58 and the tuned circuit 60 are oscillating, a strong unmodulated carrier voltage appears at the output side of the first mixer 21, having a frequency equal to the center frequency to which the resonant circuits of the first intermediate frequency section of the receiving channel are tuned. This strong carrier voltage as transmitted through the first intermediate frequency amplifier 22, the second mixer 23, the second intermediate frequency amplifier 24, and the two limiter stages 25 and 26, to the input side of the discriminator 27, effectively blocks the enumerated stages of the receiver against the transmission of the signal modulated carrier which is impressed upon the input side of the tunable radio amplifier 20 through the condenser 67. More particularly, the blocking carrier voltage which appears across the output side of the first mixer 21 in the receiver, as a result of the stray capacitance coupling between the circuit elements of this mixer and the circuit elements associated with the crystal 58, exceeds by several times the modulated signal carrier which appears at the input side of the mixer 21 due to the coupling between the transmitting and receiving channels through the condenser 67. Since the carrier voltage as derived from the crystal 58 so greatly predominates over that transmitted through the tunable radio frequency amplifier 20 to the input side of the mixer 21, those stages of the receiver which follow the mixer 21 are effectively blocked against the transmission of the signal modulated carrier to the discriminator 27. Thus, the loud speaker 29 is prevented from reproducing the audio frequency voltage developed through operation of the microphone 12 when the system is conditioned for transmission.

The crystal 58 also acts in conjunction with the fixed tuned stages of the reeciver to set the radiated carrier center frequency so that this frequency cannot be changed by the discriminator 27 and is maintained at substantially the exact desired value. Thus, due to the capacitance coupling between the circuit elements of the first mixer 21 and the circuit elements of the fixed tuned crystal 58 and resonant circuit 60, a carrier having a frequency exactly equaling the first intermediate frequency is injected into the first intermediate frequency section of the receiving channel. This carrier is mixed with the frequency produced by the oscillator section of the second mixer tube 76 to produce a carrier in the second intermediate frequency section of the receiving channel which exactly equals the center frequency to which the resonant circuit 87 is tuned. When this carrier voltage is applied to the discriminator 27, the bias voltage appearing at the output side of the discriminator between the lower terminal of the resistor 95 and ground is reduced to a negligible or zero value. Moreover, since the crystal 58 and the crystal 77 which controls the oscillator section of the second mixer tube 76 are invariably fixed to oscillate at set frequencies, the negligible bias voltage appearing at the output side of the discriminator 27 cannot be changed or altered in the slightest degree during transmission. Accordingly, the bias applied to the input electrodes of the modulator tube 38 through the resistors 131 and 37 is held at a fixed negligible value during transmission with the result that the modulator oscillator 13, 14 are inflexibly set to produce a signal modulated carrier voltage having a fixed center frequency. Thus, the crystal 58, acting in conjunction with the stages 21, 22, 23, 24, 25, 26 and 27 of the receiving channel 11, functions to stabilize the center frequency of the radiated signal carrier at the definite and fixed value desired. This center frequency value can, however, be altered by adjustment of the adjusting element U to alter the settings of the tuning elements provided in the tunable stages 14, 15, 16, 17 and 18 of the transmission channel, but once the desired value is established it is maintained by the crystal 58 in the manner just explained.

The strong carrier injected by the crystal 58 and its associated circuit elements into the first intermediate frequency channel of the receiving channel 11 through the capacitance coupling between the circuit elements associated with the crystal 58 and the circuit elements of the first mixer 21, also serves to control the muting apparatus so that the audio section 28 of the receiving channel 11 is unblocked or rendered active during signal transmission. More specifically, this carrier has the same effect, in so far as the reduction of noise voltages at the output side of the discriminator 27 is concerned, as does the application of a strong signal of a selected center carrier frequency to the antenna ground circuit 19. Accordingly, and as will be apparent by reconsidering the curve shown in Fig. 4 of the drawings, when the strong carrier is injected into the first intermediate frequency section of the receiving channel, the noise voltage developed between the cathode of the tube 88 and ground at the output side of the discriminator 27 drops to a negligible value. As a result, the oscillator section of the tube 129 stops oscillating, for reasons explained above, and the negative blocking bias is removed from the control grid of the first tube in the audio frequency amplifier 28. Thus, this amplifier is rendered operative, and may, if desired, be used to amplify and transmit to the loud speaker 29 for reproduction, any side tone voltage suitably derived from the audio channel of the transmission channel 10.

From the foregoing explanation it will be apparent that an improved system is provided in which all available tubes and circuit elements are utilized with maximum effectiveness both during reception and transmission. Thus, the master oscillator 14 is not only used as a carrier producing oscillator during signal transmission, but is also coupled to the first mixer stage 21 to operate as a local oscillator during reception. Again the modulator stage 13 is not only used to reactively modulate the carrier output of the oscillator 14 during transmission but, in addition, functions to provide automatic frequency control in the intermediate frequency sections of the receiving channel during signal reception. The use of the transmitter stages 13, 14 and 15 in the dual capacities mentioned may be directly attributed to the provision of the mixer stage 16 in the transmission channel 10. Thus by providing at this stage a mixing oscillator having an output frequency equaling the center frequency of the first intermediate frequency section of the receiving channel, it becomes practical to utilize the three stages 13, 14 and 15 of the system in the dual capacities indicated. This is true for the reason that by providing the mixing oscillator at the mixer stage 16, transmission and reception may be effected at the same center carrier frequency without in any way altering the tuning of any of the tunable stages of the system as it is selectively conditioned for signal transmission or reception. Moreover, by providing the described novel system arrangement, only the transmission mixer 16 and the power amplifier 17 are required to be controlled in order selectively to condition the system for signal transmission or reception.

While one embodiment of the invention has been disclosed, it will be understood that various modifications may be made therein, which are within the true spirit and scope of the invention.

I claim:

1. In a frequency modulated radio transmitting and receiving system which includes means for selectively conditioning the system for signal transmission or reception, a receiving channel including a mixer stage followed by an intermediate frequency section, a transmission channel including a carrier producing oscillator coupled to said mixer stage to operate as a local oscillator during signal reception, and inversely acting means coupled between said intermediate frequency channel and said oscillator for automatically controlling the output frequency of said oscillator to hold substantially constant the center frequency of a frequency modulated carrier transmitted through the intermediate frequency section of said receiving channel during signal reception.

2. In a combined radio transmitting and receiving system which includes means for selectively conditioning the system for signal transmission or reception, a receiving channel including a mixer stage followed by an intermediate frequency section, a transmission channel including a carrier producing oscillator coupled to said mixer stage to operate as a local oscillator during signal reception, and inversely acting means coupled between said intermediate frequency channel and said oscillator for automatically controlling the output frequency of said oscillator to hold substantially constant the carrier frequency of a signal modulated carrier transmitted through the intermediate frequency section of said receiving channel during signal reception.

3. In a frequency modulated radio transmitting and receiving system which includes means for selectively conditioning the system for signal transmission or reception, a receiving channel including a mixer stage followed by an intermediate frequency section and a frequency discriminator in the order named, a transmission channel including a modulator and an oscillator controlled by said modulator to produce a frequency modulated carrier during signal transmission, means coupling said oscillator to said mixer stage to operate as a local oscillator during signal reception, and means coupling the output side of said discriminator to said modulator to govern the output frequency of said oscilator so that the center frequency of a frequency modulated carrier transmitted through the intermediate frequency section of said receiving channel during signal reception is held substantially constant.

4. In a frequency modulated radio transmitting and receiving system which includes means for selectively conditioning the system for signal transmission or reception, a receiving channel including a mixer stage followed by an intermediate frequency section and a frequency discriminator in the order named, a transmission channel including an oscillator coupled to said mixer stage to operate as a local oscillator during signal reception, and means controlled by said discriminator for automatically controlling the output frequency of said oscillator to hold substantially constant the center frequency of a frequency modulated carrier transmitted through the intermediate frequency section of said receiving channel during signal reception.

5. In a combined radio transmitting and receiving system which is adapted to be selectively conditioned for signal transmission or signal reception, transmission and receiving channels

respectively including high frequency carrier and intermediate frequency carrier sections, two like sections of said channels including frequency selective stages which are tuned to the same resonant frequencies, frequency converters respectively provided in said channels at the junctions between the high and intermediate frequency sections thereof, means coupling the intermediate frequency section of said transmission channel to the frequency converter of said receiving channel so that a frequency beating carrier is supplied to said last-named frequency converter from said transmission channel during signal reception, and means for rendering the high frequency section of said transmission channel inactive when said system is conditioned for signal reception.

6. In a combined radio transmitting and receiving system which is adapted to be selectively conditioned for signal transmission or signal reception, a transmission channel provided with an audio frequency section, a tunable intermediate frequency section and a tunable radio frequency section in the order named, a receiving channel provided with a tunable radio frequency section, an intermediate frequency section and an audio frequency section in the order named, a frequency converter provided between the radio and intermediate frequency sections of said receiving channel, tuning elements respectively provided in said tunable stages, and unicontrol means for controlling said tuning elements so that regardless of the settings of said tuning elements the center resonant frequencies of said radio frequency sections are substantially equal and the center resonant frequency of at least one stage of the intermediate frequency section of said transmission channel is equal to the difference between the center resonant frequencies of the radio and intermediate frequency sections of said receiving channel, and a coupling path for injecting a carrier voltage into said converter from said one stage of said transmission channel during signal reception.

7. In a combined radio transmitting and receiving system which is adapted to be selectively conditioned for signal transmission or signal reception, a transmission channel provided with an audio frequency section, a tunable intermediate frequency section and a tunable radio frequency section in the order named, a receiving channel provided with a tunable radio frequency section, an intermediate frequency section and an audio frequency section in the order named, a frequency converter provided between the radio and intermediate frequency sections of said receiving channel, tuning elements respectively provided in said tunable stages, and unicontrol means for controlling said tuning elements so that regardless of the settings of said tuning elements the center resonant frequencies of said radio frequency sections are substantially equal and the center resonant frequency of at least one stage of the intermediate frequency section of said transmission channel is equal to the difference between the center resonant frequencies of the radio and intermediate frequency sections of said receiving channel, a coupling path for injecting a carrier voltage into said converter from said one stage of said transmission channel during signal reception, and means for rendering the radio frequency section of said transmission channel inactive when said system is conditioned for signal reception.

8. In a combined radio transmitting and receiving system which is adapted to be selectively conditioned for signal transmission or signal reception; a transmission channel provided with a modulator, a carrier producing oscillator, a tunable frequency doubler, a tunable mixer stage and a tunable radio frequency section connected in tandem in the order named; a receiving channel provided with a tunable radio frequency section, a tunable mixer stage, an intermediate frequency section and a frequency discriminator connected in tandem in the order named; means for utilizing the carrier voltage developed at the output side of said doubler as a local oscillator voltage for frequency conversion at the mixer stage of said receiving channel during signal reception, tuning elements respectively provided in said tunable stages, and unicontrol means for so controlling said tuning elements that regardless of the settings of said tuning elements the center resonant frequencies of said radio frequency sections are substantially equal.

9. In a combined radio transmitting and receiving system which is adapted to be selectively conditioned for signal transmission or signal reception; a transmission channel provided with a modulator, a carrier producing oscillator, a tunable frequency doubler, a tunable mixer stage and a tunable radio frequency section connected in tandem in the order named; a receiving channel provided with a tunable radio frequency section, a tunable mixer stage, an intermediate frequency section and a frequency discriminator connected in tandem in the order named; means for utilizing the carrier voltage developed at the output side of said doubler as a local oscillator voltage for frequency conversion at the mixer stage of said receiving channel during signal reception, tuning elements respectively provided in said tunable stages, unicontrol means for so controlling said tuning elements that regardless of the settings of said tuning elements the center resonant frequencies of said radio frequency sections are substantially equal, and means coupling the output side of said discriminator to said modulator to govern the output frequency of said oscillator so that the carrier frequency of a signal modulated carrier transmitted through the intermediate frequency section of said receiving channel is held substantially constant.

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