June 26, 1945. M. ZIEGLER ET AL 2,379,395

F-M TRANSCEIVER

Filed May 5, 1944 3 Sheets-Sheet 1

Fig. 1.

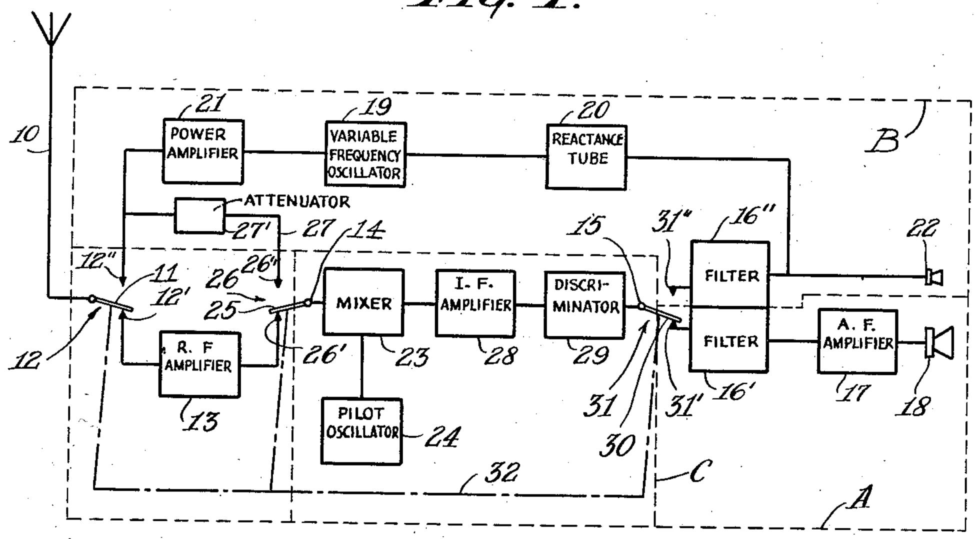
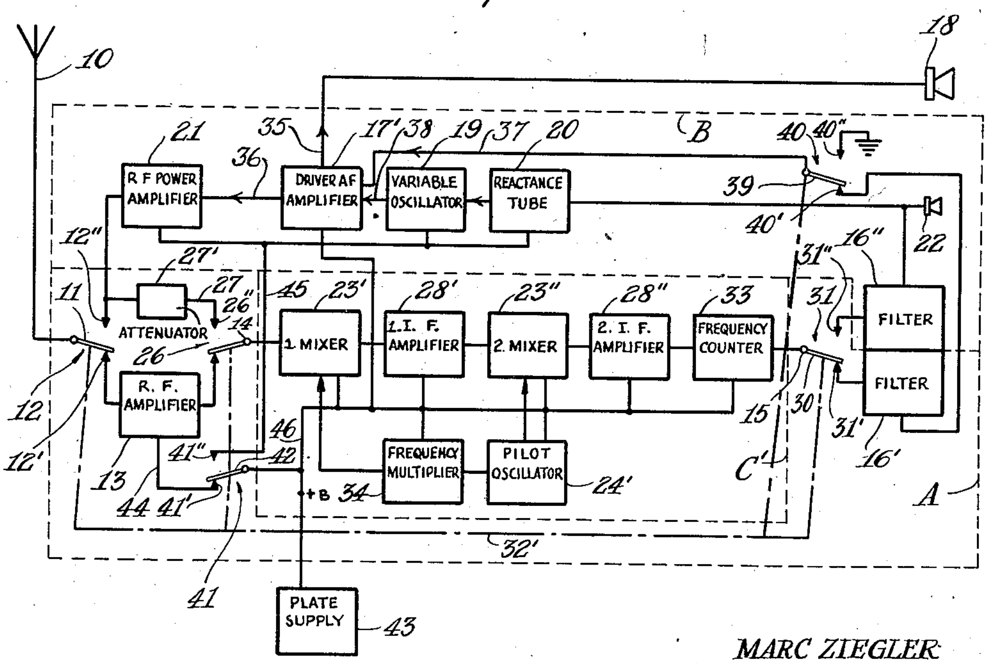


Fig. 2.



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F-M TRANSCEIVER

Filed May 5, 1944 3 Sheets-Sheet 2

Fig. 4.

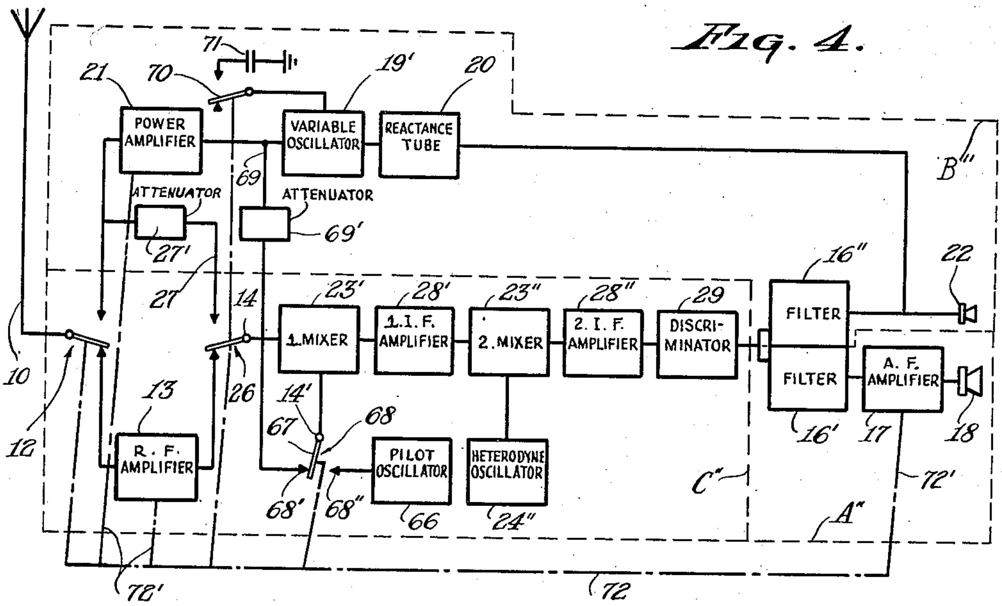

Fig. 5.

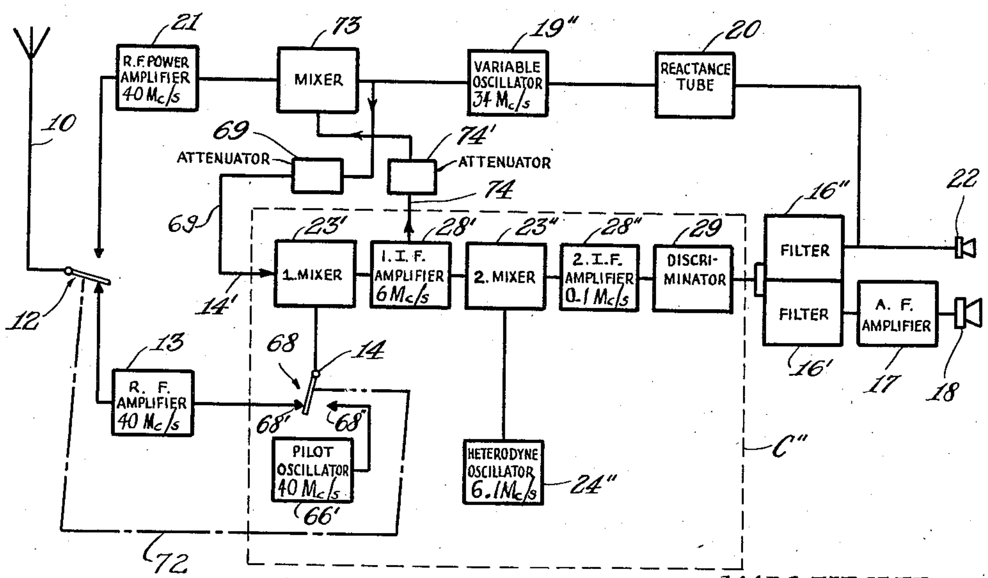

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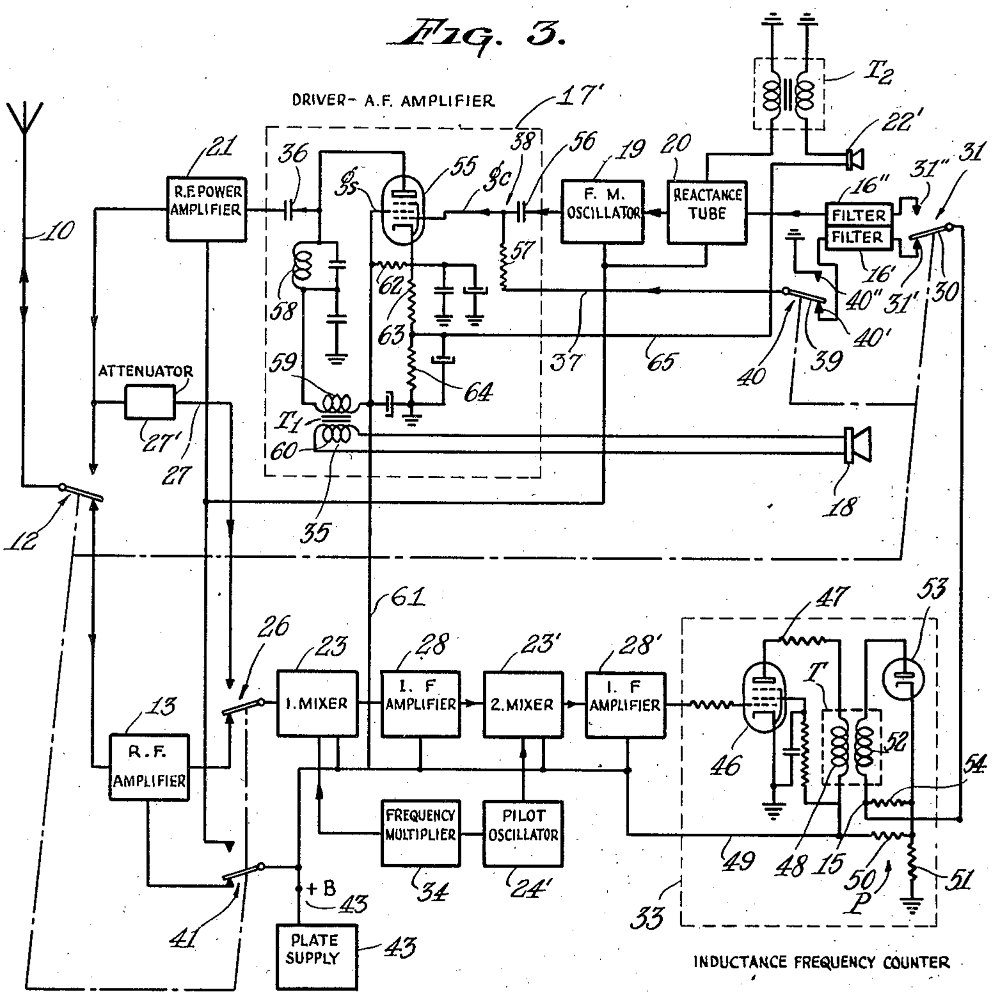
FIG. 3.



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Patented June 26, 1945 2,379,395

UNITED STATES PATENT OFFICE

2,379,395

FM TRANSCEIVER

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Application May 5, 1944, Serial No. 534,320

9 Claims. (Cl. 250—13)

The present invention relates to an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of the same mean frequency and more particularly to a "transceiver" unit, especially useful in mobile frequency modulation communication systems.

In the prior art, as far as we are aware, the receiving and the transmitting channels of FM transceivers for mobile use are designed as two electrically independent units, which usually also form two mechanically independent devices. However, since frequency modulation receiving and transmitting circuits comprise a relatively large number of circuit elements, the actual FM transceivers require a rather large mounting space, especially so if frequency stabilization is to be incorporated in the receiving or transmitting channels, or both.

We have now found that frequency modulation transceivers, including the receiving and transmitting channels in one compact unit and having excellent performance characteristics, can be obtained by utilizing during transmission the superheterodyne frequency detection system of the receiving channel to complete a frequency stabilizing link in the transmitting channel, thus maintaining the mean frequency of the outgoing wave at a predetermined value.

For this purpose, the input and output circuits of the superheterodyne frequency modulation detection system which, as is well known, may include one or more frequency changer means, together with the corresponding heterodyne oscillators, intermediate frequency amplifiers and a frequency discriminator, are provided with switching means adapted to couple said input and output circuits to the output amplifier and frequency control means of the variable oscillator, respectively. Consequently, during transmission, the emitted wave is stabilized at a mean frequency differing by a predetermined amount from the frequency of the first heterodyne oscillator of the frequency detection system.

It is therefore one of the main objects of the invention to provide a frequency modulation transceiver, of simplified, compact and light construction by utilizing the frequency detection system of the receiving channel as part of a frequency stabilizing link during transmission.

A further object of the present invention is to provide a frequency modulation transceiver comprising a minimum of tube and circuit elements, but possessing performance characteristics equal to those obtained with more voluminous units including independent receiving and transmitting channels.

A still further object of the present invention is to utilize a common quartz-crystal controlled oscillator for generating the heterodyne and pilot oscillations during reception or transmission respectively.

A further object of the present invention is to render possible the construction of a low-cost FM transceiver including frequency stabilization in one or both circuit channels.

Other objects and advantages of the invention will become apparent to those skilled in the art from the course of the following description, when read in conjunction with the accompanying drawings, which form part of the specification and which illustrate several preferred embodiments of the invention by way of example only.

In the drawings:

Fig. 1 is a block diagram schematically showing one preferred embodiment of the FM transceiver according to the present invention in a position corresponding to reception.

Fig. 2 illustrates an arrangement of a FM transceiver which differs from that of Fig. 1 in that a double conversion frequency detection system is used in the receiving channel and that the audio-amplifying means of the receiving channels is alternatively used as driver and/or frequency amplifier in the transmitting channel.

Fig. 3 is a block diagram similar to that shown in Fig. 2 but differs therefrom in that the wiring diagrams of several circuit elements are given.

Fig. 4 illustrates another embodiment of a FM transceiver in which during transmission the entire frequency stabilizing link is transferred from the receiving to the transmitting channel, and finally

Fig. 5 exemplifies another modification of the FM transceiver schematically shown in Fig. 4.

The same reference characters are used to indicate like or corresponding parts or elements throughout the drawings.

Referring now to Fig. 1 it can be seen that the frequency modulation transceiver according to the present invention comprises a receiving channel A, a transmitting channel B and an antenna **10** coupled to the movable contact member **11** of a double-throw single-pole switch **12**, the stationary contacts **12'** and **12''** of which are connected to the input of receiving channel A and the output of transmitting channel B, respectively.

Receiving channel A is constituted by a radio-amplifier stage **13** for amplifying the incoming wave and the input circuit of which is connected to contact 12′ of antenna switch 12, a superheterodyne frequency modulation detection system C having input and output terminals 14 and 15, respectively.

Receiving channel A further comprises a filter circuit 16′ having low-pass characteristics and coupled to an audio amplifier 17 provided with a loudspeaker 18.

Transmitting channel B of the FM transceiver according to the present invention comprises a variable frequency local oscillator 19 having frequency controlling means in form of a reactance tube 20 and coupled to a radio frequency power amplifier 21, the output circuit of which is connected to stationary contact 12″ of antenna switch 12 as explained hereinabove. Transmitting channel B is completed by a filter circuit 16″ having a low-pass characteristic and connected together with a microphone 22, to the input of reactance tube 20.

Frequency detection system C is constituted by a mixer stage 23 having one input circuit continually coupled to heterodyne oscillator 24, while the other input thereof, forming the input circuit 14 of frequency detection system C, is connected to the movable contact member 25 of a double-throw single-pole switch 26, stationary contact 26′ of which is connected to the output of R. F. amplifier 13. A coupling link 27 provided with attenuator means 27′ is connected between output circuit of power amplifier 21 and fixed contact 26″ of switch 26, attenuator means 27′ being adjusted to conduct only part of the outgoing wave energy to input 14 of the frequency detection system in the corresponding position of switch 26.

The output of mixer stage 23 is coupled through intermediate frequency oscillation amplifying means 28 to a frequency discriminator 29 generating a direct voltage, the amplitude and sign of which are substantially proportional to the deviations of the incoming signal from a predetermined nominal frequency corresponding to the mean frequency of the communication channel.

As can be seen in the drawings, the output of frequency discriminator 29 constitutes the output circuit 15 of the frequency modulation detection system C and is coupled to the movable contact member 30 of an output switch 31, the stationary contact 31′ of which is connected to the input of the receiving channel low-pass filter 16′, while the other stationary contact 31″ of said switch is coupled to the input of the transmitting channel low-pass filter 16″.

As indicated by the dot-dash line 32, antenna switch 12, input switch 26 and output switch 31 are controlled by a common control element (not shown in the drawings) and hence are simultaneously transferred from one operating position corresponding to reception to the other position corresponding to transmission.

In the drawing shown in Fig. 1, switches 12, 26 and 31 are illustrated in a position corresponding to reception. Thus the frequency modulation detection system C is completed to a superheterodyne receiver, in which the incoming wave, after having been amplified in the R. F. amplifier 13, is mixed with heterodyne oscillation generated by oscillator 24 to obtain an intermediate frequency oscillation. This in turn is amplified in intermediate amplifier 28. As is well known, the intermediate frequency oscillation follows the frequency deviations of the incoming wave, so that the output voltage generated by frequency discriminator 29 and applied through filter 16′ to audio amplifier 17 and loudspeaker 18 represents the intelligence carried by the incoming wave.

However, during transmission the input terminal 14 of frequency detection system C is transferred, by means of switch 26, to coupling link 27, while output terminal 15 of the detection system is switched over to the transmitting channel low-pass filter 16″ and is thus coupled to reactance tube 20 controlling the frequency of variable frequency oscillator 19. Antenna switch 12 transfers simultaneously antenna 10 to the output circuit of power amplifier 21.

The frequency of variable oscillator 19 may now be varied in accordance with the modulating potential impressed upon reactance tube 20 by microphone 22. However, due to the low-pass characteristics of filter 16″ and in view of the coupling established by input switch 26 and output switch 31, frequency detection system C forms together with reactance tube 20 a frequency stabilizing link which maintains the mean frequency of oscillator 19 at a value differing by a predetermined amount equal to the intermediate frequency from the heterodyne oscillation generated by oscillator 24. It will be understood that, due to the action of this frequency stabilizing link, the mean frequency of the outgoing wave will substantially correspond to the frequency of the incoming wave, so that the frequency modulation transceiver, according to the present invention, will be automatically maintained in the assigned communication channel.

Hence, in view of the switching means provided at the input and output circuits of frequency detection system C, the various circuit elements thereof are alternatively used during reception and transmission, thus lowering the cost of the equipment.

Those skilled in the art will understand that the receiving and transmitting channels A and B, respectively, of the FM transceiver, illustrated in Fig. 1, have been shown as block diagrams representing the main operating elements of these channels only. In fact, the frequency of variable frequency oscillator 19 will have to be considerably multiplied and amplified in one or more driver stages before applying it to power amplifier 21.

Similarly, in view of the image to signal ratio required for the correct operation of the receiving channel and in order to convert the wave into an oscillation of lower frequency suitable to be detected by the frequency discriminator 29, the frequency detection system C generally will be of the double conversion type.

A frequency modulation transceiver constructed in accordance with the above considerations is diagrammatically shown in Fig. 2, where it can be observed that the general circuit layout is quite similar to that illustrated in Fig. 1, but differs in that the frequency detection system C′ comprises a first and second mixer stage 23′ and 23″ respectively, with the corresponding intermediate frequency amplifiers 28′ and 28″ and frequency discriminator of the counter type 33.

In order to simplify the circuit layout of the frequency detection system, only the second heterodyne oscillator 24′ is constituted by a crystal-controlled oscillator. The first heterodyne oscillation is obtained by deriving a harmonic oscillation from oscillator 24′ by means of a multiplier stage 34 and injecting this harmonic oscillation into the heterodyne input circuit of first mixer 23'.

The circuit layout of the FM transceiver shown in Fig. 2 differs from that illustrated in Fig. 1 in that audio amplifier 17' connected in the receiving channel after lowpass filter 16', is permanently inserted between variable frequency oscillator 19 and power amplifier 21 and is used as driver stage during transmission, as will be explained hereinafter.

As can be seen in the drawing of Fig. 2, audio-frequency amplifier-driver stage 17' is provided with two output circuits 35 and 36, the first being connected to loud-speaker 18, while the latter is coupled to power amplifier 21 of the transmitting channel B. Audio-frequency amplifier-driver stage 17' is further provided with two input circuits 37 and 38, the latter being coupled to the output of variable oscillator 19. Input circuit 37, corresponding to the receiving channel A is connected to the movable contact arm 39 of a swtich 40 the stationary contact 40' of which, corresponding to reception, is coupled to the output of filter circuit 16', while the opposite contact 40'' thereof is connected to ground. Input circuit 37 of A. F. amplifier-driver 17' is thus transferred to ground potential during transmission, and this change over is considerably simplified in view of the different impedance characteristics of the radio and audio input circuits, 38 and 37, respectively.

Furthermore, in order to avoid interaction of transmitting channel B on receiving channel A during reception, and also to lower plate current consumption, a single-pole double-throw switch 41 is connected with its movable contact element 42 to the plate supply 43 of the transceiver, fixed contact 41' corresponding to the receiving channel, being arranged to supply the necessary plate voltage to R. F. amplifier 13, by means of conductor 44. The plate voltages for reactance tube 20, variable frequency oscillator 19 and power amplifier 21 are supplied by means of conductor 45 connected to fixed contact 41'' of switch 41.

The various circuit elements of frequency detection system C are permanently connected to plate supply 43 by means of conductor 46. As indicated by the dot-dash line 32' switch 40 and supply switch 41 are simultaneously operated with antenna switch 12 and input and output switch 26 and 31, respectively.

In one practical embodiment of a FM transceiver according to the present invention, designed for a communication channel having a nominal mean frequency of 33.663 mc./s., the second heterodyne oscillator 24' was generating an oscillation of 4.22 mc./s., the seventh harmonic of which, i. e. 29.54 mc./s. was derived by means of frequency multiplier 34, so that the first and second intermediate frequency amplifiers were tuned to 4.123 mc./s., and 97 kc./s., respectively.

Variable frequency oscillator 19 was generating the second sub-harmonic of 33.663 mc./s., while the R. F. channel 38, 36 of driver stage 17' was designed as R. F. doubler.

Hence, when the switches are in a position corresponding to reception (as shown in Fig. 2), the incoming signal is first amplified by R. F. amplifier 13 and then heterodyned and transformed into an audio-frequency by frequency detection system C', the audio-frequency obtained being then applied to the audio-amplifying channel of 37, 35 of driver 17' and reproduced by loudspeaker 18.

Since the first heterodyne oscillation is a harmonic of the pilot oscillation generated by 24', the tuning stability of receiving channel A depends mainly upon the stability of pilot oscillator 24' which, generally, comprises a quartz-crystal as a frequency controlling element, so that a tuning stability as high as desired can be obtained.

During transmission, input switch 26 and output switch 31 transfer frequency detection system C' from the receiving to the transmitting channel to complete a frequency stabilizing link controlling the frequency of variable-frequency oscillator 19, so that the mean frequency of the outgoing wave corresponds to the mean frequency of the incoming signal. In fact, the frequency stabilizing link maintains the mean frequency of the outgoing wave at a value differing by the first intermediate frequency from the frequency of the first heterodyne oscillation.

The block diagram shown in Fig. 3 is similar to that of the Fig. 2, the circuit layouts of frequency counter discriminator 33 and A. F. amplifier-driver stage 17' being shown in detail. With particular reference to frequency discriminator 33 it can be seen that the circuit thereof corresponds to a compensated inductance counter, the operation of which has been fully described in prior U. S. patent application Serial No. 477,990, filed on March 4, 1943 by Marc Ziegler. The counter is constituted by a counting tube 46 having its control grid coupled to the output of the second intermediate frequency amplifier 28', while the plate circuit of the tube is formed by current limiting resistance 47 and a primary winding 48 of a transformer T, connected with one of its ends to conductor 49 derived from plate supply 43. A potentiometer P formed of two series connected resistances 50 and 51 is inserted between conductor 49 and ground potential.

The secondary winding 52 of transformer T is inserted in a rectifier circuit constituted by a diode 53 and load resistance 54. The junction point between resistance 54 and the cathode of diode 53 is connected to the junction point between resistances 50 and 51, while the other end of the load resistance, constituting the output terminal 15 (see Fig. 2) of the frequency detection system C' is coupled to switch 31 in a manner described hereinbefore.

Resistances 50 and 51 are designed so that the output voltage of compensated frequency discriminator 33 will be zero when the mean frequency of the incoming wave corresponds to the nominal frequency of the communication channel and due to the compensating action of potentiometer P, the zero working point of the discriminator will be maintained independently of variations in plate supply 43.

Audio-frequency amplifier-driver stage 17' includes a power amplifier tube 55 the control grid g_c of which is permanently coupled by means of coupling condenser 56 to the output of variable frequency oscillator 19 and is provided with a grid leak resistance 57 constituting the A. F. input circuit 37 connected to switch 40 as already explained hereinabove.

The plate circuit of tube 55 comprises a parallel resonance circuit 58 tuned to the second harmonic of the oscillation generated by oscillator 19 and constituting the R. F. output circuit 36 of the driver stage, corresponding to the transmitting channel B of the transceiver. Tuned circuit 58 is connected in series with primary winding 59 of an output transformer T_1, the secondary winding 60 of which is connected to loudspeaker 18, transformer T_1 constituting the A. F. output circuit 35, corresponding to receiving channel A of the FM transceiver.

The end of primary winding 59 remote from resonance circuit 58 is connected by means of conductor 61 to the plate tension supply 43 to which screen grid g_s of tube 55 is also connected.

In order to provide the necessary operating bias for tube 55 and at the same time obtain a D. C. current supply for the carbon microphone 22′, three resistances 62, 63 and 64 are connected in series between the positive pole of plate supply 43 and ground potential, the cathode of tube 55 being connected to the junction point between resistance 62 and 63, while the junction point between resistances 63 and 64 is connected by means of conductor 65 to one terminal of carbon microphone 22′ the other terminal of which is connected to the primary winding of a microphone transformer T_2 whose secondary winding is coupled to the input circuit of reactance tube 20 in a manner known in the art. The junction points between resistances 62, 63 and 64 are provided with the necessary radio and audio frequency by-pass condensers so that the D. C. voltage existing across resistance 64 does not contain A. C. components and can be used as supply source for carbon microphone 22′.

It has been already pointed out hereinabove that the main feature of the frequency modulation transceiver, according to the present invention consists in that the superheterodyne frequency detection system of the receiving channel, during transmission, is switched over to the transmitting channel to form, in combination with reactance tube 20 and variable frequency oscillator 19, a stabilizing link which maintains the mean frequency of the outgoing wave at a value substantially corresponding to the mean frequency of the incoming signal. Consequently, the frequency stability in the FM transceivers, according to Figs. 1, 2 and 3, depends on the stability of the heterodyne or pilot oscillators utilized in the corresponding frequency detection system. Generally the pilot oscillator will be of the crystal controlled type having a high inherent stability, but nevertheless the frequency of the incoming wave may considerably differ from that to which the receiving channel of the transceiver is tuned, since although the crystal controlled pilot oscillators of the transceivers in the same communication net operate with pilots having like nominal frequencies, the actual frequency emitted during communication may be different, due to abnormal operating conditions of the units.

Therefore the automatic tuning of the receiver to the frequency of the incoming signal represents a considerable improvement in the reliability of communication. Frequency modulation receivers, including frequency stabilizing links, have been fully described in Ziegler application, Serial 478,705, filed on March 10th, 1943, and the block diagram shown in Fig. 4 illustrates a FM transceiver comprising a frequency stabilizing link in accordance with the above patent application.

As can be seen in the drawing of Fig. 4, the main part of the FM transceiver is formed by the double conversion superheterodyne frequency detection system C′′ forming together with reactance tube 20 and variable frequency oscillator 19′ a frequency stabilizing link common to the receiving and transmitting channels A′′ and B′′, respectively. Similar to the FM transceivers shown in Figs. 1, 2 and 3, receiving channel A′′ includes a R. F. amplifier 13 for amplifying the incoming signal, a low-pass filter 16′ coupled after frequency detection system C′′ and audio-amplifying and reproducing means 17 and 18 respectively. Transmitting channel B′′ includes a power amplifier 21, modulation means in form of microphone 22 connected to the input of reactance tube 20, and the low-pass-filter-circuit 16′′ inserted between frequency detection system C′′ and said reactance tube 20. Transmitting channel B′′ furthermore includes a crystal controlled oscillator 66 generating an oscillation corresponding to the first heterodyne oscillation of frequency detection system C′′ and equal to the mean frequency of the incoming wave plus the first intermediate frequency.

Frequency detection system C′′ comprises a signal and a heterodyne input circuit 14 and 14′ respectively, the former being connected to switch 26 as already explained in connection with Figs. 1, 2 and 3, while the latter representing the second input of the first mixer stage 23′, is connected to the movable contact member 67 of a single pole double throw switch 68. Fixed contact 68′ of switch 68, corresponding to receiving channel A′′ of the FM transceiver, is connected to the output of variable frequency oscillator 19′, by means of coupling link 69 including attenuator means 69′, while fixed contact 68′′, corresponding to transmitting channel B′′ is coupled to pilot oscillator 66.

During reception, variable frequency oscillator 19′ is operating on a frequency corresponding to the first heterodyne oscillation of frequency detection system C′′, but is shifted during transmission to a frequency corresponding to the outgoing wave by means of switch 70 and condenser 71. As already explained hereinabove, double conversion frequency detection C′′ is constituted by first mixer stage 23′, first intermediate frequency amplifier 28′, second mixer stage 23′′ with the corresponding second heterodyne oscillator 24′′, second intermediate amplifier 28′′ and frequency discriminator 29, the output circuit of which is permanently connected to low-pass filter circuits 16′ and 16′′.

As can be observed in Fig. 4 illustrating the FM transceiver according to the present invention in a position corresponding to reception, frequency variable oscillator 19′ is utilized as the first heterodyne oscillator in the frequency detection system C′′ and in view of the fact that discriminator 29 is designed to provide a zero output voltage for a predetermined frequency value of the second intermediate frequency, variable frequency oscillator 19′ will be controlled by reactance tube 20 due to the stabilizing action of the stabilizing link so as to maintain the receiving channel A′′ tuned as exactly as possible to the mean frequency of the incoming signal even if the same slightly differs from the nominal mean frequency of the communication network.

During transmission, the frequency of oscillator 19′ is shifted to a value corresponding to the mean frequency of the communication channel by means of switch 70 and condenser 71. Simultaneously heterodyne input circuit 14′ of a frequency detection system C′′ is switched over from coupling link 69 to pilot oscillator 66, while signal input circuit 14 is transferred by means of switch 26 to coupling link 27 derived from the output circuit of power amplifier 21. Hence, during transmission a frequency stabilizing link is established which maintains the mean frequency of variable frequency oscillator 19' at a value differing by the first intermediate frequency from the frequency of pilot oscillator 66, so that the mean frequency of the outgoing wave corresponds to the mean frequency of the communication channel.

Frequency stabilization is thus utilized during reception and transmission and the frequency modulation transceiver according to Fig. 4 is automatically maintained within the assigned communication channel due to the frequency correcting action of the stabilizing link.

As indicated by dot-dash line 72, switches 12, 26, 68 and 70 are coupled to a common control means defining the operating positions of the transceiver. The same control means also interrupt the plate supply to audio-amplifier 17, R. F. amplifier 13 and power amplifier 21 during transmission or reception respectively, as indicated by the dot-dash line 72'.

In the frequency modulation transceiver according to Fig. 4 variable frequency oscillator 19' has to be shifted from the first heterodyne oscillation to a frequency corresponding to the mean frequency of the communication channel or to a submultiple thereof. Furthermore, due to the particular circuit layout of the frequency stabilizing link the utilization of a waiting and squelch signal in accordance with the teachings in the application of Marc Ziegler, Serial No. 482,785, filed on April 12, 1943, will require the use of a separate oscillator.

We have now found that by a judicious choice of the first and second heterodyne oscillations and the operating frequency of the variable frequency oscillator 19', a frequency modulation transceiver including automatic frequency control during transmission and reception will be obtained in which a minimum of switching means is required to change the operating conditions of the unit and in which a waiting and squelch signal may be derived without utilizing new circuit elements.

A frequency modulation transceiver based on the above considerations is schematically illustrated in the diagram shown in Fig. 5 in which it can be observed that heterodyne input circuit 14' of the frequency detection system C'' is permanently connected by means of link 69 to the output of variable frequency oscillator 19'', while the signal input circuit 14 is connected to switch 68, the fixed contact 68' of which, corresponding to the receiving channel of the transceiver, is connected to the output of R. F. amplifier 13, while the fixed contact 68'' thereof, corresponding to the transmitting channel, is connected to the output of a pilot oscillator 66'.

The frequency modulation detection system C'' is similar to that shown in Fig. 4, the output of this frequency discriminator 29 being continuously coupled through filter circuits 16' and 16'' to audio amplifying and reproducing means 17 and 18 and to reactance tube 20 respectively.

Variable frequency oscillator 19'' is designed to operate on a frequency equal to the frequency of the incoming wave minus the first intermediate frequency and its output is permanently coupled to a mixer stage 73 operating as driver and inserted between oscillator 19'' and power amplifier 21.

By means of coupling link 74 provided with attenuator 74', part of the first intermediate frequency oscillation is injected into the other input of mixer stage 73, so that the mean frequency of the oscillation present in the output circuit thereof corresponds to the mean frequency of the communication net-work.

During reception the incoming wave is amplified by R. F. amplifier 13 and is applied to signal input circuit 14 of the first mixer stage 23' together with the oscillation generated by variable frequency oscillator 19''. Assuming the nominal net-work communication frequency to be 40 mc./s., and choosing for the first and second intermediate frequency the values of 6.0 and 0.1 mc./s. respectively, variable frequency oscillator 19'' is designed to operate on 34 mc./s. In view of the fact that frequency discriminator 29 is designed to provide a zero output voltage when the second intermediate frequency oscillation corresponds to 100 kc./s., the automatic frequency control provided by the stabilizing link will control the frequency of oscillator 19'' so that the receiving channel will be automatically tuned to the mean frequency of the incoming wave. Hence, during reception variable frequency oscillator 19'' operates as first heterodyne oscillator in an automatic frequency control system constituted by the frequency detection system C'' in combination with reactance tube 20.

During transmission pilot oscillator 66', operating on a frequency corresponding to the frequency of the incoming signal, i. e. 40 mc./s. is connected by means of switch 68 to input circuit 14 of first mixer 23 so that, due to the automatic frequency control provided by the frequency detection system C'' in combination with reactance tube 20, the mean frequency of variable frequency oscillator 19'' is maintained on its nominal frequency of 34 mc./s. In mixer stage 73 the 34 mc./s. oscillation generated by variable frequency oscillator 19'' is mixed with the 6 mc./s. oscillation derived from the first intermediate frequency amplifier 28', so that the mean frequency of the oscillation generated in the output circuit of mixer stage 73 corresponds to the mean frequency of the communication channel, i. e. 40 mc./s.

The utilization of mixer stage 73 between variable frequency oscillator 19'' and power amplifier 21 offers a good separation between the low and high power stages of the transmitting channel and simultaneously ensures that the mean frequency of the outgoing wave will correspond to the frequency of pilot oscillator 66', since the frequency of the outgoing wave is the sum of the oscillation generated by variable frequency oscillator 19'' and the first intermediate frequency signal. Furthermore the particular circuit layout of FM transceiver shown in Fig. 5 renders it possible to introduce a waiting and squelch signal in the receiving channel of the transceiver by deriving part of the oscillation generated by pilot oscillator 66' and by injecting this oscillation into the signal input circuit 14, together with the incoming wave.

It should be understood that the receiving and transmitting channels of the FM transceivers according to the present invention, though utilizing a common frequency detection system or frequency stabilizing link, can be individually designed to have particular performance characteristics independently from each other. In fact, the improvements in frequency stabilizing systems described in the co-pending U. S. patent applications Serial Nos. 514,710 and 478,705 may be used with advantage in the FM transceivers according to the present invention. Therefore, it should be understood that our invention is by no means limited to the particular organizations shown and described but that many modifications may be made without departing from the scope of our invention, as set forth in the appended claims.

We claim:

1. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel constituted by a frequency detection system including at least one heterodyne oscillator and intelligence reproducing means, a transmitting channel formed of an adjustable frequency oscillator provided with frequency-controlling means coupled to modulation means, and a commutable antenna common to said receiving and said transmitting channels: means to transfer said detection system from said receiving to said transmitting channel to complete a stabilizing link during transmission for maintaining the mean frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said heterodyne oscillator and substantially corresponding to the mean frequency of the incoming wave.

2. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel constituted by means for amplifying the incoming wave, a frequency detection system having input and output circuits and including frequency changer means, a heterodyne oscillator continuously coupled to said frequency changer means, intermediate frequency amplifier means connected after said frequency changer means and coupled to frequency responsive means including said output circuit and generating a voltage varying in amplitude and sign in accordance with the frequency variations of said incoming wave, and audio amplifying means having a low-pass filter input circuit and coupled to audio reproducing means; a transmitting channel constituted by a variable frequency oscillator provided with frequency controlling means having a low-pass filter input circuit and coupled to modulation means and outgoing wave amplifying means connected after said variable frequency oscillator: means to switch over an antenna during transmission from said incoming wave amplifying means to said outgoing wave amplifying means, means to simultaneously switch over said frequency detection system input circuit from said incoming wave amplifying means to a coupling link derived from the output circuit of said outgoing wave amplifying means, and means to simultaneously switch over said frequency detection system output circuit from said audio amplifying and reproducing means to said frequency controlling means to complete a frequency stabilizing link for maintaining the mean frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said heterodyne oscillator and substantially corresponding to the mean frequency of the said incoming wave.

3. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel constituted by means for amplifying the incoming wave, a double conversion frequency detection system having input and output circuits and including a first and second frequency changer means, means for generating a first and second heterodyne oscillation, a first and second intermediate frequency amplifying means and frequency responsive means including said output circuit and developing a voltage proportional in amplitude and sign to the frequency deviations of said incoming wave from said mean frequency and audio-amplifying means having a low-pass filter input circuit and coupled to audio reproducing means; a transmitting channel constituted by a variable frequency oscillator provided with frequency controlling means having a low-pass filter input circuit and coupled to modulation means, and means for amplifying the outgoing wave; means to switch over an antenna during transmission from said incoming wave amplifying means to said outgoing wave amplifying means, means to simultaneously switch over said frequency detection input circuit from said incoming wave amplifying means to a coupling link derived from the output circuit of said outgoing wave amplifying means, and means to simultaneously switch over said frequency detection system output circuit from said audio amplifying and reproducing means to said frequency controlling means to complete a frequency stabilizing link for maintaining the main frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said first heterodyne oscillator and substantially corresponding to the mean frequency of said incoming wave.

4. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel, constituted by means for amplifying the incoming wave, a double conversion frequency detection system having input and output circuits and including a first and second frequency changer means, a second heterodyne oscillator and frequency multiplying means to derive from said second heterodyne oscillator a harmonic first heterodyne oscillation, a first and second intermediate frequency amplifying means and a frequency responsive means including said output circuit and developing a voltage proportional in amplitude and sign to the frequency deviations of said incoming wave from said mean frequency, a first low-pass filter connectable after said frequency responsive means and audio reproducing means; a transmitting channel constituted by a variable frequency oscillator generating an oscillation the mean frequency of which corresponds to said mean frequency, said oscillation being provided with frequency controlling means having a low-pass filter input circuit and coupled to modulation means and means for amplifying the outgoing wave: thermionic amplifying means having separate radio-frequency multiplying and audio frequency amplifying input and output circuits, the said radio frequency circuits being permanently inserted in said transmitting channel between said variable frequency oscillator and said outgoing wave amplifying means to conveniently multiply the oscillation generated by said variable frequency oscillator, while the said audio-frequency amplifying output circuit is permanently connected to said audio-reproducing means, means to switch over an antenna during transmission from the input of said incoming wave amplifying means to the output of said outgoing wave amplifying means, means to simultaneously switch over said frequency detection input circuit from the output of said incoming wave amplifying means to a coupling link derived from the output of said

outgoing wave amplifying means, means to simultaneously disconnect the audio frequency input circuit of said thermionic means from the output of said first low-pass filter circuit and to connect the same to ground potential, and means to simultaneously switch over said frequency detection system output circuit from the input of said first low-pass filter circuit to said frequency controlling means to complete a frequency stabilizing link for maintaining the main frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said first heterodyne oscillator and substantially corresponding to the mean frequency of said incoming wave.

5. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel, constituted by means for amplifying the incoming wave, a double conversion frequency detection system having input and output circuits and including a first and second frequency changer means, a second heterodyne oscillator and frequency multiplying means to derive from said second heterodyne oscillator a harmonic first heterodyne oscillation, means for amplifying a first and a second intermediate frequency oscillation and a frequency responsive means comprising a source of direct current, a current limiting resistance and an inductance connected in series circuit arrangement, means to interrupt the current in said circuit responsive to the half periods of like sign of the second intermediate frequency oscillation to produce voltage impulses of substantially constant area and alternate signs across said inductance in synchronism with the half-periods of said second intermediate frequency oscillation, and means to integrate the said impulses of like sign to produce a direct voltage having an amplitude substantially proportional to the frequency of said impulses and independent of the amplitude of the incoming wave, the output circuit of said frequency responsive means constituting the output circuit of the frequency detection system, said receiving channel further comprising a low-pass filter connectable after said frequency responsive means and audio reproducing means; a transmitting channel constituted by a variable frequency oscillator generating an oscillation the mean frequency of which corresponds to said mean frequency, said oscillator being provided with frequency controlling means having a low-pass filter input circuit and coupled to modulation means, and means for amplifying the outgoing wave, thermionic amplifying means having separate radio-frequency-multiplying and audio frequency amplifying input and output circuits, said radio frequency circuits being permanently inserted in said transmitting channel between said variable frequency oscillator and said outgoing wave amplifying means to conveniently multiply the oscillation generated by said variable frequency oscillator to a value corresponding to the frequency of said outgoing wave, while the said audio frequency amplifying output circuit of said thermionic amplifying means is permanently connected to said audio-reproducing means: means to switch over an antenna during transmission from the input of said incoming wave amplifying means to the output of said outgoing wave amplifying means, means to simultaneously switch over said frequency detection input circuit from the output of said incoming wave amplifying means to a coupling link derived from the output of said outgoing wave amplifying means, means to simultaneously disconnect the audio frequency input circuit of said thermionic amplifying means from the output of said first low-pass filter circuit and to connect the same to ground potential, and means to simultaneously switch over said frequency detection system output circuit from the input of said first low-pass filter circuit to said frequency controlling means to maintain the mean frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said first heterodyne oscillator and substantially corresponding to the mean frequency of said incoming wave.

6. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel including audio amplifying and reproducing means connected after a superheterodyne frequency detection system having commutable signal and heterodyne input circuits and including variable frequency heterodyne oscillator provided with frequency controlling means connectable after frequency responsive means in a frequency stabilizing arrangement to control during reception the frequency of said heterodyne oscillator in accordance with the deviations of the incoming wave from said mean frequency; a transmitting channel including modulating means connected to said frequency controlling means and means for amplifying the outgoing wave connected after said heterodyne oscillator; a commutable antenna common to said receiving and said transmitting channels: means for generating a pilot oscillation having a frequency corresponding to said heterodyne oscillation, means to switch over during transmission said signal input circuit to a coupling link derived from said outgoing wave amplifying means to simultaneously switch over said heterodyne input circuit from said heterodyne oscillator to said pilot oscillation generating means, and means to simultaneously shift the frequency of said heterodyne oscillator to a value corresponding to the outgoing wave to maintain during transmission the mean frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said pilot oscillation.

7. In an electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency comprising a receiving channel including means for amplifying the incoming wave and audio amplifying and reproducing means connected after a superheterodyne double conversion frequency detection system having commutable signal and heterodyne input circuits and constituted of a first and second frequency changer means, a first variable frequency heterodyne oscillator provided with frequency controlling means, connectable during reception to said heterodyne input circuit, a second heterodyne oscillator generating an oscillation of predetermined frequency, a first and second intermediate oscillation amplifying means, and a frequency responsive means connected to said frequency controlling means in a frequency stabilizing arrangement to control during reception the frequency of said heterodyne oscillator in accordance with the deviations of the incoming wave from said mean frequency; a transmitting channel including modulation means connected to said frequency controlling means, and means for

amplifying the outgoing wave connected after said first heterodyne oscillator; a commutable antenna common to said receiving and said transmitting channels: means for generating a pilot oscillation having a frequency corresponding to said first heterodyne oscillation, means to switch over during transmission said signal input circuit from said incoming wave amplifying means to a coupling link derived from said outgoing wave amplifying means, means to simultaneously switch over said heterodyne input circuit from said first heterodyne oscillator to said pilot oscillator, and means to simultaneously shift the frequency of said first heterodyne oscillator to a value corresponding to said mean frequency to maintain during transmission the mean frequency of the outgoing wave at a value differing by a predetermined amount from the frequency of said pilot oscillation.

8. An electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel including audio amplifying and reproducing means connected after a superheterodyne frequency detection system having a commutable signal input circuit and including a variable frequency heterodyne oscillator provided with frequency controlling means, frequency changer means for mixing said heterodyne oscillation with the incoming wave to obtain a difference oscillation, and frequency responsive means connected after said frequency changer means and coupled to said frequency controlling means in a frequency stabilizing arrangement to control during reception the mean frequency of said heterodyne oscillation in accordance with the deviations of the incoming wave from said mean frequency, a transmitting channel including modulating means connected to said frequency controlling means and means for amplifying the outgoing wave; a commutable antenna common to said receiving and said transmitting channels; frequency changer means inserted in said transmitting channel between said heterodyne oscillator and said outgoing wave amplifying means, means to inject said intermediate frequency oscillation into said frequency changer means to obtain an oscillation having a mean frequency corresponding to the frequency of said incoming wave, means for generating a pilot oscillation having a frequency corresponding substantially to said mean frequency and means to switch over during transmission said signal input circuit from said incoming wave amplifying means to said pilot oscillation generating means to maintain during transmission the mean frequency of the said outgoing wave at a value substantially corresponding to said pilot oscillation.

9. An electrical apparatus for alternatively receiving and transmitting frequency modulated waves of substantially the same mean frequency, comprising a receiving channel including means for amplifying the incoming wave and audio amplifying and reproducing means connected after a superheterodyne double conversion frequency detection system having a commutable signal input circuit and constituted of a first and second frequency changer means, a first variable heterodyne oscillator generating an oscillation differing by a predetermined amount from the said mean frequency and provided with frequency controlling means, a second heterodyne oscillator, means for amplifying the first and second intermediate frequency oscillations, and a frequency responsive means connected after said second intermediate frequency oscillation amplifying means and coupled to said frequency controlling means in a frequency stabilizing arrangement to control, during reception, the mean frequency of said heterodyne oscillator in accordance with the deviations of the incoming wave from said mean frequency; a transmitting channel including modulation means connected to said frequency controlling means and means for amplifying the outgoing wave; a commutable antenna common to said receiving and said transmitting channels: a third frequency changer means inserted in said transmitting channel between said first heterodyne oscillator and said outgoing wave amplifying means, means to inject said first intermediate frequency oscillation into said third frequency changer means to obtain an oscillation having a frequency corresponding to the incoming wave, means for generating a pilot oscillation having a frequency corresponding substantially to said mean frequency, and means to switch over during transmission said signal input circuit from said incoming wave amplifying means to said pilot oscillation generating means to maintain during transmission the mean frequency of the said outgoing wave at a value substantially corresponding to said pilot oscillation.

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