

April 29, 1947.

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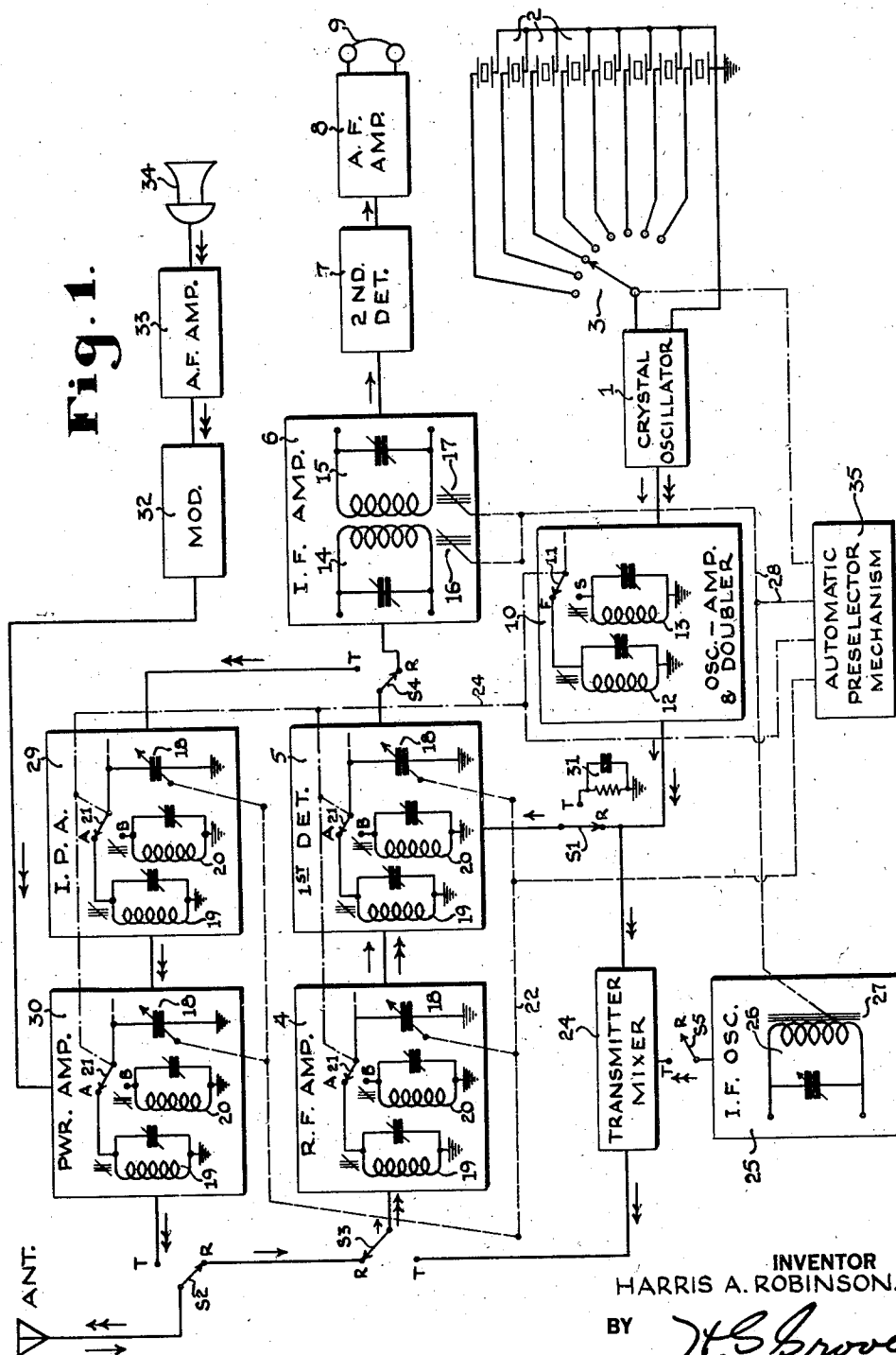
2,419,593

TWO-WAY RADIO COMMUNICATION SYSTEM

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Fig. 1.



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Fig. 2A.

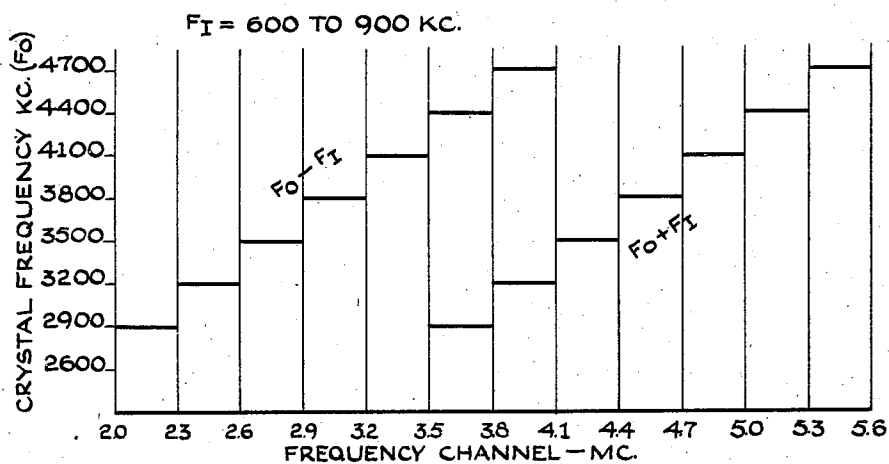
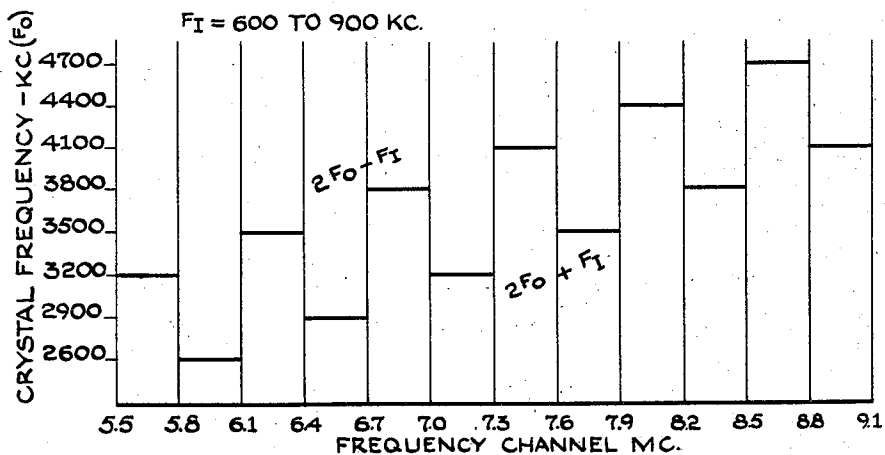


Fig. 2B.



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TWO-WAY RADIO COMMUNICATION
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9 Claims. (Cl. 250-6)

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The present invention relates in general to a radio communication system, and more particularly to an improved system for two-way communication which is capable of selective operation on any one of a multiplicity of frequency channels contained in a wide frequency spectrum.

In carrying out the invention there is employed at each of a multiplicity of points or stations a combination receiver-transmitter which is arranged to both receive and transmit on the same carrier frequency. A system of this general type is disclosed in Young Patent No. 2,113,419, assigned to the same assignee as this application, but the number of frequency channels on which that system is capable of operating is limited to the specific number of crystals employed.

In accordance with the present invention, it is possible to secure a very high order of frequency stability, closely approaching that of crystal control, with the advantages and flexibility of being able to set up the receiver-transmitter on a multiplicity of frequency channels, each of which may be selected at any desired point in a wide frequency spectrum, without the necessity of having a specific crystal ground to each desired operating frequency.

Briefly, the present system employs a crystal-controlled oscillator provided with a number of selectively operable crystals, each of which determines the stability of the receiver and transmitter on a plurality of frequency channels. The arrangement differs from the more conventional crystal-controlled transmitter-receiver circuits in that these crystals have certain frequencies which are not directly related to the final frequency of transmission or reception. Hence, this set of crystals need not be changed when setting the equipment to operate on any selected frequency throughout the operating spectrum.

The ability to set the equipment to operate at any selected frequency without changing the crystals depends upon the use of an intermediate frequency (IF) amplifier, variable in frequency over a small tuning range. An IF oscillator, ganged with this variably tuned IF amplifier, is mixed with the frequency of the crystal oscillator, or a multiple thereof, to provide the operating frequency for transmission. Thus, for each crystal a small tuning range is obtained with a negligible loss in frequency stability in comparison with the crystal stability. By combining the small tuning ranges obtained for each of a set of crystals complete coverage of the frequency spectrum is obtained. In obtaining this wide frequency coverage with a limited number of crystals, advantage

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is taken of the fact that the final frequency of transmission or reception can be the crystal frequency, or a multiple thereof, plus or minus the variable intermediate frequency.

It is therefore one of the main objects of the present invention to provide a highly flexible two-way communication system in which a multiplicity of operating channels is made available in a wide frequency spectrum with the use of a limited number of frequency controlling crystal elements.

A more specific object of the invention is to provide in a combined receiver-transmitter an intermediate frequency amplifier in the receiver and an intermediate frequency oscillator in the transmitter which are variable each over the same limited frequency thereby making available an increased number of operating frequencies.

Other objects and advantages will become apparent from the following description when read in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram of a receiver-transmitter which constitutes one of a plurality of stations in the communication system; and

Figs. 2A and 2B show graphically the various portions of the frequency spectrum between 2.0 and 9.1 mc. at which a plurality of frequency controlling crystals identified by their operating frequencies are effective in a specific embodiment of the invention.

Briefly, the method employed utilizes a selected one of a plurality of available frequencies as the carrier for transmission in one direction and the same carrier for transmission in the other direction. Tuning the receiver at station 1, for example, to the carrier frequency transmitted from station 2 will simultaneously assure perfect tuning of the receiver at station 2 in response to the carrier which will then be effective at station 1. This method is of particular value when the system is applied to military uses, for communication between mobile units, as for example, armored tanks, aircraft, or between mobile and ground stations.

The transmitter-receiver shown schematically in Fig. 1 represents a single set or station, of which any desired number of similar or other construction may be utilized for carrying out the method of communication herein described. Also, it is essential to the successful operation of the present system that a net of several stations maintain an agreed-upon common working frequency for a given period during which communication is desired. Although any desired fre-

quency range may be employed, the description that follows will be given for a transmitter-receiver set which was designed for a frequency range from 2 to 9.1 mc. in two bands.

Referring now more particularly to Fig. 1, the local oscillator voltage for the receiver and the master oscillator voltage for the transmitter are derived from a common oscillator 1, the frequency of which is controlled by one of a plurality of crystals 2 which are individually switched into circuit by an 8-position switch 3. In a practical embodiment incorporating the present invention, a set of 8 crystals was employed to cover the above mentioned wide frequency band, the crystals being ground to their respective fundamental frequencies given in the charts of Figs. 2A and 2B. As will be shown later each crystal serves to control the operation of the system over several limited, spaced-apart frequency ranges, the sum total of which occupy the entire frequency spectrum for which the apparatus was designed.

The receiver employed is of the superheterodyne type and comprises a radio frequency (RF) amplifier 4, a first detector or converter stage 5, an intermediate frequency (IF) amplifier 6, a second detector 7, and an audio frequency (AF) amplifier 8, the output of which may be fed to a pair of earphones 9 or other reproducing device. The converter 5, which may be of the type disclosed in Smith Patent No. 2,323,250, is supplied through a switch S1 in the R or receive position and through an oscillator-amplifier 10 with oscillations from the local oscillator 1, the frequency of which is determined by the setting of the crystal selector switch 3. By means of a switch 11 amplifier 10 is adapted to have included in its output one or the other of two coils 12 and 13 connected respectively to the fixed contacts F and S, so that for each position of the switch 11 either the fundamental or the second harmonic of the operative crystal is available as the heterodyne frequency.

The receiver is of conventional design except that IF amplifier 6 is tunable through a limited range of frequencies which in the present instance is from 600 to 900 kc. Although, for simplicity amplifier 6 is shown as a single stage, in actual practice it may comprise several similar stages, each having its input and output circuits individually tuned by ganged adjustable ferro-magnetic cores or ganged variable capacitors. At 14 there is shown the output circuit of one stage in coupled relation with the input circuit 15 of a succeeding stage, magnetic cores 16 and 17 being utilized for adjusting the tuning of the respective circuits.

The RF amplifier 4 is provided with a tunable input or antenna circuit and a tunable output circuit, only one of which is shown for simplicity, and the converter stage 5 is provided with a tunable input circuit, the several circuits being similar and each comprising a variable condenser 18 and one of two inductances 19 and 20 which are connected respectively to fixed contacts A and B. A band switch 21 associated with each of the tunable circuits is adapted when in contact with A to connect coil 19 in shunt across its associated variable condenser 18 to permit the circuit to be tuned over one frequency band, and when in contact with B to connect coil 20 in shunt across the same condenser to permit the circuit to be tuned over a second band. A band switching arrangement of this type is disclosed in Carlson et al. Patent No. 2,024,816. For convenience the two bands are identified as bands

A and B, respectively, to correspond with the similarly designated contacts.

The several variable tuning condensers 18 are interconnected for unicontrol adjustment by suitable means represented by the dash line 22 and the several band switches 21 are interconnected for simultaneous operation by suitable means represented by dot-and-dash line 23. A pair of switches S2 and S3 are adapted in their R or receive positions to couple an antenna (ANT.) to the input of RF amplifier 4, and a switch S4 in the R or receive position is adapted to couple the output of converter 5 to the input of IF amplifier 6.

The carrier frequency for transmission is derived from a conventional mixer or converter stage 24 which may be similar to the converter stage 5 of the receiver and of oscillator-amplifier 10 and also the output of a low-frequency variable oscillator 25 through a switch S5 in the T of transmit position. The frequency determining circuit 26 of this oscillator is variable through the same frequency range as the receiver IF amplifier 6 by means of an adjustable ferro-magnetic core 27, although a variable capacitor may be used, if desired. Oscillator 25 may therefore be called appropriately an IF oscillator. The several cores 16, 17 of amplifier 6 and the core 27 of oscillator 25 are mechanically interconnected for unicontrol adjustment by suitable means represented by the dash line 28.

In transmission the mixer 24 feeds its output successively through RF amplifier 4, converter stage 5 which now operates as an amplifier, an intermediate power amplifier (IPA) 29, and a power amplifier (PA) 30, the output of which is coupled to the antenna through switch S2 in the T or transmit position. In the T or transmit position of switch S1 the source of local oscillations is disconnected from the converter stage and there is connected a cathode biasing network 31 suitable to make this stage function as an RF amplifier, replacing the cathode biasing network (not shown) which it utilized for the stage to function as a converter or mixer. The several switches S1 to S5 are adapted for simultaneous operation between their T and R positions by means of a transmit-receive relay, not shown, commonly used in transceivers.

The IPA stage 29 is provided with tunable input and output circuits, only one of which is shown, and the PA stage 30 is provided with a tunable output circuit, the several circuits being similar to those of the receiver stages 4 and 5, their component parts therefore being similarly identified. The variable condensers 18 of stages 29 and 30 are unicontrolled with those of stages 4 and 5 by means of 22, and band switches 21 of stages 29 and 30 along with harmonic selector switch 11 of oscillator-amplifier 10 are unicontrolled with the band switches 21 of stages 4 and 5 by means of 23.

Since in the operation of the system the carrier frequency for both reception and transmission is the same, the tunable circuits included in the receiving channel and those included in the transmitting channel can conveniently be ganged together for unicontrol adjustment. It is also advantageous to utilize the tunable circuits of the receiving channel as a tuned filter for selecting the desired frequency component during transmission. This constitutes the subject matter of an application, Serial No. 546,845, filed July 27, 1944, in the name of W. A. Harris and

assigned to the same assignee as this application.

Power amplifier 30 is plate and screen modulated in the conventional manner, as shown in Lawrence Patent No. 1,923,543, by a modulator 32 energized from an audio amplifier 33 to which there is connected a microphone 34. For clarity the signal path for reception is shown by the single arrows while the signal path for transmission is shown by the double arrows.

It is desirable for a two-way communication system of the type described to be able to tune both the receiver and transmitter at each station to one of a plurality of prearranged operating frequencies, expeditiously and as accurately as possible. For this purpose there may be provided a motor-operated, automatic preselector mechanism designated 35 having a plurality of selector units, so designed that one unit adjusts the variable condensers 18, ganged together by means 22, to one of ten preselected positions, a second unit adjusting, for each of said positions, the band switches 21 and the harmonic selector switch 11, ganged together by the means 23, to one or the other of their positions, a third unit adjusting the cores 16, 17 and 27, ganged together by the means 28, to one of ten positions corresponding to the respective adjustments of condensers 18, while a fourth unit is adapted to select the particular crystal, the crystal selection depending upon the portion of the frequency range in which the desired operating frequency is located. One type of preselector mechanism that is suitable for this purpose is disclosed in the Boterweg et al. Patent No. 2,351,185.

Since it is possible with the fixed frequency of each crystal (fundamental or harmonic) to effect variations of the transmitter carrier over a narrow tuning range by means of the variable oscillator 25 and a corresponding variation in the receiver IF frequency by means of the variable IF amplifier 6, coverage of a wide band of frequencies may be had with a limited number of crystals. This is clearly shown from the charts of Figs. 2A and 2B, the former showing the frequency coverage from 2.0 to 5.6 mc. and the latter showing the frequency coverage from 5.5 to 9.1 mc. In computing the individual narrow frequency ranges for the several crystals the following frequency relation is employed.

$$F_T = F_R = nF_0 - F_1$$

where

F_T = frequency of transmission

F_R = frequency of reception

F_0 = oscillator frequency (crystal)

F_1 = variably tuned IF osc. and IF amplifier frequency

n = oscillator multiplier: $n=1, 2$, etc.

Utilizing, for example, the fundamental frequency of the crystal ground to 3500 kc. and mixing this frequency with the frequencies 600 to 900 kc. from the variable oscillator 25, the resulting difference frequencies in the range from 2.6 to 2.9 mc. may be selected as carrier frequencies for transmission by appropriately adjusting the tuned circuits of stages 4 and 5. In reception this frequency range of 2.6 to 2.9 mc., to which stages 4 and 5 of the receiver are already tuned, is heterodyned with the fixed frequency output of oscillator-amplifier 10 to produce the narrow range of frequencies, taking the difference frequencies, through which IF amplifier 6 is tunable.

However, in utilizing the sum frequencies of F_0 and F_1 there is obtained for the crystal having the fundamental frequency of 3500 kc. the frequency coverage from 4.1 to 4.4 mc. As shown in Fig. 2A, with the use of the several crystals having the fundamental frequencies of 2900 to 4700 kc. and selecting the resulting difference frequencies, the frequency coverage is from 2.0 to 4.1 mc. By utilizing the same crystals and selecting the sum frequencies the coverage is extended to 5.6 mc.

In Fig. 2B the frequency coverage is shown for the several crystals to extend from 5.5 to 9.1 mc., the second harmonic of each crystal being utilized in this case. The upper row of narrow ranges is obtained by selecting the difference frequencies ($2F_0 - F_1$) and the lower row is obtained by selecting the sum frequencies ($2F_0 + F_1$), each narrow range being 0.3 mc. wide with the ranges of the upper row alternating with those of the lower row.

It is possible to obtain a still wider frequency coverage with the use of a doubler interposed between the variable oscillator 25 and the transmitter mixer 24 and deriving the fourth harmonic of each crystal in the output of the oscillator-amplifier 10. In this case there would be employed an IF amplifier tunable over the frequency range 1200 to 1800 kc. In a practical embodiment in which these features have been employed and with the use of two additional crystals having the fundamental frequencies of 2750 kc. and 3050 kc. the frequency coverage was extended to 20.6 mc.

Although it has been specified above that the several communicating receiver-transmitter sets are of similar construction, for a satisfactory operation of the system they need not necessarily be so, since as will be understood by those skilled in the art, the system may be operable also between a receiver-transmitter embodying the present invention and one which is capable of operating on the same frequency, as for example, the receiver-transmitter disclosed in the above Young patent.

While I have shown and described a preferred embodiment of my invention, it will be understood that various modifications and changes will occur to those skilled in the art without departing from the spirit and scope of this invention. I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim is:

1. The method of two-way communication between a pair of stations, at least one of which comprises a transmitter provided with a variable oscillator and a superheterodyne receiver provided with an intermediate frequency amplifier that is tunable over a limited frequency range, which consists in generating a fixed stable high-frequency, mixing said generated fixed frequency with said selected frequency from a variable oscillator adjustable to the same frequency as the intermediate frequency amplifier of the receiver to derive a resultant frequency which constitutes the carrier frequency for the transmitter, receiving such carrier frequency from the other communicating station, and mixing the received carrier frequency with the fixed frequency to provide a beat frequency to which the receiver intermediate frequency amplifier is tuned.

2. The method of providing two-way communication on the same operating frequency between a pair of stations, at least one of which

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comprises a transmitter having a variable, relatively low frequency oscillator and a superheterodyne receiver having a variable intermediate frequency amplifier, said oscillator and amplifier being tunable in unison over a limited frequency range, which consists in generating a fixed stable high-frequency, mixing said generated fixed frequency with a selected frequency from the variable oscillator to derive a resultant frequency which constitutes the carrier frequency for the transmitter, receiving such carrier frequency from the other communicating station, and mixing the received carrier frequency with the generated fixed frequency to provide a beat frequency which is the frequency to which the receiver intermediate frequency amplifier is tuned.

3. A two-way communication system comprising a plurality of similar radio stations which are adapted to communicate with one another on the same carrier frequency, each station comprising a transmitter and a superheterodyne receiver, a fixed frequency oscillator common to both receiver and transmitter, means during reception for supplying the oscillator frequency to the first detector of the receiver, a variable frequency oscillator tunable over a limited range of frequencies, and means during transmission for mixing a predetermined frequency from the variable oscillator and the frequency of the fixed oscillator to obtain a resultant frequency which is utilized as the carrier frequency for the transmitter.

4. A two-way communication system comprising a plurality of similar radio stations which are adapted to communicate with one another on the same carrier frequency, each station comprising a transmitter and a superheterodyne receiver provided with a variable intermediate frequency amplifier that is tunable over a limited frequency range, a fixed frequency oscillator common to both receiver and transmitter, means during reception for supplying the oscillator frequency to the first detector of the receiver, a variable frequency oscillator ganged with the intermediate frequency amplifier and tunable over the same limited frequency range, means during transmission for mixing a predetermined frequency from the variable oscillator and the frequency of the fixed oscillator to obtain a resultant frequency which is utilized as the carrier frequency for the transmitter and which upon reception is mixed with the frequency of the fixed oscillator to produce in the intermediate frequency amplifier the same frequency as the predetermined frequency from the variable oscillator.

5. Two-way communication equipment adapted to communicate on the same carrier frequency, and comprising a transmitter and a superheterodyne receiver, said receiver including an intermediate frequency amplifier that is tunable over a limited frequency range, a fixed frequency oscillator common to both receiver and transmitter, a variable frequency oscillator tunable in unison with the receiver intermediate amplifier over the same limited frequency range, means during transmission for mixing a predetermined frequency from the variable oscillator and the frequency of the fixed oscillator to obtain a resultant frequency which is utilized as the carrier frequency for the transmitter, and means during reception for mixing said carrier frequency from a remote station with the frequency of the fixed oscillator to obtain a resultant frequency to which the receiver intermediate frequency amplifier is tuned.

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6. Two-way communication equipment comprising a transmitter, a superheterodyne receiver provided with an intermediate frequency amplifier which is tunable through a predetermined frequency range, a fixed stable high-frequency oscillator serving as the local oscillator for the receiver, a variable oscillator tunable through the same frequency range as the receiver intermediate frequency amplifier, means for simultaneously adjusting the receiver intermediate frequency amplifier and the variable oscillator to the same frequency, and means for mixing a selected frequency of the variable oscillator with the frequency of the fixed oscillator to provide a selected carrier frequency for the transmitter which carrier frequency upon being received at one station from a second station is mixed with the local oscillator frequency to provide a resultant frequency to which the intermediate frequency amplifier of the receiver at said one station is tuned.

7. Two-way communication equipment adapted for selective operation on one of a plurality of frequency channels which is the same for both transmission and reception, each station comprising a transmitter, a superheterodyne receiver provided with an intermediate frequency amplifier which is tunable through a limited frequency range, a variable oscillator tunable through said same limited frequency range, means for simultaneously adjusting said variable oscillator and said intermediate frequency amplifier to a predetermined frequency within said limited range, an oscillator having associated with it a plurality of piezo-electric crystals which are adapted for selective connection to control the oscillator at a different fixed frequency, said fixed frequency crystal-controlled oscillator adapted during reception to serve as the local oscillator for the receiver and adapted during transmission to be mixed with said predetermined frequency of the variable oscillator to provide a desired carrier frequency for the transmitter, means for mixing the frequencies of the fixed and variable oscillators, and means for selecting the desired carrier frequency from said mixed frequencies.

8. In two-way communication equipment adapted to communicate on a selected one of a plurality of frequency channels which are contained in a wide frequency spectrum, said selected frequency channel being the same for both transmission and reception, equipment comprising a transmitter and a superheterodyne receiver, an oscillator having associated with it a plurality of piezo-electric crystals which are adapted for selective connection to control the oscillator each at a different fixed frequency, each crystal determining a particular portion of the frequency spectrum in which the selected frequency channel is located, an intermediate frequency amplifier included in the receiver tunable through a limited frequency range, a variable oscillator tunable through the same limited frequency range, means for simultaneously adjusting said variable oscillator and said intermediate frequency amplifier to a predetermined frequency within said limited range, said predetermined frequency determining the selected frequency channel located within the particular portion of the frequency spectrum as determined by the operative crystal, said fixed frequency crystal-controlled oscillator adapted during reception to serve as the local oscillator for the receiver and adapted during transmission to be mixed with said predetermined frequency of the variable oscillator to

provide the selected carrier frequency for the transmitter, means for mixing the frequencies of the fixed and variable oscillators, and means for selecting the desired carrier frequency from said mixed frequencies.

9. A combination receiver-transmitter for obtaining a high order of frequency stability, closely approaching that of crystal control with the advantages and flexibility of being able to set up the receiver and transmitter on a multiplicity of frequency channels, selected at any desired points in a wide frequency spectrum, without the necessity of having specific crystals for the selected frequencies; equipment comprising a superheterodyne receiver and associated transmitter, an oscillator having associated with it a definite set of piezo-electric crystals which are adapted for selective connection to control a stable high-frequency oscillator at a definite fixed frequency, each crystal frequency or multiple thereof, determining a particular portion of the overall frequency spectrum in which the selected frequency channel is located, an intermediate fre-

quency amplifier included in the receiver tunable through the limited range of frequencies by which each of the crystals in the set differs from the adjacent crystal frequencies, a variable oscillator tunable through the same limited frequency range, means for simultaneously adjusting said variable oscillator and said intermediate frequency amplifier to a predetermined frequency within said limited range, said predetermined frequency determining the selected signal frequency channel located within the particular portion of the frequency spectrum as determined by the operative crystal, said fixed frequency crystal-controlled oscillator adapted during reception to serve as the local heterodyne oscillator for the receiver and adapted during transmission to be mixed with said predetermined frequency of the variable oscillator to provide the selected carrier frequency for the transmitter, and means for selecting the desired carrier frequency from said mixed frequencies.

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