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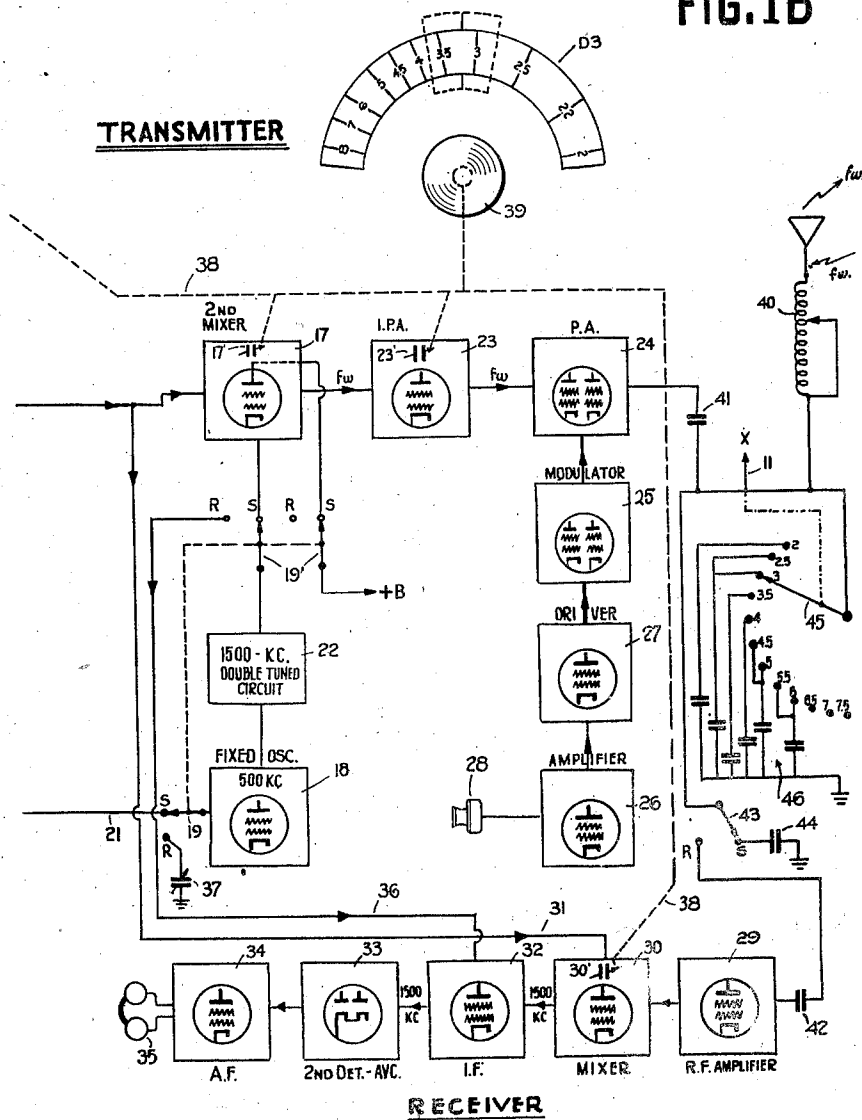
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TWO-WAY RADIO COMMUNICATION SYSTEM

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FIG. 1B



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TWO-WAY RADIO COMMUNICATION
SYSTEM

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The present invention relates generally to a two-way radio communication system, and more particularly to an improved two-way system wherein the operating or working frequency for both transmission and reception is the same.

Point-to-point communication, between two remote radio stations, for example, is frequently accompanied by difficulty in establishing contact, particularly when no time schedule has been arranged. At the ultra-high frequencies, furthermore, there is difficulty in maintaining an exact frequency of the carrier wave, and elaborate control apparatus is commonly needed at both receiving and transmitting ends. The system according to our present invention overcomes these disadvantages to a large extent, since by its use any station may communicate in both directions with a "mate" station by simply tuning in a transmission from that "mate" station.

Accordingly, it is an object of our invention to provide a communication system in which the establishment of a suitable carrier frequency for two-way communication may be determined from either one of two or more stations.

Another object of our invention is to provide a two-way communication system in which adjustment of the receiver at one station to the carrier frequency transmitted from another station automatically adjusts the transmitter at the first station to the same carrier frequency.

A more specific object of our invention is to provide at each of a plurality of similar stations an oscillator system of high stability which is utilized for both transmission and reception and which results in extreme accuracy in frequency setup and in perfect communication between the several stations, so that "netting" between stations is unnecessary.

Other objects and advantages will be apparent from the following description when read in conjunction with the accompanying drawings, in which Figs. 1A and 1B, when placed side by side, represent a diagrammatic block diagram of a preferred embodiment of the invention, and Fig. 2 is a schematic circuit diagram of the harmonic selector utilized in the oscillator section of Fig. 1A.

Briefly, the method we employ utilizes a selected one of a plurality of available frequencies as the carrier for transmission in one direction and

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the same carrier for transmission in the other direction. Tuning the receiver at station A, for example, to the carrier frequency transmitted from station B will simultaneously assure perfect tuning of the receiver at station B in response to the carrier which will then be effective at station A. 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 Figs. 1A and 1B represents a single set or station, of which any desired number of similar construction may be utilized for carrying out the method of communication above mentioned. Also, it is essential to the successful operation of our 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 frequency range may be employed, the description that follows will be given for a transmitter-receiver set which was designed and successfully operated for a frequency range of 2-8 mc., in one band, and capable of two modes of operation, namely, CW and radio telephone.

Referring now more particularly to Figs. 1A and 1B, the local oscillator voltage for the receiver and the master oscillator voltage for the transmitter are derived from a common oscillator circuit. This circuit consists of a one megacycle (mc.) crystal-controlled oscillator 1, the appropriate harmonic of which is mixed with a 500 to 1000 kc. variable oscillator 2. This mixed signal is used as the local oscillator for the receiver and is 1500 kc. higher than the working frequency (*f_w*). For "send" or "transmit," the above mixed signal is mixed a second time with a 1500 kc. signal, which reduces the signal to the working frequency (*f_w*). The 1500 kc. signal is locked-in to the crystal, as will be explained later, and thus the only possible netting errors would come from the 500 to 1000 kc. variable oscillator. As this oscillator only contributes a small percentage of the signal and may be constructed to have maximum stability, practically perfect netting results.

The crystal used in oscillator circuit 1 has a fundamental frequency of one megacycle and is

accurate to $\pm 0.1\%$ over a temperature range of -40° to $+50^\circ$ C. The output of the crystal oscillator is coupled to the input of an harmonic generator 3. The output of the harmonic generator is fed to a pair of tuned circuits 4 and 5, which are tuned to the desired harmonic by a pair of 12-position selector switches 6 and 7, respectively, which tie-in appropriate padders and trimmers of condenser-networks 8 and 9, as shown more particularly in Fig. 2. The tuned circuits 4 and 5, the switches 6 and 7 and their respective condenser-networks 8 and 9 constitute the harmonic selector 10 of Fig. 1A. The selector switches 6 and 7 are ganged to a common control shaft 11, which is brought out through the front panel of the set and terminates in a control knob 12, identified also by the legend "Selector switch control." A dial D1 is utilized in conjunction with the control knob 12 in order to identify the position of the selector switch and is calibrated in 0.5 mc. intervals from 2 to 8 mc., as shown. The use of the harmonic generator and the double-tuned circuit gives good selectivity to the selected harmonic.

The selected harmonic is fed to the grid of a first mixer stage 13, which may be constituted by a single tube or two tubes connected as a balanced mixer, where it is mixed with the 500 to 1000 kc. variable oscillator 2. The variable oscillator is of the well-known Hartley type, the grid being tapped down the coil to increase stability. The variable oscillator 2 is tuned by a variable condenser 14 and is temperature compensated. The condenser is adjustable by means of a control knob 14' affixed to the condenser shaft which is represented by the chain line 14''. Mounted on this shaft for movement therewith is a dial D2 which is calibrated in one direction from 0 to 500 kc. and in the opposite direction from 500 to 1000 kc., the calibrations being marked off in 10 kc. intervals.

To reduce spurious response the 500 to 1000 kc. signals are fed to the first mixer 13 through a low-pass filter 15. The mixed signal from 13, the output of which is tuned by a variable condenser 13', is fed to the receiver mixer or converter 30 (Fig. 1B) through a tuned amplifier 16, which serves to attenuate the unwanted sidebands from the mixer, the output of the amplifier being tuned by variable condenser 16'.

For sending, the output of the oscillator amplifier 16 is in effect switched from the receiver converter to the grid of a second oscillator mixer 17 the output of which is tuned by a variable condenser 17'. There it is mixed with a 1500 kc. signal obtained from a 500 kc. fixed oscillator 18 also of the Hartley type. In order to stabilize the frequency of oscillator 18, the latter is "locked-in" with oscillator 1 which is crystal-controlled. For this purpose there is provided a coupling from the output of oscillator 1 to the input of oscillator 18. As shown in the drawing this coupling is obtained through the natural capacity 20 created by placing the free end of a conductor 21 close to the output of the crystal oscillator, and connecting the other end through a switch 19 in the "S" or send position to the input of oscillator 18. This coupling may also be obtained by a directly connected condenser. The third harmonic (i. e., 1500 kc.) of the fixed oscillator 18 is selected by a double-tuned circuit 22 and fed to the second mixer 17 through one pole of a double-pole send-receive switch 19'. The difference signal (i. e., the receiver local oscillator frequency minus 1500 kc.) is fed

through a driver or intermediate power amplifier stage 23, tuned by a variable condenser 23', to a power amplifier stage 24 which may be a twin tube or separate tubes, the two sections or tubes being operated in parallel and as class "C."

For radio telephone transmission the power amplifier 24 is plate-modulated by a class "B" modulator stage 25 which may also utilize a twin tube or separate tubes, the two sections of tubes being operated in push-pull. The modulator is driven by a two stage audio amplifier 26 and 27, a microphone being connected to the input of the first amplifier stage 26.

The receiver portion of the set consists of an R. F. amplifier stage 29 which is coupled to a converter or mixer stage 30, the input of which is tuned by a variable condenser 30'. The signal from the oscillator above described is fed to the mixer stage by way of a conductor 31, the output of the mixer being tuned to 1500 kc., which is the receiver I. F. or intermediate frequency. The latter is then amplified in one or more I. F. stages 32, the output of which is coupled to a diode detector 33, the rectified signal being amplified in one or more audio stages 34, and then reproduced in a telephone 35, or other suitable indicating means.

For receiving CW signals, the crystal lock-in 20, 21 is removed by actuating switch 19 to the "R" or receive position. The switch 19 is operated in conjunction with the double pole switch 19', one pole of which disconnects the power supply +B from the plate of the second mixer 17, and the other of which disconnects the 1500 kc. oscillator output from the second mixer and connects it to the I. F. amplifier 32 of the receiver. The 1500 kc. signal is then used as a beat frequency oscillator, the signal of which is fed by way of conductor 36 to the receiver I. F. amplifier 32 provide a beat note the frequency of which may be adjusted by condenser 37.

The several variable condensers above mentioned, namely, 13', 16', 17', 23' and 35' which tune respectively the output of the first mixer 13, the output of the oscillator amplifier 16, the output of the second mixer 17, the output of the intermediate power amplifier 23 and the input to the receiver mixer 30, are ganged to a common shaft, represented by the dash line 38. This shaft is provided with a control knob 39 for manually adjusting the condensers and it is also provided with a dial D3 which is calibrated from 2 to 8 mc., as shown.

The transmitter channel is coupled to an antenna coil 40 of the rotary type by way of a coupling condenser 41, and the receiving channel is also coupled to the antenna coil by way of a coupling condenser 42 and a switch 43 when in the "R" or receive position, the switch 43 being under control of a keying relay not shown. In the "S" or send position of this switch, the low end of the antenna coil is connected to ground through a compensating condenser 44. The low end of the antenna coil is also connected to a switch arm 45 which is adapted to be uni-controlled, as indicated by the chain line 11 broken at x-x, with the switch arms 6 and 7 of the harmonic selector 10. Cooperating with the switch arm 45 are a plurality of contacts, corresponding to those associated with the harmonic selector switch arms 6 and 7 of Fig. 2. A condenser-network 46 of appropriate trimmers is associated with the contacts for tuning the output of the transmitter channel and the input of the receiver channel to the indicated fre-

quencies. At the switch positions for the higher frequencies, namely 6, 6.5, 7 and 7.5 mc., sufficient distributed capacity is present in the associated circuits so that the connection of separate trimmers is unnecessary.

The procedure for tuning each of the sets of the communicating net to any prearranged frequency is as follows (assuming that the working frequency is to be 3.250 mc.):

1. The selector switch control knob 12 is set so that the dial reading of D1 is 3, that is, the nearest half-megacycle point below the desired frequency which, in the example given, is 3.250.

2. The variable oscillator dial D2, by the rotation of the variable oscillator control knob 14', is set to the last three significant figures of the frequency, that is, to 250. It is to be noted that this dial is provided with two calibrations, an upper one from 0 to 500 and a lower one from 1000 to 500, as previously mentioned. These calibrations may be of different colors, such as red and black, respectively, for ease of identification. When the desired frequency is in a half megacycle (e. g., between 3 and 3.5 mc.) the upper or red calibration is used. When the desired frequency is in a half megacycle immediately below an even megacycle (e. g., between 4 and 5 mc.) the lower or black calibration is used. In the example given, the desired frequency is in the half megacycle between 3 and 3.5 mc. so that the upper or red calibration is used, being set to 250 as shown.

3. Then the dial D3, by rotation of the control knob 39 for the R. F. amplifier circuits, is set to the desired frequency, i. e., to 3.250 mc.

4. Finally, the antenna tuning coil 40 is rotated to resonance. For this purpose there is provided a meter (not shown) which indicates when the antenna is tuned up by the maximum deflection of the needle. (In an application of W. B. Morrison, Serial No. 584,393, filed concurrently herewith, there is disclosed a system for tuning the antenna tuning coil to resonance in an automatic manner in response to antenna current.)

The common oscillator circuit for the transmitter and receiver of each set provides the facility that 10 kc. channels may be set up from 2 to 8 mc. with extreme accuracy, so that a net of such sets may be independently set up to any channel within this range and be in perfect communication with one another, without the requirement of netting. In addition, this oscillator circuit lends itself admirably to automatic tuning to predetermined preset positions by means known in the art. In the actual construction of the combined transmitting-receiving set described herein automatic motor-driven control means was provided for adjusting the variable oscillator 2 and the condenser ganged interconnected by dash line 38, and a stepping relay was provided for the harmonic selector, all to three preset operative frequencies.

The chart below lists the selected harmonic for each position of the selector switch 12, the frequency range of the signals in the output of the 1st mixer (which is also the frequency range of the signals fed to the receiver mixer 30) corresponding to each selector switch position, as well as the corresponding ranges of the working frequency. It should be noted that for certain of the selector switch positions the frequency of the variable oscillator is added to the selected harmonic for those positions, while for other switch positions the frequency of the variable oscillator

is subtracted from the selected harmonic for those positions.

Switch Position	Selected Harmonic	500-100 Kc. Var. Osc. (+Add -Sub.)	1st Mixed Frequency	1500 Kc. Fixed Osc.	Difference or Working Frequency
2-----	3	+	3.5-4	1.5	2 -2.5
2.5-----	6	-	4 -4.5	1.5	2.5-3
3-----	4	+	4.5-5	1.5	3 -3.5
3.5-----	6	-	5 -5.5	1.5	3.5-4
4-----	5	+	5.5-6	1.5	4 -4.5
4.5-----	7	-	6 -6.5	1.5	4.5-5
5-----	6	+	6.5-7	1.5	5 -5.5
5.5-----	8	-	7 -7.5	1.5	5.5-6
6-----	7	+	7.5-8	1.5	6 -6.5
6.5-----	9	-	8 -8.5	1.5	6.5-7
7-----	8	+	8.5-9	1.5	7 -7.5
7.5-----	10	-	9 -9.5	1.5	7.5-8

The trimmers and padders of the condenser-networks 8 and 9 are chosen of such values that the required harmonic is obtained for each selector switch position. It will be noted that for certain positions, such as for 2.5 and 4, the 5th harmonic is selected for both positions, and for 3.5 and 5, the 6th harmonic is selected. In one case, however, the frequency of the variable oscillator frequency 2 is added to and in the other it is subtracted from the same harmonic. Whether the frequency of the variable oscillator is added or subtracted is dependent upon the adjustment of the variable tuning condenser 13' in the output of the 1st mixer. The frequency output of this mixer (F_m) is in each case 1500 kc. (the frequency F_0 of fixed oscillator 18-22) above the working or carrier frequency (F_w) and is also the local oscillator frequency (F_l) that is injected into the mixer stage 30 of the receiver, so that at the receiver the intermediate frequency (F_i) is in each case also 1500 kc., the difference between the receiver carrier (F_w) from a "mate" station and the local oscillator or 1st mixer stage frequency. Mathematically the above frequency relations may be stated as follows:

$$F_m - F_0 = F_w, \text{ or } F_m - F_w = F_0 \text{ and } F_l - F_w = F_i$$

45 F_m being equal to F_l and F_0 being equal to F_i .

While our present invention has been disclosed as embodied in a particular form it will be understood that it may be embodied in other and different forms without departing from the spirit and scope of our invention. For example, as will be obvious to those skilled in the art, other selected harmonics may be chosen, and the range of the variable oscillator and the frequency of the fixed oscillator may be different.

55 What we claim is:

1. The method of providing two-way communication between a pair of remote stations, each of which consists of a transmitter and a superheterodyne receiver operating at a fixed intermediate frequency, which consists in generating a fixed frequency, selecting a predetermined harmonic of said fixed frequency, mixing said selected harmonic with a predetermined frequency from a variable oscillator to derive a resultant frequency, feeding said resultant frequency to the mixer stage of the receiver, mixing said resultant frequency with the frequency of a fixed oscillator to derive the carrier frequency for the transmitter, transmitting said carrier frequency to a remote station, and receiving from said remote station a frequency which is the same as that of the transmitted carrier frequency and which is so related to the frequency fed to the receiver mixer stage that the difference frequency is that of the receiver intermediate frequency.

2. The method of providing two-way communication between a pair of remote stations, each of which consists of a transmitter and a superheterodyne receiver operating at a fixed intermediate frequency, which consists in generating a fixed frequency, selecting a predetermined harmonic of said fixed frequency, mixing said selected harmonic with any selected frequency from a variable oscillator which is tunable through a predetermined range, deriving a resultant frequency which is included in a corresponding frequency range, feeding said resultant frequency to the mixer stage of the receiver which is also tunable over a corresponding frequency range, mixing said resultant frequency with the frequency of a fixed oscillator which is locked with the first fixed frequency generator to derive a carrier frequency which is included in a corresponding frequency range, transmitting said carrier frequency to a remote station, and receiving from said remote station a frequency which is the same as that of the transmitted carrier frequency and which is so related to the frequency fed to the receiver mixer stage that the difference frequency is that of the receiver intermediate frequency.

3. A two-way communication system operable between a pair of remote stations, each of which consists of a transmitter and a superheterodyne receiver operating at a fixed intermediate frequency, comprising means for generating a fixed frequency, means for selecting a predetermined harmonic of said fixed frequency, a variable oscillator, means for mixing said selected harmonic with a predetermined frequency from said variable oscillator, means for feeding a portion of said resultant frequency to the mixer stage of the receiver, a fixed frequency oscillator, means for mixing another portion of said resultant frequency with the frequency of said fixed oscillator to provide a carrier frequency for the transmitter, means for transmitting said carrier frequency to a remote station, and means at the receiver for receiving from said remote station a frequency which is the same as that of the transmitted carrier frequency and which is so related to the frequency fed to the receiver mixer stage that the difference frequency is that of the receiver intermediate frequency.

4. A two-way communication system operable between at least two radio stations, each station comprising a transmitter, a superheterodyne receiver, and an oscillator common to the transmitter and the receiver, said oscillator comprising a fixed frequency oscillator, an harmonic generator coupled to said fixed frequency oscillator, means for selecting a predetermined harmonic from said generator, a variable frequency oscillator, means for mixing a predetermined frequency from the variable oscillator and the selected harmonic to obtain a resultant frequency which is utilized as the local oscillator of the receiver, a second fixed frequency oscillator, and means for mixing said resultant frequency and the frequency of said second fixed oscillator to obtain a difference frequency which is utilized as the carrier frequency for the transmitter.

5. A two-way communication system operable between at least two radio stations, each station comprising a transmitter, a superheterodyne receiver, and an oscillator common to the transmitter and the receiver, said oscillator comprising a fixed frequency oscillator, an harmonic generator coupled to said fixed frequency oscillator, means for selecting a predetermined harmonic

from said generator, a variable frequency oscillator, means for mixing a predetermined frequency from the variable oscillator and the selected harmonic to obtain a resultant frequency which is utilized as the local oscillator of the receiver, a second fixed frequency oscillator, means for locking the second fixed oscillator to the first mentioned fixed oscillator, and means for mixing said resultant frequency and the frequency of said fixed oscillator to obtain a difference frequency which is utilized as the carrier frequency for the transmitter.

6. A two-way communication system operable between at least two radio stations, each station comprising a transmitter and a superheterodyne receiver which are adapted for radio telephone and CW operation, and an oscillator common to the transmitter and the receiver, said oscillator comprising a fixed frequency oscillator, an harmonic generator coupled to said fixed frequency oscillator, means for selecting a predetermined harmonic from said generator, a variable frequency oscillator, means for mixing a predetermined frequency from the variable oscillator and the selected harmonic to obtain a resultant frequency which is utilized as the local oscillator of the receiver, a second fixed frequency oscillator, means operable when the system is arranged for telephone operation for mixing said resultant frequency and the frequency of said second fixed oscillator to obtain a difference frequency which is utilized as the carrier frequency for the transmitter, and means operable when the system is arranged for CW operation for converting said second fixed frequency oscillator to serve as a beat frequency oscillator, the frequency of which is applied to the receiver I. F. stage.

7. A two-way communication system operable between at least two similar radio stations, which are adapted to communicate on the same carrier frequency, each station comprising a transmitter, superheterodyne receiver, and an oscillator common to the transmitter and the receiver, said oscillator comprising a fixed frequency crystal-controlled oscillator, an harmonic generator coupled to said fixed frequency oscillator, means for selecting a predetermined harmonic from said generator, a variable frequency oscillator tunable over a limited range of frequencies, means for mixing a predetermined frequency from the variable oscillator and the selected harmonic to obtain a resultant frequency which is utilized as the local oscillator of the receiver and which is different for each variable oscillator predetermined frequency, a fixed frequency oscillator, and means for mixing said resultant frequency and the frequency of said fixed oscillator to obtain a difference frequency which is utilized as the carrier frequency for the transmitter and which is also different for each variable oscillator frequency.

8. A communication system as defined in claim 7 wherein means are provided for locking the fixed oscillator to the fixed frequency crystal-controlled oscillator to stabilize its frequency.

9. A two-way communication system operable between at least two similar radio stations which are adapted to communicate on the same carrier frequency, each station comprising a transmitter, a superheterodyne receiver, and an oscillator common to the transmitter and the receiver, said oscillator comprising a fixed frequency oscillator, an harmonic generator coupled to said fixed frequency oscillator, means including a manual

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selector switch for selecting a predetermined harmonic from said generator, a variable frequency oscillator having means for manually adjusting its frequency, means for mixing a predetermined frequency from the variable oscillator and the selected harmonic to obtain a resultant frequency which is utilized as the local oscillator for the mixer of the receiver, a second fixed frequency oscillator, and means for mixing said resultant frequency and the frequency of said second fixed oscillator to obtain a difference frequency which is utilized as the carrier frequency for the transmitter, said first and second mixing means and the receiver mixer being provided with manual control means for adjusting their respective output frequencies in unison.

10. A two-way communication system as defined in claim 9 wherein the harmonic selector switch has associated with it a dial calibrated in half megacycles, and the manually adjustable means for the variable oscillator has associated with it a dial calibrated in 10 kc. divisions through its range, and the last mentioned control means has associated with it a dial calibrated for the range of the system in megacycles, the

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arrangement being such that in selecting a desired working frequency the harmonic selector switch is set to the nearest half megacycle point below the desired frequency, the variable oscillator control means is set to the second, third and fourth significant figures of the desired frequency, and the last mentioned control means is set to the desired frequency calibration on the dial, which is the sum of the settings to which the first two dials are set.

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