

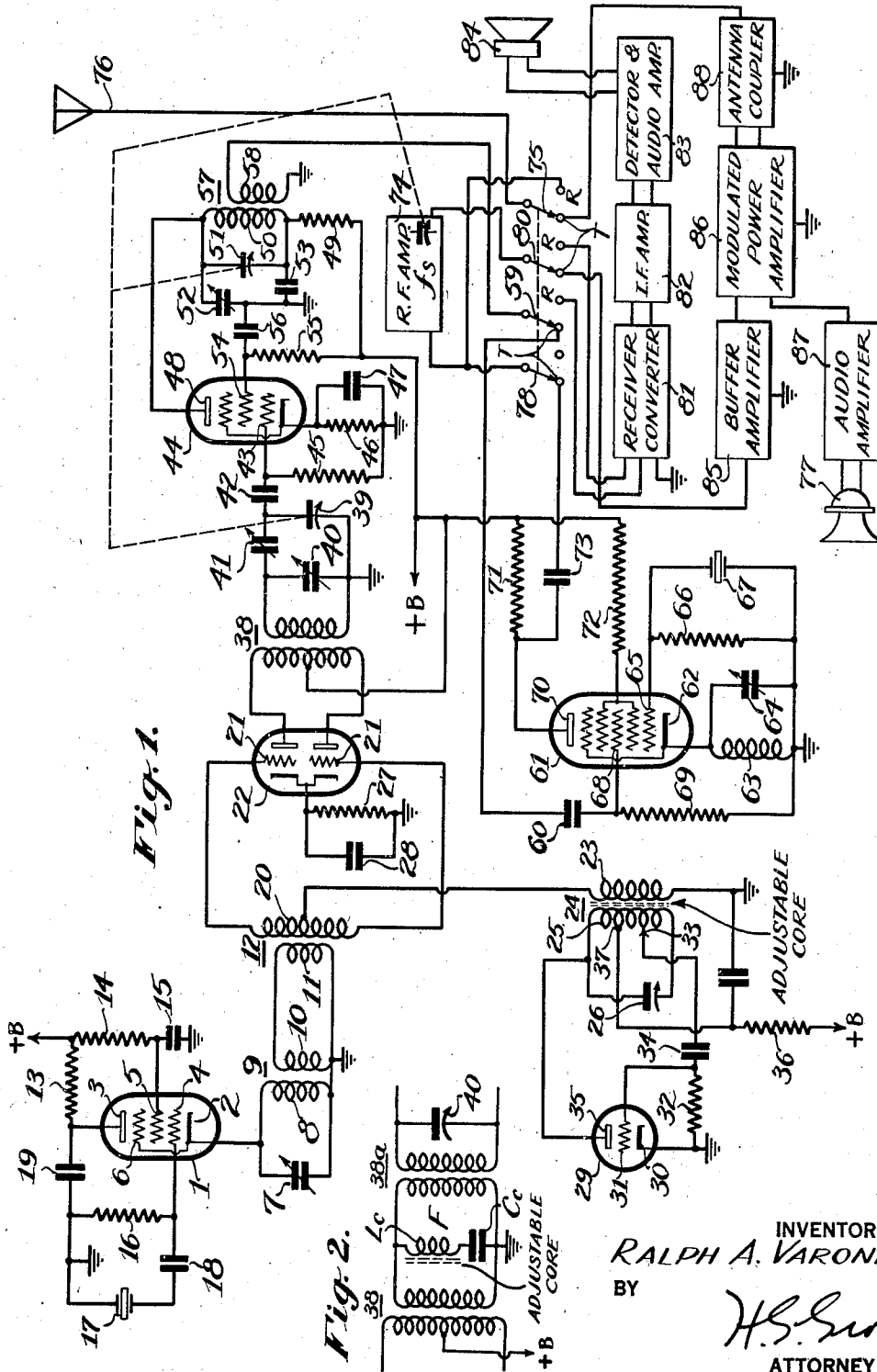
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R. A. VARONE

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TWO-WAY RADIO SYSTEM

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INVENTOR
RALPH A. VARONE
BY

H. S. Simon
ATTORNEY

UNITED STATES PATENT OFFICE

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TWO-WAY RADIO SYSTEM

Ralph A. Varone, Audubon, N. J., assignor to
Radio Corporation of America, a corporation of
Delaware

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This invention relates to two-way radio systems and is particularly directed to the wave generating equipment to be used therein.

It is important that reception and transmission in a two-way radio system shall be maintained with a high degree of frequency stability in respect to the carrier wave. It is important also that a superheterodyne receiver be controlled by a local oscillator having the greatest possible frequency stability.

It is, therefore, an object of my invention to provide a two-way radio system having generator equipment capable of a high degree of frequency stability and adjustably tunable within a wide range of frequencies.

Another object of my invention is to provide a two-way radio system in which a radio frequency amplifier and converter may be used in common by the transmitting and receiving equipment.

Still another object of my invention is to provide generator equipment in which a crystal-controlled high frequency generator is used in combination with a variably tunable low frequency oscillator to obtain a heterodyne frequency which may be continuously varied over a relatively wide range of frequencies.

Other objects and advantages of my invention will be brought out in the more complete description to follow. This description is accompanied by a drawing in which Figure 1 represents diagrammatically a practical circuit arrangement for carrying out the invention, and Figure 2 shows an inductive interstage coupling arrangement which may be preferred in place of a more direct coupling shown at one part of Figure 1.

Referring to Figure 1, I show therein a crystal controlled oscillator comprising an electron discharge tube 1 which is preferably of the pentode type having a cathode 2, an anode 3 and three grids numbered respectively 4, 5 and 6. In a connection between the cathode 2 and ground is a tunable resonant circuit comprising an adjustable capacitor 7 in parallel with the primary winding 8 of a transformer 9. The secondary 10 of this transformer is coupled to the primary winding 11 of another transformer 12.

The anode 3 is supplied with positive potential from any suitable direct current source indicated as +B. Connection of the anode to this source is made through a resistor 13. The screen grid 5 is also connected to the source through a suitable resistor 14. The screen grid is coupled to ground through a capacitor 15 in order to bypass unwanted frequency components.

The control grid 4 is grounded through a circuit which includes a grid resistor 16. Grid 4 is also coupled to ground through a circuit which includes a piezo-electric crystal 17 in series with a capacitor 18. A capacitor 19 serves to

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bypass unwanted frequencies to ground as they may appear on the anode 3.

The circuit arrangement described in the foregoing paragraphs is that of a more or less conventional crystal oscillator. The output is fed to the transformer 12 the secondary winding 20 of which has its two terminals connected respectively to separate grids 21 in a twin triode discharge tube 22. A center-tap on the transformer 10 winding 20 is connected to one terminal of a secondary winding 23 in a transformer 24. The primary winding 25 of this transformer forms the inductance of a tunable resonant circuit. Tuning of the circuit is accomplished by permeability tuning. The parallel capacitance of this circuit includes an adjustable capacitor 26, and a fixed capacitor 26a. The adjustable capacitor is used for setting the circuits to calibration at the low frequency end of the band.

The input circuit for tube 22 may be traced from the grids 21 through the two ends of the secondary winding 20 to its center tap and thence through the secondary winding 23 to ground. The common cathode in tube 22 is connected to ground through a resistor 27. This resistor is shunted by a capacitor 28.

A low frequency oscillator variable within a considerable range of frequencies is shown to include a triode discharge tube 29. The cathode 30 of this tube is grounded. Its control grid 31 is connected to the grounded cathode through a resistor 32. Control energy is fed to the grid 31 through a circuit which includes a tap 33 on the permeability tuned inductance 25 of the resonant circuit, this tap being coupled to the grid 31 across a capacitor 34. Anode potential is supplied to the anode 35 from the +B source which in this case is fed through a resistor 36 to a tap 37 on the permeability tuned inductance 25.

The circuit which includes tube 22 will be recognized by those skilled in the art as a balanced modulator. The output from the crystal oscillator is fed to the grids 21 in push-pull. That is, the two grids are excited 180° out of phase with each other. In the output circuit which includes the two space paths of the twin triode tube 22 and the primary winding of a transformer 38 it will be observed that the even harmonics of the crystal oscillator frequency are substantially suppressed.

From the foregoing observations it will be understood that the output circuit from the balanced modulator will contain current at the frequency of the crystal oscillator (f_c) and heterodyned with frequency components of frequencies resulting from the combined outputs of the two generators. These components may be represented as $(f_c \pm f_o)$. Tuning elements C_c and L_c

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in the link are tuned to f_c in order to attenuate components of f_c . Fig. 2 shows the link F.

The secondary winding of transformer 38 forms the inductance of a suitable resonant circuit the variable capacitance of which is represented by a main tuning condenser 39 and a vernier condenser 40. This resonant circuit is tuned to either of the frequencies $(f_c + f_o)$ or $(f_c - f_o)$. The balanced modulator circuit makes possible the suppression of even harmonics of the frequency f_c and odd harmonics of the frequency f_o . It is, however, possible to interchange the connections between the oscillators and the transformer 12 so that frequency f_c may be applied in push-push and frequency f_o may be applied in push-pull.

To continue with the circuit description: The output from the transformer 38, or from transformer 38a (Fig. 2), is fed across capacitors 41 and 42 to the control grid 43 in a discharge tube 44 which may be used if desired as a single side band frequency multiplier. Tube 44 has a conventional input circuit including a grid resistor 45 and a cathode resistor 46, the latter being shunted by a capacitor 47. Elements 45, 46 and 47 are all grounded at one end. The anode 48 is connected to the positive terminal of the direct current source +B through a resistor 49 in series with the primary winding 50 of an output transformer 51. This primary winding constitutes the inductance of a tunable resonant circuit the capacitive elements of which are shown as a main tuning condenser 51 and a vernier condenser 52. Condenser 53 and resistor 49 act as a decoupling network isolating resonant circuit 50, 51 from the +B connection. The screen grid 54 is supplied with suitable positive potential from the +B source fed through a resistor 55. Unwanted frequency components appearing on the screen grid 54 are bypassed to ground through a capacitor 56.

As shown in Fig. 2 the primary winding of transformer 38 may be inductively coupled to the input side of a filter network F if desired. This network includes a shunt inductance L_c in series with a shunt capacitance C_c . The output side of this network is coupled through a transformer 38a to the tuned circuit comprising elements 39, 40 and 41 as shown in Fig. 1.

It will be understood that the resonant circuit including inductance 50 and capacitance 51 may be tuned to any desired multiple frequency with respect to the output from the balanced modulator stage. In other words, the output fed across the transformer 51 is that which is selected by the resonant frequency of the tuned circuit 50, 51. This resonant circuit and its associated tube 44 is thus constituted as a multiplier stage operating on one of the side bands produced in balanced modulator 22, the output thereof being suitable for use both for transmission and for reception, but is preferably tuned to a frequency which may be heterodyned with the received carrier wave to deliver the fixed frequency of the I. F. amplifier in the receiver.

The secondary winding 58 in transformer 57 is grounded at one end and is connected at the other end to a switch blade 59 in a four-pole-double-throw switch. When the blades of this switch are thrown to the left (points T) they are in position for utilizing the transmitter of the two-way radio system. When the switch blades are thrown to the right (points R) they are in position for reception.

A frequency converter unit is shown having a discharge tube 61 which includes a cathode 62, an anode 70 and a multiplicity of grids. The

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purpose of this tube is to generate oscillations which may be mixed with the frequency derived from the hereinbefore described multiplier stage 44. When this converter stage is used a carrier frequency f_s may be derived according to the formula $f_s = n(f_c \pm f_o) \pm f_{it}$. The frequency f_{it} is to be that of an intermediate frequency amplifier 82 which is used in the receiver section. A resonant circuit composed of an inductance 63 in parallel with an adjustable capacitor 64 is inserted between the cathode 62 and ground. This frequency f_{it} is maintained constant by means of a piezo electric crystal 67 having substantially the same natural frequency. The control grid 65 is connected to ground through a resistor 66. The piezo electric crystal 67 is in shunt with this resistor.

The second control grid 68 is connected to ground through a resistor 69 and receives control potentials from the frequency multiplier stage across a coupling capacitor 60. Direct current potential is supplied to the anode 70 through a resistor 71 leading to the positive terminal, +B, of the direct current source. Screen grid potential for the second and fourth grids in the tube 61 is applied from the direct current source through resistor 72. The output from the converter tube 61 is coupled across a capacitor 73 to the input circuit of a conventional radio frequency amplifier unit 74, which is tuned to the carrier frequency f_s to be used for transmission and reception.

The purpose of the four-pole-double-throw switch is to provide alternative use of the transmitter section and the receiver section respectively. Assuming that the switch blades of this four-pole-double-throw switch are moved to the left, that is onto contact points T, then the transmitter section will be utilized as follows: The carrier frequency f_s is conducted across capacitor 73 to switch blade 78 and thence to the input side of the radio frequency amplifier 74, this amplifier being tuned to the frequency f_s . The output from the R.F. amplifier is then fed through switch blade 80 to a buffer amplifier unit 85 and thence to a modulated power amplifier 86. A microphone or other source of intelligence signals 77 is used to control an audio amplifier 87 the output from which is fed to the modulated power amplifier unit 86. In place of the microphone 77 any suitable source of intelligence signals may be employed, such as a telegraph keying device (whether manual or automatic), a facsimile transmitter or a television transmitter.

The carrier frequency and the modulation signals are combined in the unit 86 and the output is fed to an antenna coupler 88. The output from the coupler unit is then fed through switch blade 75 to the antenna and is radiated for purposes of transmission.

When the blades of the four-pole switch are moved to the right, suitable conditions are obtained for reception. For such purpose the circuit connections through the switch may be described as follows:

The output from the frequency multiplier 44 is the frequency designated $n(f_c \pm f_o)$. The frequency will, therefore, heterodyne with the incoming carrier wave f_s to produce the frequency f_{it} to which the I. F. amplifier 82 is tuned. Remembering now that the switch blades are moved to the right, the local oscillator energy fed through transformer 57 is conducted through switch blade 59 to the receiver converter unit 81

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where it is combined with the incoming modulated carrier wave from the antenna 76 now connected through switch blade 75 to its R contact. This contact is directly connected to the input side of the R. F. amplifier 74. The output from unit 74 is now connected through switch blade 80 to the receiver converter 81. Accordingly, the incoming signals are amplified, heterodyned with the local oscillations and fed through the I. F. amplifier 82 to a detector and audio amplifier 83. This last mentioned unit supplies output energy to a loud-speaker 84 or other translating device.

In order to increase the frequency range of the wave generating equipment without appreciable sacrifice in its stability it is, of course, to be understood that I may provide facilities for convenient interchange of crystals in the place of crystal 17.

If four crystals are taken and cut to oscillate at the following frequencies

2000 kc., 2300 kc., 2600 kc., and 2900 kc.

it will then be seen that they cover four frequencies from 2000 to 2900 kc. If each of these crystals one at a time is heterodyned with a variable frequency oscillator of say 600 to 900 kc., then it is possible to utilize the side bands of the two beating oscillators. Let us assume that the upper side bands are utilized for purposes of this discussion. A variable range of frequencies is then available with an increment of 300 kc. for the selection of each crystal. The new band of frequencies now available is:

2000 kc. crystal	2300 kc. crystal
2600 to 2900 kc.	2900 to 3200 kc.
2600 kc. crystal	2900 kc. crystal
3200 to 3500 kc.	3500 to 3800 kc.

Hence a band of frequencies that are continuously variable are now available in the range of 2600 to 3800 kc. The total increment is $3800 - 2600 = 1200$ and that is equal to 4×300 when 300 kc. is the increment of the variable frequency oscillator.

For each combination of one crystal and the variable frequency oscillator $f_i = (f_c \pm f_o)$.

Now if the side band obtained by heterodyning is multiplied by a frequency multiplier then a new band of frequencies is available with a given set of crystals. This new band of frequencies will be related to the original by a multiplying factor (n) which may be 1, 2, 3, 4, etc. If the original band has a continuous range, then all other bands multiplied by the factor (n) will be continuous. Therefore, it is possible to select a number of crystals and a variable frequency oscillator and generate a continuous range of frequencies. It is merely required that the frequency increment covered by the variable frequency oscillator be equal to the difference frequency between crystals. Hence a general expression for the frequency may be written,

$$f = n(f_c \pm f_o) \quad (1)$$

where,

f is the generated frequency

f_c is the crystal frequency

f_o is the frequency of the variable oscillator

n is the multiplying factor 1, 2, 3, etc.

In Equation 1 ($\pm$) sign is used to include both side bands, the upper and lower.

If f_o , the frequency of the variable frequency oscillator is made a small percentage of f_c , the crystal frequency, then the frequency stability of f approaches the stability of the crystal.

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The selection of a desired multiple frequency to be used in the frequency multiplier unit is readily made by use of gang control of certain tuning condensers. These condensers 39 and 51 and a tuning condenser (not shown) within the R. F. amplifier unit 74 may all be ganged together. Condensers 41 and 52 are used as tracking condensers.

Various modifications of my invention may, of course, be made without departing from the spirit and scope as will be understood by those skilled in the art. For example, in place of a frequency multiplier operating on one of the side bands produced in modulator 22, I may, if desired, employ a regenerative frequency multiplier unit having balanced discharge devices, the controlled grids of which would be conventionally connected to the secondary terminal of an output transformer while the anode of the two discharge devices would be connected in parallel to the output circuit. Other modifications will, of course, suggest themselves to those skilled in the art.

What is claimed is:

1. In a two-way radio system, a wave generator having three primary sources of oscillations for producing respectively the frequencies f_c , f_o and f_i , piezo-electric devices respectively in circuit with the sources f_c and f_i for stabilizing their frequencies, means for varying the frequency f_o within a limited range, a converter for combining the outputs from sources f_c and f_o thereby to obtain the frequency $f_c \pm f_o$, means for deriving therefrom a multiple frequency $n(f_c \pm f_o)$, a radio frequency amplifier tuned to a frequency f_s which is equal to the sum or difference frequency defined by the formula $f_s = n(f_c \pm f_o) \pm f_i$, a transmitter including means for modulating a wave of frequency f_s derived from the mixture of wave energy from the three said sources, the output side of said amplifier being connectable to cascaded amplifier and mixer stages in said transmitter, a receiver including means responsive to an incoming modulated wave fed through said amplifier for heterodyning the same with energy of the frequency $n(f_c \pm f_o)$ which is obtained as output from said multiple frequency deriving means, and switching means for utilizing said transmitter and receiver alternatively.

2. The combination according to claim 1 in which said switching means is constituted as a four-pole-double-throw switch.

3. A signaling system comprising an antenna, a transmitter, a receiver having an intermediate frequency amplifier therein, a radio frequency amplifier common to the transmitter and the receiver, switching means providing circuit connections from said antenna through said amplifier to the receiver for producing a response to incoming signals, said switching means also providing circuit connections for operation of said transmitter and for feeding modulated signal energy therefrom to said antenna, three local oscillators of which two are crystal-controlled and the third is tunable over a predetermined frequency band, means for deriving a carrier wave by the mixing and filtering of energies derived from the three said oscillators for use in said transmitter, and means for mixing the wave output from the tunable oscillator and one of the crystal oscillators and for heterodyning a derivative therefrom with incoming signal energy to obtain an intermediate frequency acceptable to said intermediate frequency amplifier in said receiver.

4. In a system adapted to transmit and to re-

ceive signals on the same carrier wave f_s , means for generating two waves of frequencies f_c and f_o , respectively, means for deriving from the outputs of said generating means a multiple frequency $n(f_c \pm f_o)$, an oscillator converter stage into which energy of the frequency $n(f_c \pm f_o)$ is injected from said means for deriving that frequency, the output from said stage being of a frequency f_i , which satisfies the formula $f_i = f_s \pm n(f_c \pm f_o)$, an amplifier tuned to the frequency f_s , a transmitting circuit arrangement including means for modulating and further amplifying the output from said amplifier of the frequency f_s , and a receiving circuit arrangement including a converter, an I. F. amplifier tuned to the frequency f_i , a detector-audio-amplifier and translating device, said receiver being arranged to mix the locally derived wave of frequency $n(f_c \pm f_o)$ with an incoming modulated wave of frequency f_s to derive the frequency f_i .

5. The method of generating, frequency multiplying and mixing electrical waves of several different frequencies for use both in the transmission and in the reception of radio signals, said method comprising generating and mixing two waves to derive a wave of the frequency $f_c \pm f_o$, where f_c and f_o represent the outputs from a frequency-stabilized oscillation generator and a variable frequency generator respectively, multiplying the derived wave by a factor n to obtain a wave of frequency $n(f_c \pm f_o)$, generating a wave of frequency f_i and mixing the same with said wave of multiplied frequency to obtain a wave of frequency f_s which equals $n(f_c \pm f_o) \pm f_i$, transmitting signals which are characterized as modulated signal energy having a carrier component of the frequency f_s , and receiving modulated signal energy so characterized when that energy is heterodyned with a wave of frequency $n(f_c \pm f_o)$ to produce an intermediate frequency wave f_i .

6. The method according to claim 5 in combination with processes of filtering out unwanted harmonic components of the waves of frequencies f_c and f_o , thereby to purify the utilized carrier wave component f_s , and the wave of frequency $n(f_c \pm f_o)$ when used for heterodyne reception.

7. The method of generating, frequency multiplying and mixing electrical waves of several different frequencies for use both in the transmission and in the reception of radio signals, said method comprising generating and mixing two waves of frequencies f_c and f_o respectively to derive a beat frequency wave of the frequency $f_c \pm f_o$, multiplying the derived beat wave, generating a wave of frequency f_i and mixing the same with said wave of multiplied frequency to obtain a wave of frequency f_s , transmitting signals which are characterized as modulated signal energy having a carrier component of the frequency f_s , and receiving modulated signal energy so characterized that when said signal energy is heterodyned with said multiplied wave an intermediate frequency wave f_i is produced.

8. The method of generating, frequency multiplying and mixing electrical waves of several different frequencies for use both in the transmission and in the reception of radio signals, said method comprising generating and mixing two waves to derive a beat frequency wave, multiplying the derived beat frequency wave, generating a fourth wave and mixing the same with said wave of multiplied frequency to obtain a fifth wave, transmitting signals which are characterized as modulated signal energy having a carrier component of the frequency of said fifth wave and receiving modulated signal energy so characterized that when signal energy is heterodyned with a wave of the frequency of said multiplied wave an intermediate frequency wave of a frequency equal to said fourth wave is produced.

RALPH A. VARONE.

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