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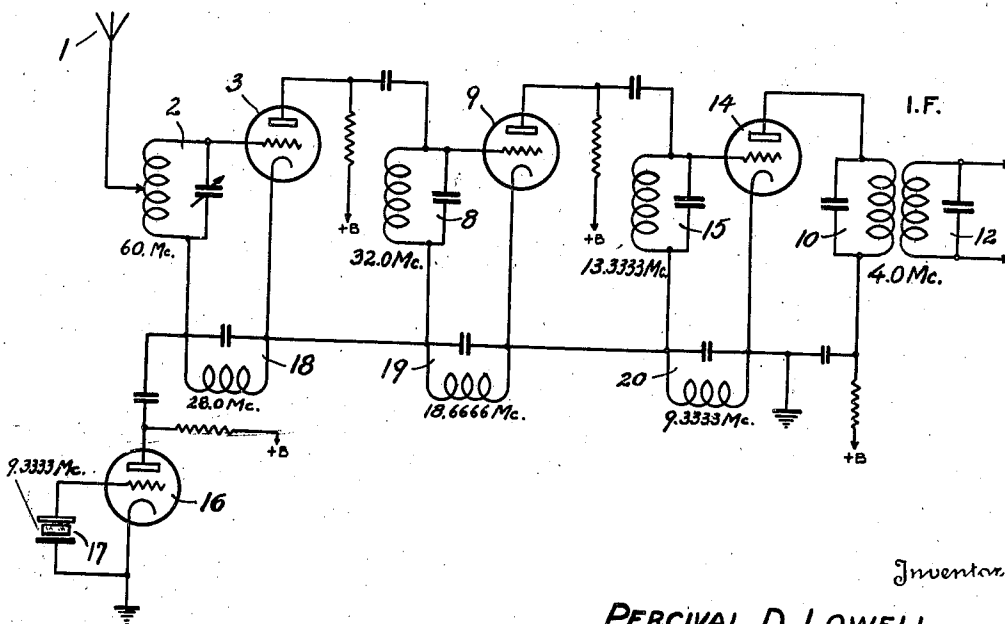
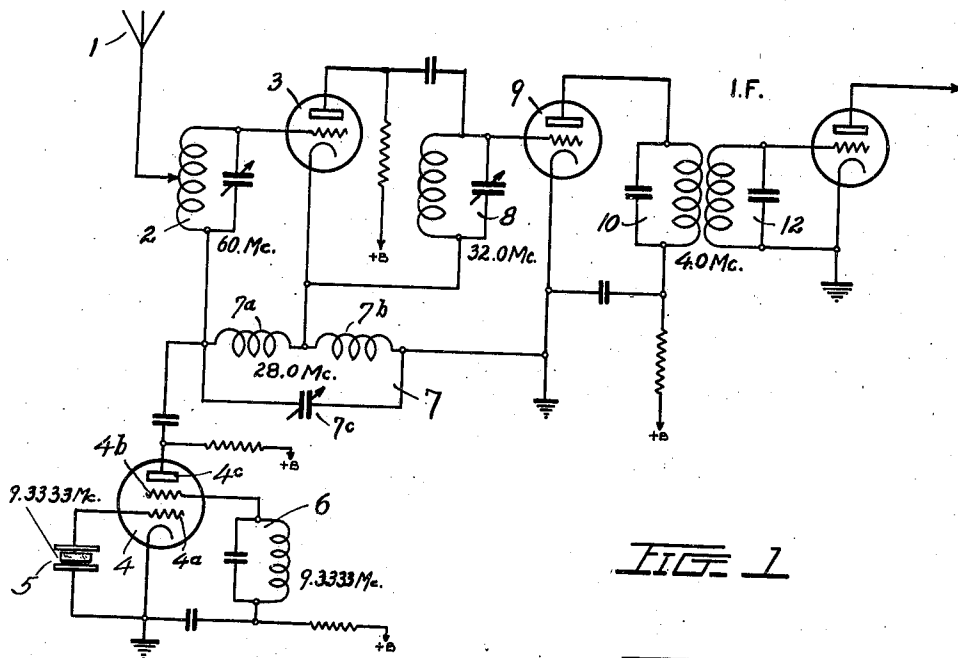
P. D. LOWELL

2,186,980

SUPERHETERODYNE SIGNAL RECEIVING SYSTEM

Filed Sept. 24, 1937

2 Sheets-Sheet 1



PERCIVAL D. LOWELL,

By

John B. Brady
Attorney

Attorney

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2 Sheets-Sheet 2

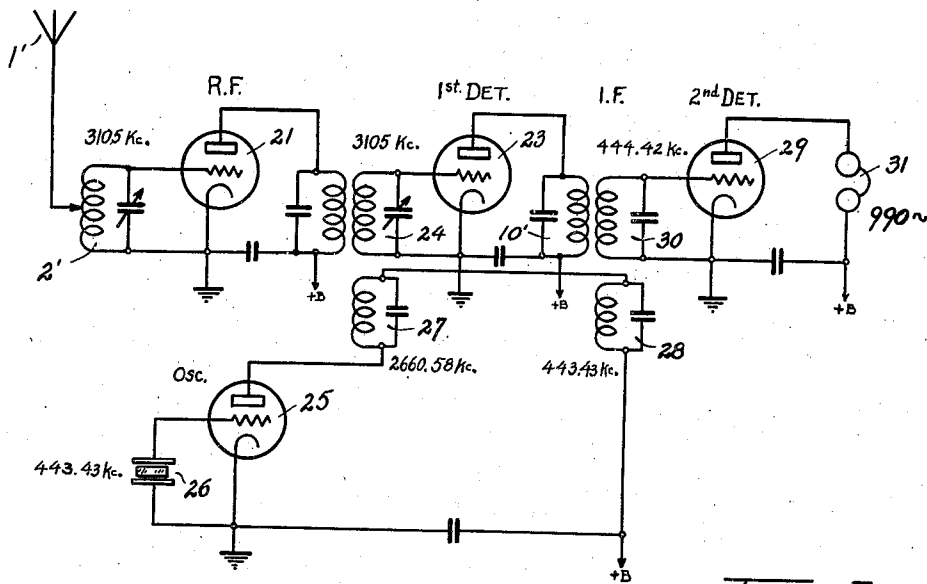


FIG. 3

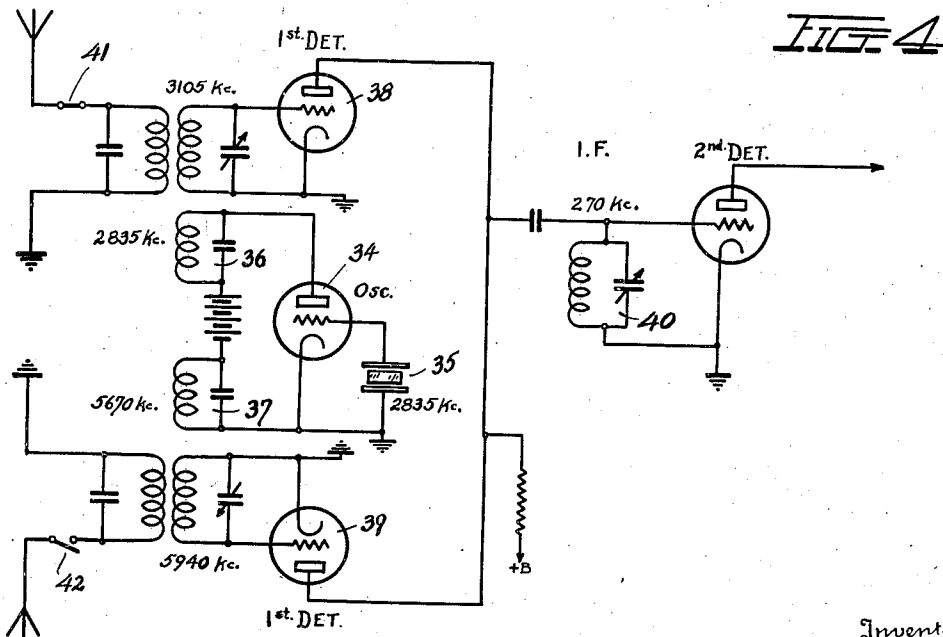


FIG. 4

Inventor.

PERCIVAL D. LOWELL,

By

John B. Brady
Attorney

UNITED STATES PATENT OFFICE

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SUPERHETERODYNE SIGNAL RECEIVING
SYSTEM

Percival D. Lowell, Chevy Chase, Md.

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7 Claims. (Cl. 250—20)

My invention relates broadly to radio receiving circuits and more particularly to the superheterodyne type of receiver and arrangements for employing a piezo-electric crystal element for controlling the frequency converting oscillator.

The principal object of my invention is to provide means for using a combination of fundamental and harmonic frequencies, or a combination of harmonics, derived from the converting oscillator to produce the desired signal reproduction.

Another object of my invention is to provide an arrangement of double frequency conversion employing conversion oscillations derived from a single piezo-electric crystal controlled oscillator.

A further object of my invention is to provide an arrangement for successive frequency conversions resulting in the desired intermediate frequency, each conversion oscillator being derived as the fundamental or a harmonic of a piezo-electric crystal controlled oscillator.

Still another object of my invention is to provide a superheterodyne circuit arrangement for receiving continuous wave transmissions, employing converting and beat oscillations derived from a single piezo-electric crystal controlled oscillator.

A still further object of my invention is to provide means for receiving any of a plurality of signal oscillations of different frequencies, employing as converting oscillations the fundamental and harmonics derived from a single piezo-electric crystal controlled oscillator.

Still another object of my invention is to provide arrangements for employing the fundamental and harmonic oscillations derived from a single oscillator to produce desired results of frequency conversion or the like in a plurality of portions of a radio receiving system without interference between the several portions of the system.

Other and further objects of my invention reside in the circuit arrangements, hereinafter more fully described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of one arrangement for dual conversion of the signal oscillation, employing a single piezo-electric crystal controlled oscillator; Fig. 2 is a modified form of the circuit of Fig. 1; Fig. 3 is a schematic diagram illustrating a piezo-electric crystal controlled oscillator employed in the reception of continuous wave signals; and Fig. 4 is a schematic diagram showing the further arrangement of a piezo-electric crystal controlled oscillator for the reception

of either or both of two signals of different frequencies.

The superheterodyne type of radio receiver is highly selective in differentiating radio signals of closely related frequencies, due principally to the intermediate frequency scheme of amplification, which permits the use of most efficient amplifier designs for the particular intermediate frequency selected. Proper and most effective use of this type of receiver depends, therefore upon the stability of the intermediate frequency wave which is produced as the beat of the incoming signal and a local oscillation. For frequencies of a few megacycles, sufficiently stable converting oscillators may be built so that the frequency thereof may be varied over a range equal to the tuning range of the receiver, and intermediate frequency waves of satisfactory stability be correspondingly produced.

In higher frequency ranges however, in order to maintain high selectivity in the intermediate frequency amplifier, it is imperative that the frequency of the conversion oscillator be controlled within extremely narrow limits. For this reason, variable frequency conversion oscillators for ultra-high frequency receiving circuits are not feasible, and piezo-electric crystal controlled oscillators for the individual signal frequencies received have been suggested. One of the principal difficulties which exist is the problem of constructing piezo-electric crystal controlled oscillators capable of converting the ultra-high signal frequencies to the relatively low frequencies of intermediate frequency amplifiers. By the system of my invention this difficulty is overcome in a practical manner, and numerous variations besides those disclosed are contemplated within the scope of my invention.

Referring to the drawings in more detail, Fig. 1 illustrates the antenna at 1 feeding signal energy to the tuned circuit 2 connected with the grid of a first conversion stage 3. The local heterodyning oscillator comprises the pentode tube shown at 4, having piezo-electric crystal 5 connected with the control grid 4a, and the screen grid 4b serving as an anode and connected with resonant circuit 6. The output circuit connects with the anode 4c and includes resonant circuit 7 which comprises individual inductances 7a and 7b jointly tuned by combination with a condenser 7c. The inductance 7a is included with tuned circuit 2 in the input of the first conversion stage 3, and the output circuit 8 thereof is tuned to the conversion frequency resulting from beating of oscillations at the signal frequency and

the frequency of the resonant circuit 7. The inductance 7b is connected in series with the tuned circuit 8 in the input of a second conversion stage 9, and the output circuit 10 thereof is tuned to the conversion frequency resulting from beating of the signal having the frequency of tuned circuit 8 and an oscillation of the frequency of resonant circuit 7. An intermediate frequency amplifier is coupled to the output circuit 10 by suitable means as at 12, and leads to the remainder of a conventional superheterodyne receiving system including the second detector and audio frequency amplifying means connected to a reproducer. Suitable operating potentials are supplied to the various electrodes in conventional manner, and it will be understood that the circuits of Fig. 1, and all the figures are intended to be schematic and illustrative only of the system arrangements of my invention.

Fig. 1 shows a double frequency conversion superheterodyne receiver where the incoming signal is first converted to a lower frequency by beating with one harmonic of the oscillator and then converted to a still lower frequency, the intermediate frequency by beating again with the same harmonic. In the case of Fig. 1, as an example, take the received signal to be at 60 megacycles. In this ultra-high frequency region it is practically impossible to grind a crystal for a frequency which would beat directly with 60 megacycles to produce an intermediate frequency of 4.0 megacycles, approximately the frequency commonly used under these conditions. In Fig. 1, I have indicated a crystal for operation at 9.3333 megacycles, connected in the control grid circuit of the oscillator tube 4, the screen grid therein being tuned to the crystal frequency at resonant circuit 5, thus forming a normal triode crystal oscillator circuit. In the plate output circuit, the resonant circuit 7 constitutes a split harmonic trap circuit tuned to the third harmonic of the crystal or 28.0 megacycles. Section 7a of this trap circuit couples into the grid return of the first conversion stage 3 and the 28.0 megacycle harmonic beats with the incoming signal at 60 megacycles and produces a resultant frequency of 32.0 megacycles which appears in the tuned circuit 8. This tuned circuit is connected also with the grid of the second conversion stage 9 and its return leads through the second section 7b of the 28.0 megacycle harmonic trap circuit, so that the 32.0 megacycle signal and the 28.0 megacycle harmonic beat to produce the intermediate frequency wave of 4.0 megacycles to which the second output plate circuit 10 is tuned. From this point on, the circuits are the same as used in common practice.

The circuits of Fig. 2 likewise include the antenna 1, tuned circuit 2 and first conversion stage 3 having output circuit 8 connected also in the input of a second conversion stage 9. Fig. 2 further shows a third conversion stage 14, coupled with the preceding stage 9 by means of tuned circuit 15. The final tuned output circuit 10 is connected with the conversion stage 14. Fig. 2 differs from Fig. 1 principally in the conversion oscillator, shown in Fig. 2 as a triode 16, having a piezo-electric crystal 17 in the grid circuit, and a series of independently tuned circuits in the anode circuit thereof. Tuned circuit 18 is connected in series with circuit 2 in the input of the first conversion stage 3; and tuned circuits 19 and 20 likewise respectively connected in series with circuits 8 and 15 in the inputs of the second and third conversion stages 9 and 14.

In considering Fig. 2, take for example, the signal frequency to be 60 megacycles and the intermediate frequency to be 4.0 megacycles, as in Fig. 1. The 60 megacycle signal is first beat with a 28.0 megacycle wave which is the third harmonic of a crystal frequency of 9.3333 megacycles, this harmonic being selected by properly tuning the circuit 13 which is part of the grid return of the first conversion stage 3. The plate circuit 8 of the first conversion stage is tuned to 32.0 megacycles, which is the resultant frequency. This resultant frequency is then beat with an 18.6666 megacycle wave, the second harmonic of the crystal frequency, selected in tuned circuit 19, to produce a resultant of 13.3333 megacycles in the tuned output circuit 15 of the second conversion stage. Similarly, this last frequency is beat in the third conversion stage 14 with the fundamental crystal frequency selected in the third tuned circuit 20, and the final resultant or intermediate frequency of 4.0 megacycles appears in the tuned output circuit 10. From there on the circuit is conventional, as in Fig. 1.

Fig. 3 shows a modified arrangement of the system of my invention employed when a superheterodyne receiver is desired for receiving continuous wave signals with crystal control on both the frequency converting oscillator and the beat frequency oscillator. One crystal is used for both purposes. In this arrangement, an antenna 1' and tuned circuit 2' feed into a radio frequency amplifying stage 21 which is coupled with the conversion stage 23 through means including a resonant circuit 24 which is electromagnetically coupled with the output of the conversion oscillator. The conversion oscillator is shown as a triode 25 having piezo-electric crystal 26 connected in the grid circuit thereof and a pair of tuned circuits 27, 28, connected in series in the plate output circuit. Tuned circuit 27 is coupled with the resonant circuit 24, and supplies oscillations of the proper converting frequency for producing the correct intermediate frequency wave which appears in the output circuit 10'.

Detection of the continuous waves is effected in the detector stage 29, in the grid circuit of which is resonant circuit 30 coupled with the output circuit 10' of the conversion stage 23, and with tuned circuit 28 of the crystal controlled oscillator which supplies oscillations of proper frequency for beating with the signal waves in the detector 29 to produce an audible signal in telephones 31 connected in the output of the detector.

In considering Fig. 3, assume that the signal frequency is 3105 kilocycles and that a beat frequency of about one kilocycle is desired. The crystal then should be ground for 443.43 kilocycles and the triode to which it is connected has a tuned circuit 28 resonant with the fundamental frequency of the crystal and the tuned circuit 27 resonant at the sixth harmonic, which at 2660.58 kilocycles, beats with the signal frequency of 3105 kilocycles in the conversion stage 23 to produce an intermediate frequency of 444.42 kilocycles. This intermediate frequency wave is then amplified, and detected in a normal way, which in continuous wave transmission requires a local beating oscillation. To produce this oscillation, some of the power from the circuit 28, tuned to the fundamental crystal frequency, is fed into the detector circuit 29 and a 990 cycle audible beat frequency is produced.

In each of the circuits shown in Figs. 1-3, the frequency of the crystal can be readily determined as the quotient of the signal frequency minus the resultant frequency desired, divided by the total of the harmonics of the crystal frequency to be employed. When the fundamental is also used it is added to the sum of the harmonic numbers as plus 1. That is to say, should the third and second harmonics and the fundamental be employed the sum would be considered $3+2+1=6$. By the total or sum of the harmonics I do not mean merely the aggregate quantity thereof, that is, two harmonics and the fundamental in the foregoing example. In Fig. 1 the resultant frequency is 4.0 megacycles, and the total of the harmonics used in this case is 6. In Fig. 2 the total of the harmonics used is 5. The fundamental is also used, making a total of 6 to be the denominator. In Fig. 3 the resultant frequency is taken as one kilocycle, and the total of the harmonics plus the fundamental 7; because of decimal fractions in the calculations, however, the resultant appears from the formula as .99 kilocycles. The relation may be expressed in the equation form as:

$$f_x = \frac{f_s - f_r}{h}$$

using f_x to designate the crystal frequency, f_s the signal frequency, f_r the resultant frequency and h the total of the harmonics employed in conversion plus 1 if the fundamental frequency is also used.

It will be noted that the circuit of Fig. 3 is structurally similar to that of Fig. 2 in the series arrangement of differently tuned circuits in the oscillator plate circuit, and the coaction of these circuits with separate stages in the signal circuits of the receiver in similar frequency modification functions. The systems of Figs. 2 and 3 differ in results, however, because of the different type of signal energy prescribed in regard to Fig. 3, and the relative proportionment of frequency values.

In Fig. 4, I have illustrated a further modification, in the use of the crystal controlled circuits of my invention in superheterodyne receivers for reception through more than one signal channel. Dual antenna and conversion systems are illustrated with a single crystal controlled oscillator arranged to supply the proper frequency for conversion to each system. The oscillator comprises a triode 34 having piezo-electric crystal 35 connected in the grid circuit and tuned circuits 36 and 37 in the plate output circuit. Tuned circuit 36 is coupled with the conversion stage 38 in the one signal channel, and tuned circuit 37 with the conversion stage 39 in the other signal channel. The outputs of the two signal channels are fed through a common circuit 40, resonant at the selected intermediate frequency to the remainder of the usual superheterodyne circuit, similarly as in Fig. 1.

In Fig. 4, the two antenna and conversion circuits are shown by way of example to receive signals at 3105 kilocycles at conversion stage 38, and 5940 kilocycles at conversion stage 39. The one crystal oscillator is provided with a 2835 kilocycle crystal, and in the output, circuit 36 is tuned to the fundamental frequency and circuit 37 to the second harmonic at 5670 kilocycles. The outputs of the two conversion circuits are connected in parallel to the intermediate frequency circuit tuned to 270 kilocycles, which is the resultant frequency from both conversions. As will

be seen from Fig. 4, the fundamental crystal frequency will beat with the 3105 kilocycle signal and produce a 270 kilocycle wave; and likewise the 5670 kilocycle second harmonic of the crystal frequency will beat with the 5940 kilocycle signal to produce a 270 kilocycle wave. To avoid interference in the intermediate frequency amplifier when signals at both frequencies are received at the same time, a switching arrangement may be provided as at 41, 42, to make inoperative one or the other of the receiving channels as desired.

For more widely separated signal frequencies, different values of crystal frequency and different harmonics may be employed. A formula may be derived for determining the frequency of the crystal from the following basic relations, using f_x to designate the crystal frequency, f_1 and f_2 the signal frequencies, h_1 and h_2 the corresponding harmonics of conversion, and f_r the resultant intermediate frequency, which is a constant:

$$f_x = \frac{f_1 - f_r}{h_1} \quad (1)$$

$$f_x = \frac{f_2 - f_r}{h_2} \quad (2)$$

$$f_x = \frac{f_1 - f_2}{h_1 - h_2} \quad (3)$$

By equating (1) and (2):

$$(f_1 - f_r) h_2 = (f_2 - f_r) h_1 \quad (4)$$

from which a nominal relation of h_1 and h_2 can be obtained by substituting appropriate desired values for f_1 , f_2 and f_r . With the relation thus established, suitable harmonics may be selected and the frequency of the crystal then determined from Equation 3. Using the values shown in Fig. 4 for f_1 , f_2 and f_r , the Equation 4 reads:

$$5670 h_2 = 2835 h_1;$$

or, upon reducing $2 h_2 = h_1$. The simplest values, therefore, are $h_1 = 2$ and $h_2 = 1$, and inserting these in Equation 3 f_x is determined as

$$\frac{2835}{2-1} = 2835 \text{ kilocycles}$$

Values of $h_1 = 4$ and $h_2 = 2$ would correspondingly require a crystal frequency of 1417.5 kilocycles.

My invention as hereinbefore set forth will thus be seen to extend the adaptability of stabilized oscillations without decrease in the degree of precision obtainable in frequency conversions where a directly stabilized fundamental oscillation is a component. The same stabilized oscillator circuit may therefore be employed to supply converting and beating oscillations, as indicated in Fig. 3, or the converting oscillations for a plurality of signals of different frequencies, as indicated in Fig. 4, as well as oscillations adapted to convert ultra-high frequency signals to intermediate frequency level, as indicated in Figs. 1 and 2.

I have indicated my invention schematically for the sake of clearness, and the modifications illustrated are intended merely as examples of the applicability of crystal controlled oscillator circuits in accordance with my invention. Thus while I have described my invention in certain preferred embodiments, I do not intend to be limited thereto.

For example, I may provide a relationship of circuits in which

$$f_x = \frac{f_1 + f_2}{2}$$

where f_x is the crystal frequency, and f_1 and f_2 are signal frequencies. The same crystal is used for reception of both signal frequencies and only the fundamental frequency thereof is employed and harmonics of the crystal frequency are not employed.

Wherever, in the claims I refer to a piezo-electric crystal controlled oscillator, I intend this term to include all electro-mechanical vibrators such as magnetostriction oscillators and other constant frequency devices and currents.

I desire that it be understood that other modifications may be made in my invention within the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In an ultra-high frequency superheterodyne radio receiver, in combination, an intermediate frequency amplifier stage of fixed frequency characteristics, and a conversion oscillator circuit including piezo-electric crystal frequency control means, a plurality of output circuits, and means for independently tuning each of said output circuits for establishing different selected harmonic frequencies of oscillation relative to the natural frequency of vibration of the crystal, the natural frequency of vibration of the crystal and the harmonics thereof derived being selected with reference to the radio frequency of the received signal and the fixed frequency of operation of said intermediate frequency amplifier stage in said superheterodyne radio receiver for effecting conversion of the frequency of the received signal to the frequency of intermediate amplification in steps.

2. In an ultra-high frequency superheterodyne radio receiver, in combination, an intermediate frequency amplifier stage of fixed frequency characteristics, converter means, a conversion oscillator including a piezo-electric crystal and a resonant circuit tuned to the natural frequency of vibration of said crystal, an independently tuned output circuit including a split inductance component connected with said oscillator and said converter means and resonant at a selected harmonic of said crystal frequency, oscillations derived across a portion of said inductance being adapted to convert an ultra-high radio frequency in a signal to a middle frequency, and oscillations derived across the remaining portion of said inductance being adapted to convert said middle frequency to the fixed frequency of operation of said intermediate frequency amplifier stage in said superheterodyne radio receiver.

3. In an ultra-high frequency superheterodyne radio receiver, in combination, an intermediate frequency amplifier stage of fixed frequency characteristics, and a conversion oscillator circuit including piezo-electric crystal frequency control means, a plurality of output circuits, and means for independently tuning each of said output circuits for establishing different selected harmonic frequencies of oscillation relative to the natural frequency of vibration of the crystal, oscillations derived from said tuned circuits being adaptable to convert received signal oscillations of ultra-high frequency to oscillations of the fixed frequency of operation of said intermediate frequency amplifier stage in said superheterodyne radio receiver in steps beginning with the highest harmonic frequency.

4. In a superheterodyne radio receiver for continuous wave reception, a piezo-electric crystal controlled oscillator, independently tuned means for deriving an oscillation therefrom at a selected upper harmonic of the natural frequency of vibration of the crystal, said oscillation being adapted to convert signal waves to the intermediate frequency of said superheterodyne radio receiver, and separate independently tuned means for deriving from said oscillator an oscillation at a selected lower harmonic, the last said oscillation being adapted to beat with signal waves of the intermediate frequency to produce audible notes.

5. In a superheterodyne radio receiver for continuous wave reception, a piezo-electric crystal controlled oscillator, individually tuned means for deriving oscillations from said oscillator at selected harmonic frequencies of the fundamental frequency of vibration of the crystal, and means for progressively converting the frequency of the received wave to a resultant audible frequency for signal detection, the fundamental frequency of vibration of the crystal f_x being determined by the relation:

$$f_x = \frac{f_s - f_r}{h}$$

where f_s is the frequency of the signal, f_r is the audible frequency of detection, and h is the total of the harmonics employed in the successive conversions when the fundamental frequency is considered as the first harmonic.

6. In an ultra-high frequency superheterodyne radio receiver, in combination, an intermediate frequency amplifier stage of fixed frequency characteristics, a piezo-electric crystal controlled oscillator, and individually tuned means for deriving a plurality of oscillations from said oscillator at selected harmonic frequencies adapted for successive conversion of the signal wave to produce a desired fixed intermediate frequency; the frequency of vibration of the crystal being determined as the quotient of the signal frequency minus the desired intermediate frequency, divided by the total of the harmonics embraced by the plurality of oscillations derived from said crystal controlled oscillator.

7. In a superheterodyne radio receiver for continuous wave reception, a piezo-electric crystal controlled oscillator, independently tuned means for deriving oscillations therefrom at selected harmonic frequencies of the fundamental frequency of vibration of the crystal, and means for employing the oscillations of the crystal for progressively converting the frequency of the received wave to a resultant audible frequency for signal detection, the fundamental frequency of vibration of the crystal f_x being determined by the relation

$$f_x = \frac{f_s - f_r}{h}$$

where f_s is the frequency of the signal, f_r is the audible frequency of detection, and h is the total of the harmonics employed in the successive conversions plus one when the fundamental is also used.

PERCIVAL D. LOWELL.