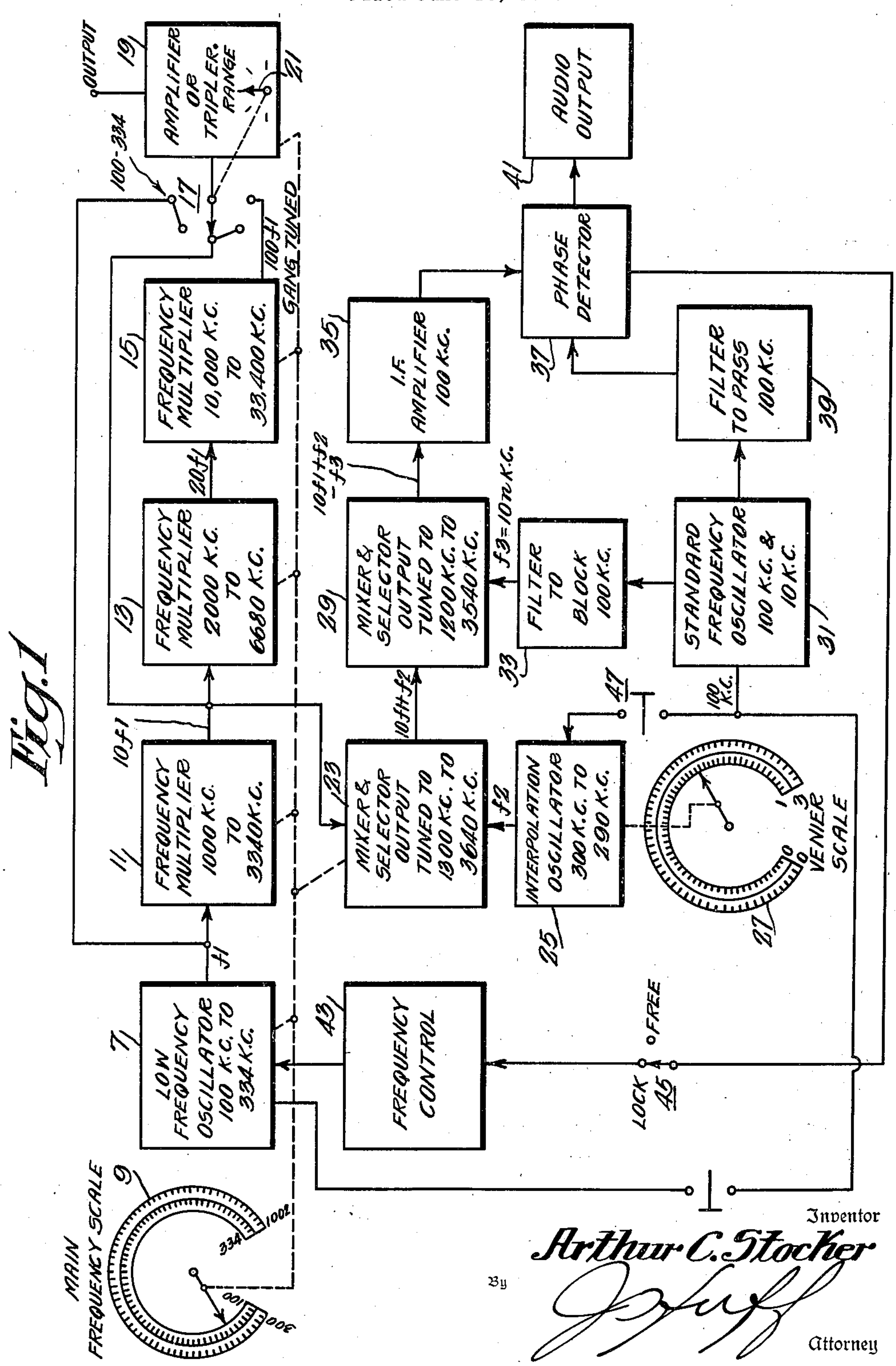
FREQUENCY GENERATOR

Filed June 16, 1939 2 Sheets-Sheet 1

Fig. 1



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July 8, 1941. A. C. STOCKER 2,248,442

FREQUENCY GENERATOR

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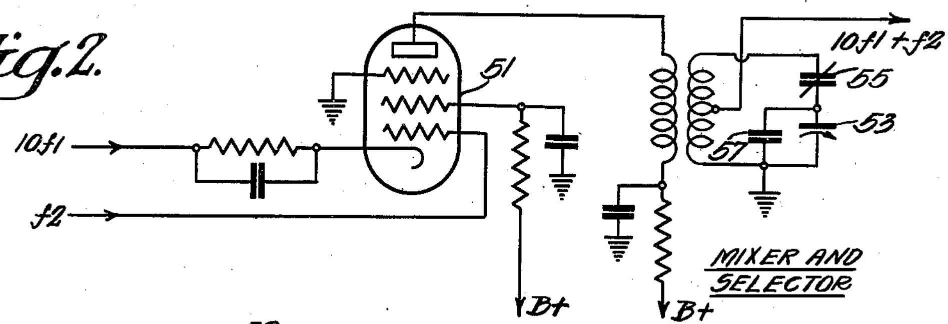
Fig. 2.



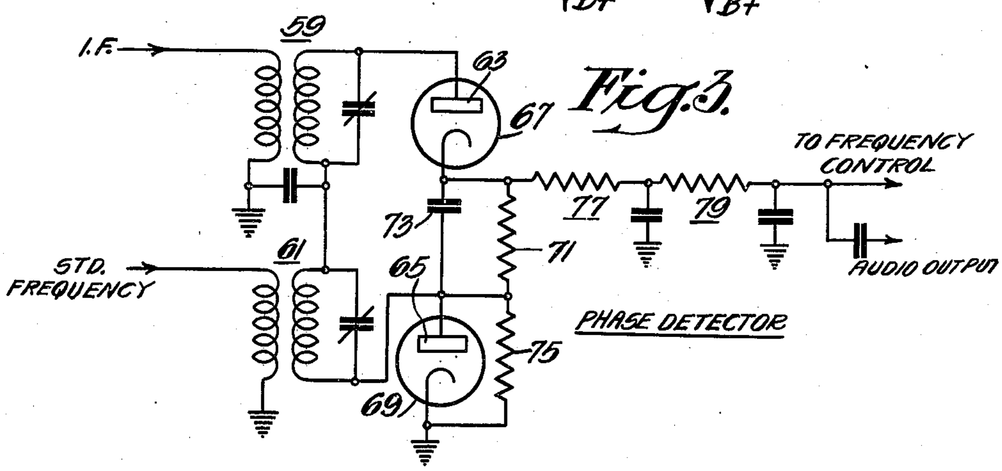


Fig. 4.

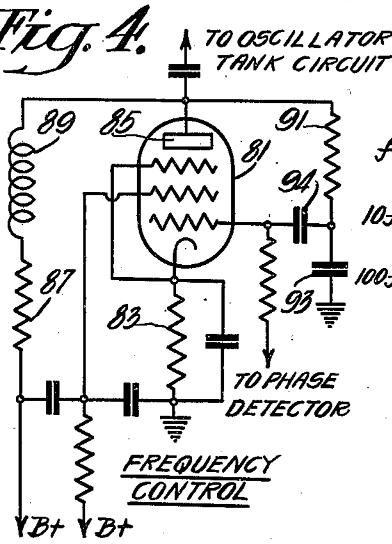
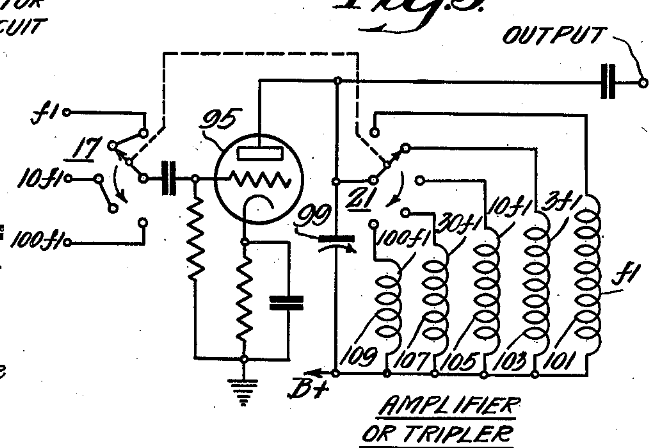


Fig. 5.



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UNITED STATES PATENT OFFICE

2,248,442

FREQUENCY GENERATOR

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Application June 16, 1939, Serial No. 279,544

13 Claims. (Cl. 250—36)

This invention relates to frequency generators, and more particularly to a generator for producing continuously variable oscillations throughout a wide range of frequencies, the actual frequency of the generator output being accurately determinable by a convenient indicator.

Generators for producing oscillations of continuously variable frequency are frequently used in the analysis of radio receivers, for the measurement of the frequency of unknown signals, and for many other purposes. In order to provide a wide frequency range, it is customary to operate the oscillator through increasingly high ranges by means of tapped or separate coils and a selector switch. The condenser which controls the oscillator frequency is usually calibrated in terms of the frequency corresponding to the various ranges. Such a system necessarily represents a compromise between the most stable operating condition in the extreme frequency ranges, and consequently the oscillator cannot be designed to have the best stability in any particular range. In addition, a separate calibration curve is usually required for each frequency range. The multiplicity of calibrations tends to become confusing if they are applied directly to the dial of the tuning condenser. It is likewise disadvantageous when the separate calibration curves are made up on charts to which reference must be made.

It is, therefore, an object of this invention to provide an improved frequency generator which is directly calibrated without confusion through a number of frequency ranges and with a minimum of calibration scales, one scale being used for frequencies in several harmonically related frequency bands.

It is a further object of this invention to provide a frequency generator for producing output currents of accurately determined frequency in a plurality of adjacent ranges, the actual frequency of which may readily be determined by reference to two calibrated dials. The combined reading of the two dials determines the digits expressing the output frequency, while the location of the decimal point is determined by the setting of a range switch.

Oscillators which are designed to cover a wide range of frequency necessarily involve the use of a capacitor of wide range. Consequently, the capacity present in the circuit at the high frequency end of the band must be kept at a minimum. This means that changes due to humidity, temperature, tube capacities and the like are sufficient to cause considerable frequency drift at the high frequency end of the range. It is apparent that if a wide range of frequency is to be covered, any attempt to decrease the range of each band to improve the stability is made at the expense of economy, for, as the range of each band is decreased, the number of separate bands must be increased. On the other hand, an oscillator which has a large amount of fixed capacity in its frequency-determining circuit has a limited frequency range, although by utilizing temperature-compensated elements a highly stable oscillator can be produced.

Devices of the prior art also commonly provide vernier tuning by means of a small variable capacitor which is connected in parallel with the main tuning capacitor. Under this system, if the vernier is calibrated in increments of frequency between the smallest increments indicated on the main dial, it is apparent that if the frequency calibration of the vernier is to have any meaning at all, the main dial must be set precisely at a predetermined frequency. For example, if the main dial covers a range, say, from 100 kc. to 350 kc. and is calibrated in 10 kc. steps, and the vernier dial covers a 10 kc. range and is calibrated in 0.5 kc. steps, then before the vernier can be used to indicate frequencies within the 10 kc. steps of the main dial, the main dial itself must be set to better than ± 0.5 kc. The accuracy of the vernier is therefore limited by the accuracy of the main dial, including errors in frequency drift and the operator's ability to set the capacitor dial accurately.

It is, therefore, an object of this invention to combine the desirable features of a wide range oscillator with the stability of a small range oscillator by utilizing separate oscillators, one of each kind, by applying the principles of automatic frequency control to prevent unwanted changes in the frequency of the wide band oscillator, and by a unique circuit arrangement to operate the stable small range oscillator as a vernier on the main oscillator without the disadvantages pointed out above.

This invention will be better understood from the following description when considered in connection with the accompanying drawings. Its scope is indicated by the appended claims.

Referring to the drawings, Figure 1 is a diagrammatic illustration of a device made in accordance with this invention; Figure 2 is a schematic diagram of a mixer and selector; Figure 3 is a schematic diagram of a phase detector; Figure 4 is a schematic diagram of a phase control circuit; and Figure 5 is a schematic diagram of an amplifier or tripler.

The general arrangement of a preferred embodiment of my invention is illustrated in Fig. 1, to which reference is now made. A low frequency oscillator **7** is provided with a calibrated dial **9** which contains two scales, 100 kc.–334 kc. and 300 kc.–1002 kc., for example, the latter being the third harmonic of the former. The harmonic scale is provided merely for convenience to avoid having to multiply the fundamental scale by 3. The oscillator is a wide range oscillator, but need only cover a single frequency range starting at the lowest desired output frequency, assumed to be 100 kc. in the present instance. This oscillator need not be particularly stable since any tendency to drift will be compensated in a manner which will be described hereinafter.

The output of oscillator **7** is connected to a series of frequency multipliers **11**, **13**, **15**, which are connected in cascade. The frequency multiplier may be a tuned amplifier resonant at the desired harmonic of the fundamental frequency. A frequency multiplication of 10 times is produced by multiplier **11**. This may be accomplished, for example, by successively multiplying two and five times. If the output of the fundamental oscillator **7** is called $f1$, then the output from the first multiplier **11** will be 10 $f1$, and it, therefore, covers a range from 1000 kc. to 3340 kc. To illustrate how a multiplication of 10 times is achieved, the second and third multipliers **13** and **15** are illustrated as being respectively designed to multiply two and five times, so that the output from third multiplier **15** is 100 $f1$ and covers a range from 10,000 kc. to 33,400 kc. For convenience, the oscillator **7** and the multipliers are simultaneously tuned so that single dial control is achieved.

A five-point switch **17** is provided so that the output from oscillator **7**, multiplier **11**, or multiplier **15** may be selected at will, the first two named output connections each being made to two contact points. The switch, in turn, feeds the current into an amplifier or tripler **19**, which is provided with a range switch **21**, operable in conjunction with switch **17**, by means of which the circuit constants are selected so that the amplifier resonates throughout the fundamental frequency range $f1$, or 3, 10, 30, or 100 times fundamental. A suitable amplifier or tripler of this type is illustrated in detail in Fig. 5. The selector or range switch provides, for example, five ranges as follows: 100 kc. to 334 kc., 300 kc. to 1,002 kc., 1,000 kc. to 3,340 kc., 3,000 kc. to 10,020 kc., and 10,000 kc. to 33,400 kc. The term "amplifier or tripler" is used because the circuit constants for the various ranges are so chosen that the fundamental frequency is selected and amplified on the first, third and fifth positions of the range switch, while the third harmonic is selected and amplified on the second and fourth positions.

One important advantage of the frequency multiplication system shown lies in the fact that substantially pure sine wave output currents are delivered by the generator due to the resonant amplification at the output frequency, since a resonant circuit tends to reduce harmonics and spurious frequencies. Systems which obtain output currents by the selection of harmonics by the receiver under test, for example, do not have the advantage of the present invention.

The output 10 $f1$ of the first frequency multiplier **11** is also applied to the input of a tuned mixer and selector **23**, illustrated in detail in Fig. 2, in which it is combined with the output $f2$ of an interpolation oscillator **25**, which is a stable, small range oscillator. The frequency range of the interpolation oscillator preferably covers only a range sufficient to vary the master oscillator between the smallest frequency steps into which the main frequency scale **9** is divided. In the present instance, the interpolation oscillator covers a 10 kc. range, from 300 kc. to 290 kc., for example, and the dial **27** has two scales which read from 0 to 1 kc. and from 0 to 3 kc., respectively, the scale to be used depending on whether or not the frequency is tripled by the output amplifier **19**.

The output of the mixer and selector **23** is gang-tuned from the common tuning dial **9** and covers a frequency range from 1300 kc. to 3640 kc., that is, the upper side band of the input frequencies 10 $f1$ and $f2$ is selected. The upper side band is then fed into a second mixer and selector **29**, and there combined with currents from a standard frequency oscillator and multivibrator **31**, which supplies output in 10 kc. steps to mixer **29**. A filter **33** is included to reduce the intensity of the fundamental 100 kc. signal.

Mixer **29**, therefore, combines upper side band currents 10 $f1+f2$ from the first mixer **23** and currents of frequency $f3$ which may be any desired harmonic of 10 kc. The circuit into which the standard frequency currents $f3$ are coupled is tuned to cover a frequency range displaced by some intermediate frequency from the range covered by the upper side band 10 $f1+f2$, 100 kc., for example. The resonant input circuit of mixer **29**, therefore, covers a range from 1200 kc. to 3540 kc. The output of mixer **29** is fed into an intermediate frequency amplifier **35**, which is tuned to the lower side band of the resultant produced by the second mixer **29**, 10 $f1+f2-f3$, or 100 kc. By this arrangement, the algebraic sum of the multipled master oscillator frequency, 10 $f1$, the interpolation oscillator frequency, $f2$, and some harmonic of the standard frequency, $f3$, may always be set equal to the intermediate frequency.

The output of the intermediate frequency amplifier and a signal of equal frequency from the standard frequency oscillator **31** are fed to a phase detector **37**, which is illustrated in detail in Fig. 3. A 100 kc. pass filter **39** is used to filter out the 10 kc. components of the standard frequency. The phase detector may be used to actuate an audio output device **41**, such as a pair of headphones, and also to produce a direct voltage, the value of which varies with a change in the input currents. The direct voltage is then applied to a frequency control device **43**, which, in turn, is connected to the low frequency master oscillator **7** so as to affect its frequency. A two-position switch **45** is included in the connection between the phase detector **37** and the frequency control device **43**.

The operation of the circuit will be explained by describing the steps to be taken to obtain an output current of a desired frequency, say 200.5 kc., for example: Range selector switch **21** is placed in the first position corresponding to the 100–334 kc. range. Switch **45** is placed in the "free" or open position so that the phase detector **37** is disconnected from the control device **43**. The frequency of the interpolation oscillator is set accurately to 300 kc., corresponding to "0" on the dial. The accuracy of this setting may be conveniently checked by coupling the standard frequency oscillator 31 to the interpolation oscillator and beating the interpolation oscillator against the third harmonic of the 100 kc. standard frequency oscillator. The beat note will be heard in the output device 41. A push button 47 is provided to make this connection. The frequency of the low frequency master oscillator 7 is then set at 200 kc. by means of the calibration on the 100–334 kc. scale of dial 9. This adjustment need only be accurate enough to make certain that the frequency is within 0.3 or 0.4 kc. This degree of accuracy is readily attained with an oscillator operating at a low frequency. However, the accuracy of the output frequency is not destroyed by the error arising in this adjustment, since the next step automatically adjusts the frequency of the master oscillator to exactly 200 kc., within the limits of accuracy of the standard frequency oscillator 31.

To accomplish the last described step, switch 45 is placed in the "lock" or closed position. As a result, the output of the phase detector 37 is applied to the frequency control device which operates on the master oscillator and changes its frequency until a balanced condition is reached, that is, until the phase of the intermediate frequency, with respect to the standard frequency, reaches some value which lies between 0° and 180°. Any tendency for the master oscillator to shift in frequency, and hence in phase, is thereafter immediately compensated by the frequency control device, in a manner which is quite common in the radio receiver art. It is to be noted that this locking in can occur every 1.0 kc. throughout the range of the low frequency oscillator 7, since an increase in the frequency of the low frequency oscillator produces 10 times the increase at the mixer 29. Thus, by placing switch 45 in the "free" position and changing the frequency of the master oscillator 1 kc., the frequency of the side band $10\,f1+f2$ increases 10 kc. and since this is combined with $f3$, which contains multiples of 10 kc., the 100 kc. intermediate frequency will be produced by a new harmonic of the standard. In actual operation, the dial of the master oscillator is caliberated in 1 kc. steps, and the oscillator is locked in at the calibration point next below the desired output frequency.

Having closed switch 45, and the master oscillator being locked in to a frequency which is exactly 200 kc., the interpolation oscillator dial is now set at 0.5 on the 0—1 scale. This decreases $f2$ by 5 kc., and since the intermediate frequency, $10\,f1+f2-f3$, must remain constant, and since $f3$ cannot change, $10\,f1$ must necessarily increase 5 kc., that is, $f1$ increases 0.5 kc., this change being accomplished by the phase detector 37 and frequency control 43.

Adding the readings of the two dials shows that the output frequency is 200.5 kc., as required. By setting the range selector switch 21 on the successively higher ranges, the output frequency becomes 601.5 kc., 2005 kc., 6015 kc., and 20,050 kc., respectively, but the frequency control operation just described is not affected. Other output frequencies are obtained in the same manner, using, using, for convenience, the appropriate scale which multiples the indicated frequency by three, and determining the decimal point from the position of the range switch. Of course, the switch 45 must be set in the "free" position before attempting to change the frequency of the low frequency oscillator.

Referring, now to Fig. 2, a typical mixer and selector is illustrated which is suitabale for use as element 23 of Fig. 1, for example. While multi-grid mixer tubes may be employed, a satisfactory mixer includes means for applying the two input currents, $10\,f1$ and $f2$, for example, to the cathode and control grid, respectively, of a triode or pentode 51. The anode output circuit is tuned to resonance, and includes a variable capacitor 53 which is mechanically coupled to the other variable capacitors in the system. Tracking and adjusting capacitors 55, 57 are also used so that the amplifier will cover the required range. In the case of the second mixer and selector 29, the input circuit to which $f3$ is applied, the control grid, for example, is tuned, instead of the output.

Fig. 3 illustrates a phase detector which provides satisfactory operation in connection with this invention. This device produces a direct voltage, the amplitude and polarity of which depends on the phasal relation of the two applied radio frequency voltages from the intermediate amplifier and the standard frequency oscillator. The circuit includes two input transformers 59 and 61, the secondaries of which are connected in series, and by-passed to ground at their common point. The secondary windings are connected respectively to the anode electrodes 63, 65 of a pair of rectifiers 67, 69. The cathode of rectifier 67 is connected to the anode of rectifier 69 through parallel circuits which include a resistor 71 and a capacitor 73. The cathode of rectifier 69 is grounded, and its anode is connected to ground through a load resistor 75. Output is taken from the cathode of rectifier 67, and the circuit may include filters 77, 79.

It will be seen that the output voltage will depend upon the sum of the voltages developed by the rectifiers across the two resistors 71 and 75. The two component voltages are of opposite polarity, so that the resultant output voltage will be zero when the two components are of equal amplitude and opposite polarity, and will change in one direction or the other, as one component or the other predominates. This condition is, in turn, a function of the relative phase of the two radio frequency input voltages. By properly connecting the output voltage to the frequency control tube, any tendency for the intermediate frequency to change causes a voltage to be developed which tends to prevent the change, so that a fixed balance is reached and the phase of the intermediate frequency is maintained in an exact relation to the standard frequency.

Fig. 4 illustrates a frequency control circuit which may be employed, although other systems will be apparent to those skilled in the art. The bias voltage on a pentode 81 is varied by the output of the phase detector. Self bias is provided by a cathode resistor 83. The anode 85 is shunt fed from a battery, or the like, through a resistor 87, choke 89 combination. A resistor 91 and a capacitor 93 are serially connected between anode and ground, their mid-point being coupled to the control grid of tube 81 by a capacitor 94. The anode 85 is coupled to the tank circuit of the low frequency master oscillator 7. A radio frequency voltage is therefore impressed on the grid of tube 81 which is in quadrature with the oscillatory voltage of the master oscillator. The amplified quadrature voltage is applied to the oscillator tank and is equivalent to a shunt reactance across the oscillatory circuit, the magnitude of which varies with the grid bias, so that the frequency of the oscillator is controlled.

Fig. 5 is an amplifier or tripler, so called because it tunes over a frequency range equal to the fundamental or the third harmonic of the applied voltage, depending on the position of the range selector switch 21. Input is derived from selector switch 17, as shown in Fig. 1, and is applied to the input of an amplifier 95. A second selector switch 21 is connected in the output circuit and permits a coil to be selected which, in combination with a variable capacitor 99, permits the output to be tuned over the desired frequency range. Thus, inductor 101 covers the $f1$ frequency range, and inductors 103, 105, 107 and 109 permit the output to be tuned throughout the $3 f_1$, $10 f_1$, $30 f_1$ and $100 f_1$, respectively. Tracking and trimming capacitors may be included in the various circuits as required.

For convenience, the various elements of my invention have been shown in block diagram form in their operative arrangement. To avoid confusion, single connecting lines have been used to indicate electrical connections, and are intended to indicate the usual two-wire connection, one of which is commonly grounded. Each of the elements illustrated may take an infinite variety of forms, and, while I have illustrated specific embodiments of several of the elements which may not be entirely familiar, this invention is not to be limited thereby. Furthermore, while I have given particular operating frequency ranges to certain elements, this is merely by way of example. The frequency ranges or the operating frequency of the component elements may be changed without departing from the spirit of my invention.

I claim as my invention:

1. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, means for calibrating the frequency of said low frequency currents in incremental steps, an interpolation oscillator for producing beating currents having a frequency range corresponding to the range of one of said incremental steps, means for calibrating the frequency of said interpolation oscillator in incremental steps small with respect to the calibration of said low frequency oscillator, means for producing changes in the frequency of said low frequency oscillator in response to changes in the frequency of said interpolation oscillator, and means for deriving output currents from said low frequency oscillator bearing a fundamental or desired harmonic relation to the frequency of said low frequency oscillator.

2. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, a standard frequency generator, means for indicating the frequency of said low frequency currents in incremental steps, an interpolation oscillator for producing beating currents having a frequency range which corresponds to the range of one of said incremental steps, means for calibrating the frequency of said interpolation oscillator in incremental steps small with respect to the calibration of said low frequency oscillator, means for producing changes in the frequency of said low frequency oscillator in response to changes in the frequency of said interpolation oscillator, and means for deriving output currents from said low frequency oscilator bearing a fundamental or desired harmonic relation to the frequency of said low frequency oscillator.

3. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a fixed range of frequencies, a standard frequency oscillator for producing currents of harmonically related frequencies, an interpolation oscillator for producing beating currents variable over a range of frequencies small with respect to said fixed range, means for combining currents derived from said low frequency producing means with said beating currents to obtain combination currents, means for utilizing one of said harmonics of said standard frequency currents to convert said combination currents to intermediate frequency currents, and means responsive to a change in said intermediate frequency currents for shifting the frequency of said low frequency currents to compensate for said change, whereby a change in the frequency of said interpolation oscillator produces a change in the frequency of said low frequency producing means.

4. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, means for multiplying the frequency of said low frequency oscillatory currents, means for selecting the fundamental or desired harmonic of said low frequency oscillatory currents to obtain output currents of a desired frequency, an interpolation oscillator for producing beating currents variable over a range of frequencies small with respect to the range of said low frequency currents, means for combining currents derived from said low frequency producing means with said beating currents to obtain combination currents of a different frequency, means including a source of harmonically related standard frequency currents for converting said combination currents to intermediate frequency currents, and means responsive to a change in said intermediate frequency currents for shifting the frequency of said low frequency currents in a direction which opposes said change, so that a change in the frequency of said interpolation oscillator produces a change in the frequency of said low frequency producing means, said interpolation oscillator being calibrated in terms of the resultant change of frequency produced on said low frequency oscillator.

5. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, means for calibrating said low frequency producing means to indicate increments of frequency small with respect to the range of said low frequency producing means, an interpolation oscillator for producing beating currents whose frequency is variable over a range corresponding to the range of said increments, means for deriving currents from said low frequency producing means, means for combining said derived currents with said beating currents to obtain currents of a different frequency, a standard frequency oscillator for producing currents of harmonically related frequencies in which the difference between adjacent frequencies corresponds to said increments, means including one of said harmonically related standard frequency currents for converting said combination currents into currents of a predetermined intermediate frequency, means responsive to a change in said predetermined frequency for changing the frequency of said low frequency currents in a direction which tends to maintain constant the frequency of said currents of intermediate frequency so that changes in the

frequency of said interpolation oscillator produce compensating changes in said low frequency oscillator within said incremental range, and means for producing output currents having fundamental or a selected harmonic relation to said low frequency currents.

6. A device of the character described in claim 5 which includes means for calibrating said interpolation oscillator whereby incremental steps of frequency between the points of calibration of said low frequency oscillator are determinable.

7. A device of the character described in claim 5 in which said means responsive to a change in said predetermined frequency includes a phase detector operative to produce a direct current potential whose amplitude and polarity are a function of the phasal relation of said intermediate frequency currents and currents derived from said standard frequency oscillator.

8. A device of the character described in claim 5 in which said means for deriving currents from said low frequency oscillator includes a frequency multiplier.

9. A device of the character described in claim 5 in which said means for producing low frequency currents has a frequency range of the order of 3 to 1, and said interpolation oscillator has a relatively small frequency range.

10. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, an interpolation oscillator for producing beating currents variable over a range of frequencies small with respect to the range covered by said low frequency currents, means for combining currents derived from said low frequency producing means with said beating currents to obtain combination currents of different frequencies, a standard frequency oscillator, and means including said standard frequency oscillator for converting said combination currents to predetermined frequency currents, means responsive to a change in said predetermined frequency currents for shifting the frequency of said low frequency oscillator to compensate for said change, so that a change in the frequency of said interpolation oscillator produces a change in the frequency of said low frequency producing means, and output means coupled to said low frequency producing means for deriving an output current whose frequency is a desired multiple of the frequency of said low frequency oscillator.

11. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, indicating means for determining the approximate frequency of said currents in incremental steps, means for obtaining output currents from said low frequency currents, an interpolation oscillator for producing beating currents variable over a range of frequencies corresponding to said incremental steps, means for combining currents derived from said low frequency producing means with said beating currents to obtain combination currents, means including a source of harmonically related standard frequency currents for converting said combination currents to resultant currents of a predetermined frequency, and means responsive to a change in the frequency of said resultant currents for shifting the frequency of said low frequency currents in a direction to overcome said change, whereby a change in the frequency of said interpolation oscillator produces a change in the frequency of said low frequency producing means within the limits of said incremental steps.

12. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, indicating means for determining the approximate frequency of said low frequency currents in incremental steps, an interpolation oscillator for producing beating currents variable over a range of frequencies small with respect to the range of said low frequency producing means, means for combining currents derived from said low frequency producing means with said beating currents to obtain combination currents, means including a standard frequency oscillator for producing currents of harmonically related frequencies, means for combining said harmonically related currents from said standard frequency oscillator with said combination currents to obtain a resultant current, means for selecting currents of a single desired frequency from said resultant currents, and means responsive to a change in the frequency of said selected currents for varying the frequency of said low frequency oscillator to thereby maintain constant the frequency of said selected current, so that a change in the frequency of said interpolation oscillator produces a like change in the frequency of said low frequency producing means within the range of said incremental steps.

13. An oscillation generator comprising means for producing low frequency oscillatory currents tunable over a range of frequencies, means for calibrating said low frequency producing means to indicate increments of frequency, a calibrated interpolation oscillator for producing beating currents variable over a range of frequencies equal to ten times the smallest increment indicated by said low frequency calibration, means for combining the tenth harmonic of said low frequency currents with said beating currents to obtain combination currents of different frequencies, means including a source of harmonically related standard frequency currents for converting said combination currents to intermediate frequency currents, and means responsive to a change in said intermediate frequency currents for shifting the frequency of said low frequency currents in a direction tending to oppose said change, so that the approximate frequency of said low frequency currents is indicated by the calibration of said low frequency producing means, and the calibration of said interpolation oscillator indicates the exact frequency of said low frequency producing means.

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