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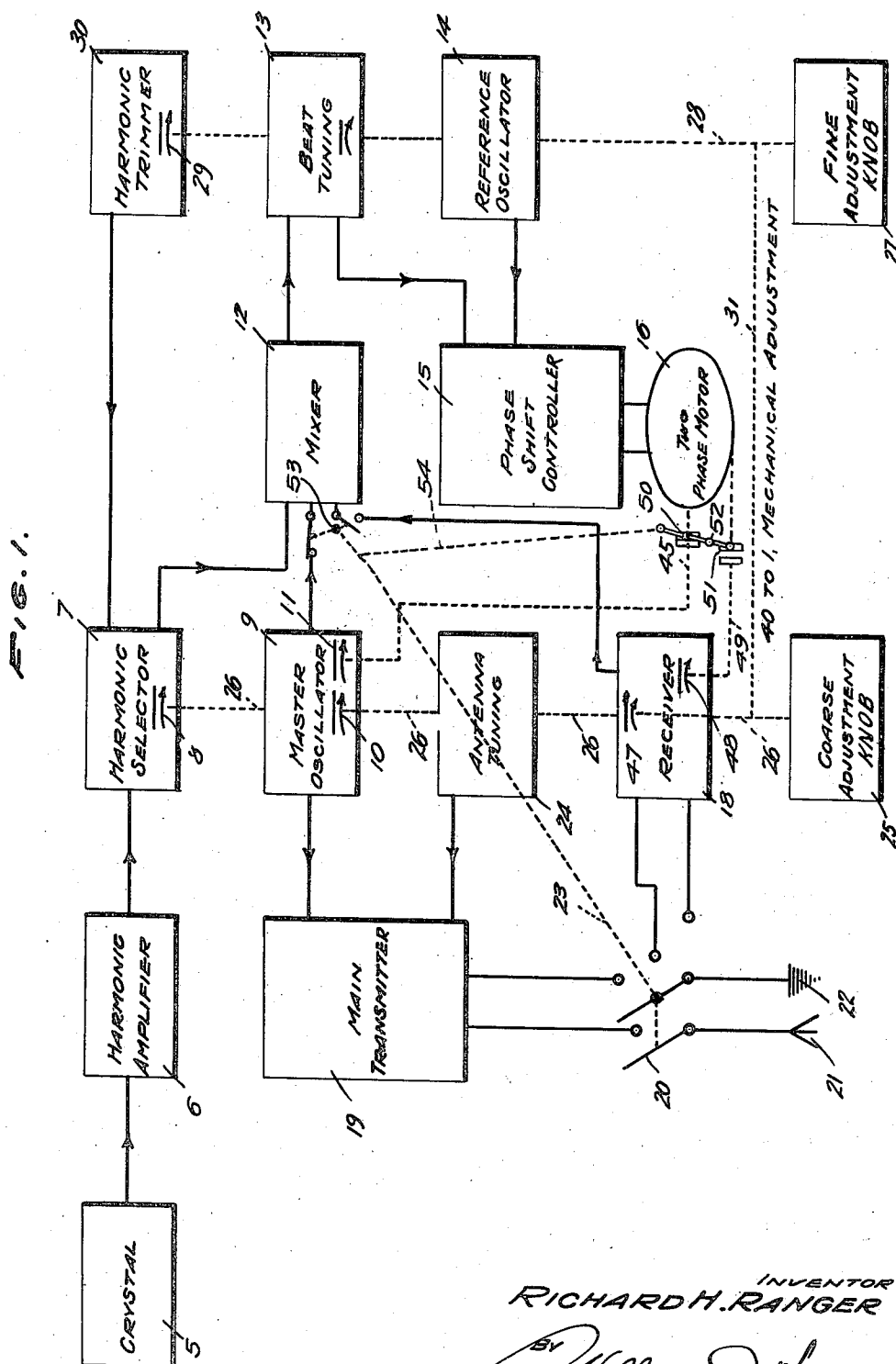
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2,452,601

FREQUENCY CONTROL MEANS

Filed June 10, 1944

2 Sheets-Sheet 1



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FIG. 2.

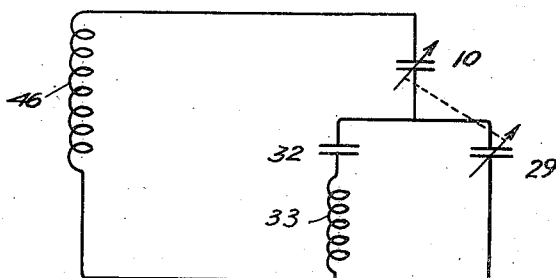


FIG. 3.

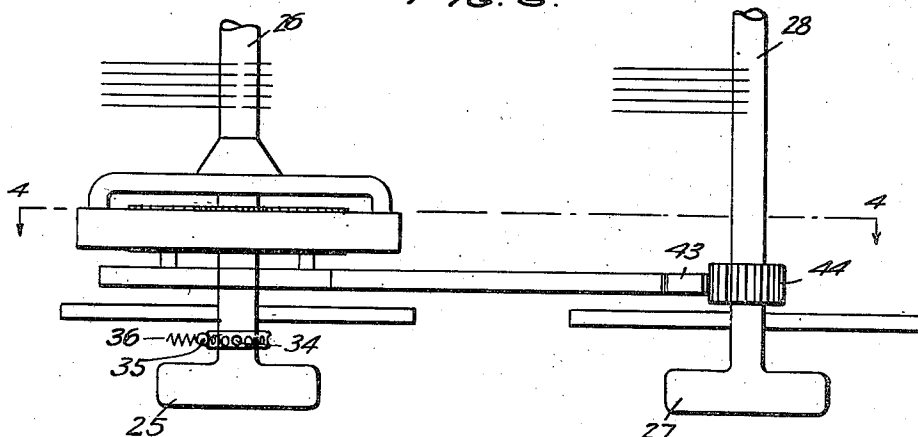
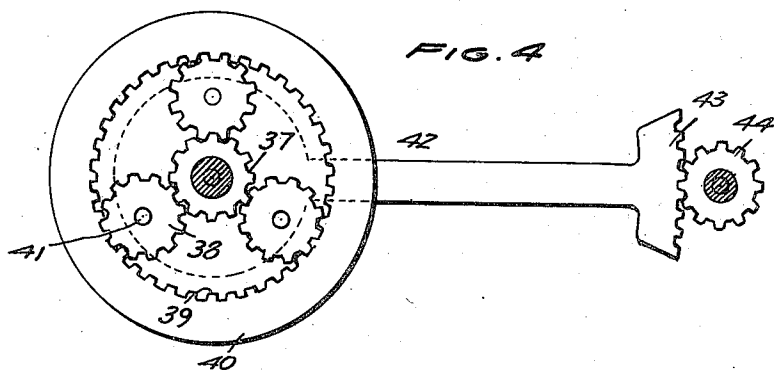


FIG. 4.



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FREQUENCY CONTROL MEANS

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The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to means for controlling the frequency of electricity supplied to radio apparatus including both transmitters and receivers.

This frequency control is attained by providing a standard of reference, which may be adjusted by hand to give a selected standard output frequency, an oscillator simultaneously set to the same approximate frequency, and a motor which responds to any deviation of the oscillator from the selected standard frequency and causes the oscillator to be adjusted so that its output frequency is made to correspond and remain on the frequency originally selected. In order to permit the selection of any frequency within the range covered by the instrument, there is provided a piezoelectric crystal, which affords a source of a series of frequencies by selection of harmonics of the fundamental frequency of the crystal, and an adjustable oscillator, which is adjustable simultaneously with the selection of said harmonics and thus affords a source of a second series of frequencies having values which may differ from those of said first series, and a second adjustable oscillator having a lower and limited range of output frequencies and serving to supply the values of frequencies intermediate those represented by any two harmonics of the first mentioned series of frequencies. A motor is electrically connected into a circuit involving the output of this crystal and these oscillators so that the motor is movable in response to any difference in frequency between the selected harmonic of said crystal and said oscillators, this motor having mechanical connections with means for adjusting the output frequency of the first oscillator to the frequency of the selected harmonic plus or minus the frequency of the second oscillator.

It is an object of this invention to provide a device for controlling the frequency of a radio apparatus. This device comprises a circuit containing a crystal arranged to oscillate and controlled in such a way that various harmonics may be selected, a master oscillator also controlled in such a way that its output frequency may be selected, a mixer circuit in which the selected harmonic and the selected frequency may be mixed to produce a beat, a second oscillator which, too, may be controlled to afford selection of the frequency emitted thereby, and to which said beat is to be compared, an electric motor movable in response to any difference in frequency between

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said beat and the output frequency of said second oscillator, and a mechanical connection between said motor and the controller of said master oscillator, whereby said motor adjusts the frequency of said master oscillator to match that of the selected harmonic plus or minus that of said reference oscillator. In other words, when a variation occurs in the frequency of the electricity energizing a radio apparatus, a motor is operated which restores the frequency to that which was pre-selected.

Another object of this invention is the provision of a pair of operating devices such that the frequency of the electricity which energizes a radio apparatus may be varied by relatively large or small differences or increments.

Yet another object of this invention is to supply, in addition to the means for selecting a desired harmonic of the oscillations afforded by a crystal, means operable in the reverse sense to said selecting means, whereby the tuning of the harmonic selected is maintained constant despite necessary adjustments of the main control to cover intermediate frequencies.

Further objects and explanation of this invention are set forth in the specification below and in the annexed drawings.

In the drawings:

Figure 1 is a block diagram.

Figure 2 is an electrical circuit diagram.

Figure 3 is a top or plan view of the operating mechanism.

Figure 4 is a vertical cross section on line 4—4 of Figure 3.

But one modification of my device is to be described in the specification and depicted in the accompanying drawings. Many other modifications will readily appear to those skilled in this art.

The frequency control mechanism of this invention comprises a crystal 5 electrically connected to a harmonic amplifier 6 which in turn is electrically connected to a harmonic selector 7 having a selector or control element 8 forming a part thereof. A master oscillator 9 is provided with a tuning or selecting mechanism 10 and with an additional selecting mechanism 11. Selector 7 and master oscillator 9 are both electrically connected to the mixer circuit 12 which, in turn, is electrically connected to a beat-tuning circuit 13. A reference oscillator 14 is provided and is electrically connected to a phase-shift-control circuit 15, which also receives the electrical output of the beat-tuning circuit 13. Circuit 15 includes, as a part thereof, a two-phase motor 16. The output

of master oscillator 9 is connected to the main transmitter 19. A double-pole double-throw manually operable switch 20 is connected to the output side of transmitter 19 and to the input side of receiver 18 and serves to connect antenna 21 and ground 22 to transmitter 19 or to receiver 18. Transmitter 19 has an antenna tuning circuit 24 electrically connected thereto. Receiver 18 contains a manually adjustable tuning element 47 movable by means of shaft 26 and a mechanically adjustable tuning element 48 movable by means of a mechanical connection 49 connecting with motor 16. Mechanical connections 45 and 49 each contain a clutch, 50 and 51, respectively. Clutches 50 and 51 are mechanically interconnected by means of interlock 52 so that when one of these clutches is engaged the other must be disengaged. A double-pole, single-throw switch 53 controls the circuit connections between master oscillator 9 and mixer 12 and also between receiver 18 and mixer 12 in such a way that one circuit is closed when the other is open. A mechanical connection 54 fastens interlock 52 to the operating connection 23 between switches 20 and 53.

The means for adjusting this mechanism are provided by a knob 25 turning a shaft which is indicated by dotted line 26 which operates harmonic selector circuit 7, master oscillator 9, antenna tuning 24 and receiver 18. This means also includes a fine adjustment knob 27 which turns a shaft 28 controlling reference oscillator 14, beat-tuning circuit 13, and tuning mechanism or capacitor 29 of a harmonic trimmer 30. Between shafts 26 and 28 there is provided a mechanical interlock generally indicated at 31. Interlock 31 has a mechanical ratio of 40 to 1 so that knob 25 provides a main or coarse adjustment while knob 27 provides a fine adjustment. In other words the main shaft 26 changes all the units connected to it, first, by its main discrete steps and, second, by means of gearing from the fine shaft 28 to points in between the main discrete steps.

In order that the harmonic selected by controller 8 may serve as a fixed reference and remain constant despite the intermediate adjustment of shaft 26 caused by movement of the fine knob 27, means must be provided for compensating for any changes in the adjustment of controller 8. This is done by means of harmonic trimmer circuit 30 and the tuning mechanism 29 forming part of this trimmer circuit. Capacitor 29 is operated in the opposite direction or reverse sense to the controller 8 and thereby serves to keep the frequency of harmonic selector 7 constant as the fine knob turns with 29 directly and 8 indirectly by the mechanical link 31 between the shafts 28 and 26. The electric circuit shown in Figure 2 aids in accomplishing this. This represents the harmonic selector 7 made up of the main inductance 46 and the main capacitor 8. Capacitor 29 is connected in series with capacitor 8. Capacitor 8 varies in the ratio 4 to 1 while capacitor 29 must be larger, a convenient size being four times that of capacitor 8. That is to say, if capacitor 8 has values which are in the ratio of 4 to 1, capacitor 29 should have values of 16 to 4. It is still not possible to get absolute control of this situation, so it may be necessary to add the series tuning element shown as fixed capacitor 32 and inductance 33 which provide resonance at the lower end of the band worked with. The effect of this series tuning element will be to increase the effective capacity on the low end.

A more complete showing of the details of the manual control is to be found in Figures 3 and 4. There, it will be seen that main knob 25 has a plurality of hemi-spherical depressions 34 in its shaft which cooperate (one at a time) with a detent formed by ball 35 and spring 36. Knob 25 carries gear 37 on it (see Figure 4). This gear serves as a sun gear about which planet gears 38 may rotate. Planet gears 38 mesh at their outer portions with internal gear 39 forming part of a ring 40 mounted on the end of shaft 26. Planet gears 38 are rotatably mounted on pins 41 carried by lever 42 which has at its outer end a segment 43 which meshes with gear 44 connected to knob 27 and shaft 28. The gear reduction ratio between shaft 28 and 26 is 40 to 1.

The operation of my device is as follows: A frequency is selected by the main adjustment 25. By shaft 26 this tunes master oscillator 9 and antenna tuning 24 for the same frequency. Also harmonic selector 7 picks a harmonic of crystal 5. This harmonic will differ from the frequency of the master oscillator 9 so as to give a beat in the output of the mixer 12. This beat will be compared with the frequency of the second reference oscillator 14. If the beat and reference oscillator are the same in frequency the main tuning is correct. If they are not, and say the beat is higher than the reference oscillator, the phase shift controller 15 will cause two-phase motor 16 to turn to bring the frequency of the beat into accord with the reference oscillator 14. A convenient frequency for crystal 5 is 200 kilocycles (kc.) This crystal serves as a master reference. Assume a band coverage from 4 to 8 megacycles (mc.). This means twenty 200 kc. harmonic points from 4 to 8 mc. As there is a spread of 200 kc. between any two harmonics of the crystal 5 such as for example the twenty-second and twenty-third at 4.4 mc. and 4.6 mc. respectively, reference oscillator 14 must cover this range. It is convenient to accomplish this for example in the normal intermediate frequency ranges as from 300 kc. to 500 kc. This will give a frequency range well handled by the normal 4 to 1 capacitor in tuning the reference oscillator 14. At the same time this is as low a frequency as is conveniently possible without getting into trouble. The lower the frequency, the more accurate the final adjustment. Now if the master oscillator setting is at 4.7 mc., and the harmonic selector is on the twenty-second harmonic or 4.4 mc., there will be a beat of 0.3 mc. or 300 kc. in the mixer 12. If the fine adjustment knob 27 is at zero, the shaft 28 will have turned the reference oscillator 14 to its lower end or 300 kc., and the set is in adjustment. If the master oscillator 9 is slightly below 47 mc., the beat note will be less than 300 kc., and the phase-shift controller 15 and its associated two-phase motor 16 will act mechanically to decrease trimmer capacitor control 11 to raise the frequency of the master oscillator 9. Now, if the fine adjustment knob is turned up 100 kc., this will act to increase reference oscillator 14 frequency to 400 kc. and beat tuning 13 to 400 kc. and harmonic trimmer 30 to hold the harmonic selector 7 to the same twenty-second harmonic by decreasing the capacitor 29. At the same time, the mechanical link 31 will turn the main shaft 26, to increase the frequency of the master oscillator 9 and antenna tuning 24 by this same 100 kc. If fine readjustment is necessary to make the master oscillator 9 now exactly 100 kc. higher or 4.8 mc., the phase controller 15 will again act

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through two-phase motor 16 on trimmer 11 on the master oscillator 9.

Receiver 18 is a superheterodyne receiver and depends on the master oscillator to act as the local oscillator. The intermediate frequency is 200 kc. So when the shift is made from transmit to receive, the same switching which operates 20 will operate to move the detent mechanism 35 and 36 around one notch in such a direction as to drop it back one step so that the master oscillator and harmonic selector will drop back 200 kc. The receiver, by the same token, will be brought to its correct tuning point of say 4.8 mc. It is 200 kc. too high in tuning on transmission.

When it is decided to operate transmitter 19 or receiver 18, switch 20 is manually set in the desired position so that it connects the antenna 21 and ground 22 to the transmitter 19 or to the receiver 18. Detent 35 yieldingly retains knob 25 in the position to which it is moved. Knob 25 is manually adjusted, turning shaft 26, which moves controller 8 so as to select a harmonic of the output frequency of crystal controlled oscillator 5. This output contains twenty available harmonics which are spaced 200 kc. apart. If it is desired to operate at a frequency intermediate one of those provided by the harmonic selector 7, knob 27 and shaft 28 are manually adjusted so that in effect the numerical value of the setting of the reference oscillator 14 (having a range of 200 kc.) is added to the frequency of the harmonic selector. It would be equally possible to work down from a selected harmonic to intermediate values in which case the value of the second reference oscillator would be subtracted from the main frequency setting. Whenever reference oscillator 14 is adjusted, harmonic trimmer 30 is also adjusted in the opposite sense, so that the frequency output from harmonic selector 7, modified by the harmonic trimmer 30, is fed to mixer circuit 12. The frequency output from master oscillator 9, as adjusted by controller 10, is also fed to mixer 12 and a beat between these two frequencies occurs. The purpose of the IF or beat tuning circuit 13 is to select the beat out of all the hash that may be present in the input from the master oscillator 9 and from harmonic selector 7 so that a nice, clear beat is accomplished. This beat is then combined with the frequency output of IF or reference oscillator 14 in a normal two-phase arrangement with 90° shift of phase by means of phase-shift controller circuit 15. This type circuit is shown in detail in my copending application Serial Number 494,892, filed July 14, 1943, now abandoned, where two frequencies are compared and a motor is made to run in one direction or the other depending upon whether one frequency is above or below the other. However, to accomplish the adjustment of the master oscillator frequency to the proper value, any system for this purpose, already known to the art, which operates on a comparison of two frequencies may be used instead. If there is any frequency difference between the beat and the output of reference oscillator 14, two-phase motor 16 turns controller 11 by means of mechanical connection 45 and adjusts the output of this master oscillator into agreement with the setting which has been made on the reference oscillator 14.

The master oscillator 9 must be 300 kc. off the harmonic selected in order to be in adjustment at the low end of the fine shaft setting. At this point the primary beat between master oscillator 9 and the selected harmonic will be 300 kc. If it is not, there will be a beat between this frequency and

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the frequency put out by the reference oscillator 14 which is at 300 kc. This secondary beat actuates the two-phase motor 16 and this automatically adjusts control 11 of the master oscillator 9 to the point where the oscillator is 300 kc. off the selected harmonic. The beat between the output of the mixer 12 and reference oscillator 14 thus approaches zero.

I claim:

1. Means for maintaining constant the frequency at which radio apparatus operates, said means comprising, first means adapted to generate a first selected frequency, second means adapted to generate a second selected frequency, a circuit arranged to receive said first frequency and said second frequency and to transmit the beat between said frequencies, first manually operable means controlling the respective frequencies of the component waves which together form said beat, third means adapted to generate a third selected frequency, second manually operable means interlocked with said first manually operable means and affording a more delicate control of the respective frequencies of the component waves which together form said beat, a two-phase motor operable in response to any frequency difference between said beat and said third frequency, a mechanical connection between said motor and said second means, whereby said motor tunes said second means so that said beat frequency is equal to the frequency of said third frequency and therefore the operating frequency of the apparatus is maintained constant, and sixth means mechanically connected under the control of said second manually operable means and electrically connected to the first means so as to tune said first means to compensate for any change in the first selected frequency caused by operation of said first manually operable means.

2. Radio apparatus having high inherent frequency stability and comprising a first source of electricity of a few, relatively stable frequencies, a second source of electricity of a larger number of relatively unstable frequencies, means for mixing said frequencies from said sources and for producing a beat frequency between them, a third source of electricity adjustable to produce a lower order frequency, an electric motor electrically connected to respond to any phase difference between said beat frequency and said lower order frequency selected, a mechanism driven by said motor to cause said beat frequency to match said lower order frequency selected, a mechanical coupling connecting said first source and said second source to said third source and manually operable to tune the output frequency of said sources to select desired frequencies, and a frequency-controlling element mounted for movement in response to movements of said coupling and interconnected in circuit with said first source so as to vary the frequency of said first source in the opposite direction to the variation in its frequency under the control of said coupling.

3. A controller for stabilizing the operational frequency of a radio apparatus, said controller being constituted by an electric circuit arranged to generate a relatively fixed frequency and containing an adjustable element operable to select harmonics of said frequency, a master oscillator arranged to generate a relatively variable frequency and adjustable to select the frequency generated, a mixer circuit connected to said electric circuit and to said master oscillator so as to receive the outputs thereof and combine said outputs into a beat, a reference oscillator arranged

to generate one of a band of relatively low frequencies and adjustable to select the frequency of the wave generated, a phase shift circuit including a two-phase motor and connected to said mixer circuit and to said reference oscillator so as to receive said beat and said frequency selected for said reference oscillator, said motor being operable in response to any difference therebetween, a mechanical connection between said motor and said master oscillator whereby the output frequency of said master oscillator is adjusted by said motor to eliminate any frequency difference between said beat and the output frequency of said reference oscillator, and a second adjustable element for selecting the frequency generated by the reference oscillator, said second adjustable element being mechanically interlocked with the adjustable element of said electrical circuit and operable upon said electric circuit to maintain substantially constant the frequency of the harmonic selected for said electric circuit.

4. A frequency control system comprising: first oscillator means including first tuning means for adjusting the output frequency of the first oscillator means to a selected one of at least two different frequencies; master oscillator means including second tuning means for adjusting the output frequency of such master oscillator means; reference oscillator means including third tuning means for adjusting the output frequency of the reference oscillator means to a selected value which is smaller than that of the difference in frequency between any two adjacent frequencies of those frequencies from which the frequency of the first oscillator means may be selected; mixer means deriving input from the first oscillator means and the master oscillator means and producing a beat frequency having a value which is equal to the difference between the frequencies of the respective inputs; frequency-setting means deriving input from the mixer means and from the reference oscillator means, such frequency-setting means being connected to the master oscillator means and responsive to a difference between the respective frequencies of its inputs to tune

the master oscillator means and thus to bring the output frequency of the master oscillator means to a value such that the beat frequency output of the mixer means equals the output frequency of the reference oscillator means; first selector means for operating the first and second tuning means; second selector means for operating the third tuning means; interlocking means interlocking the second selector means to the first selector means so that operation of the second selector means to an extent corresponding to a certain change of frequency causes operation of the first selector means to an extent corresponding to the same change of frequency; and fourth tuning means operated by the second selector means and connected to the first oscillator means to maintain the frequency of the first oscillator at the selected value corresponding to the position of the first selector means.

5. A frequency control system, as described in claim 4, in which the mixer means include beat tuning means for the purpose of selecting a clear beat out of the inputs to the mixer means.

6. A frequency control system, as described in claim 4, in which the frequency-setting means include a two-phase motor connected to the master oscillator means and include also means so connecting the motor with the mixer means and the reference oscillator means that the motor is responsive to a difference between the respective frequencies of its inputs to tune the master oscillator means.

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