

Sept. 27, 1938.

H. GRANGER

2,131,558

SELECTIVE HIGH FREQUENCY OSCILLATOR SYSTEM

Filed July 27, 1934

7 Sheets-Sheet 1

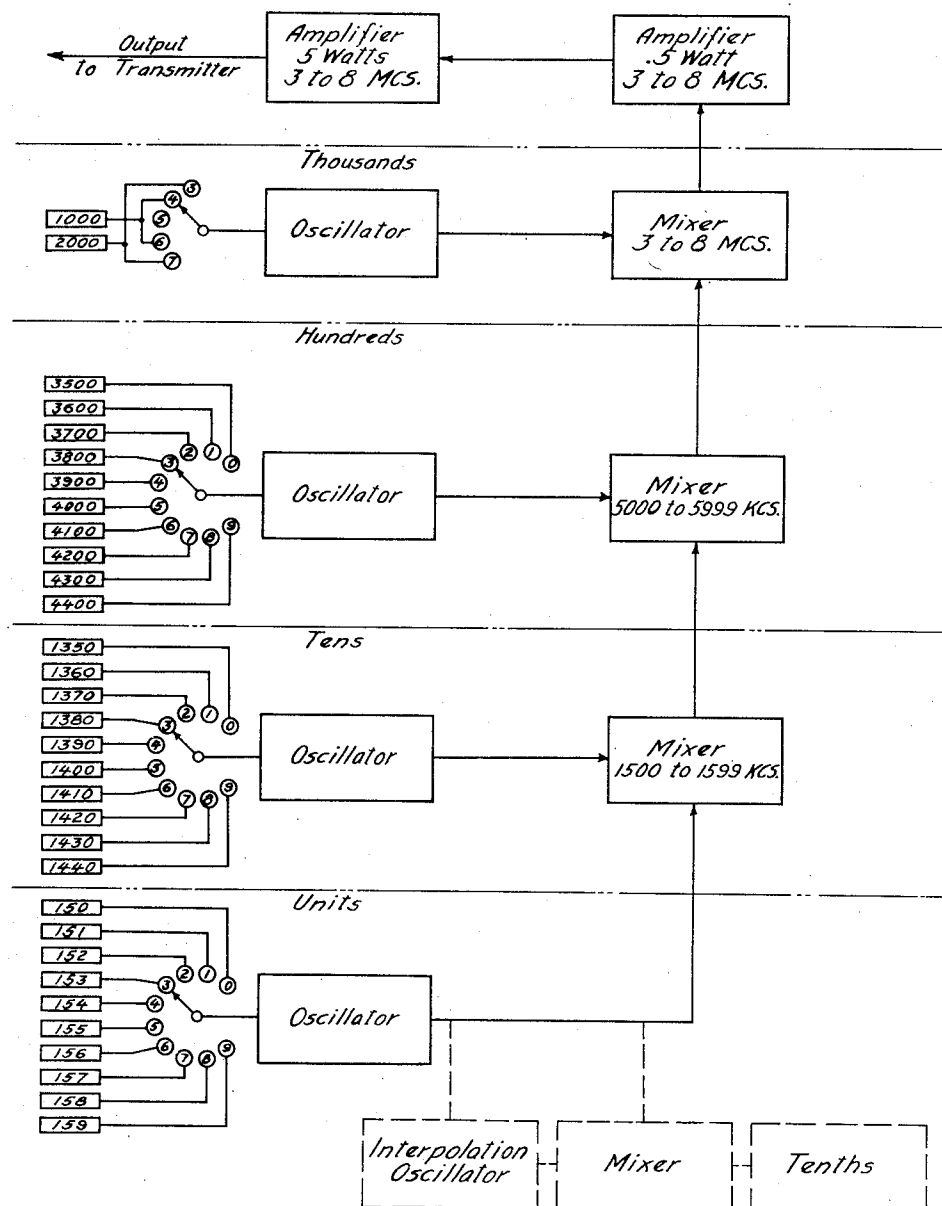


Fig. 1

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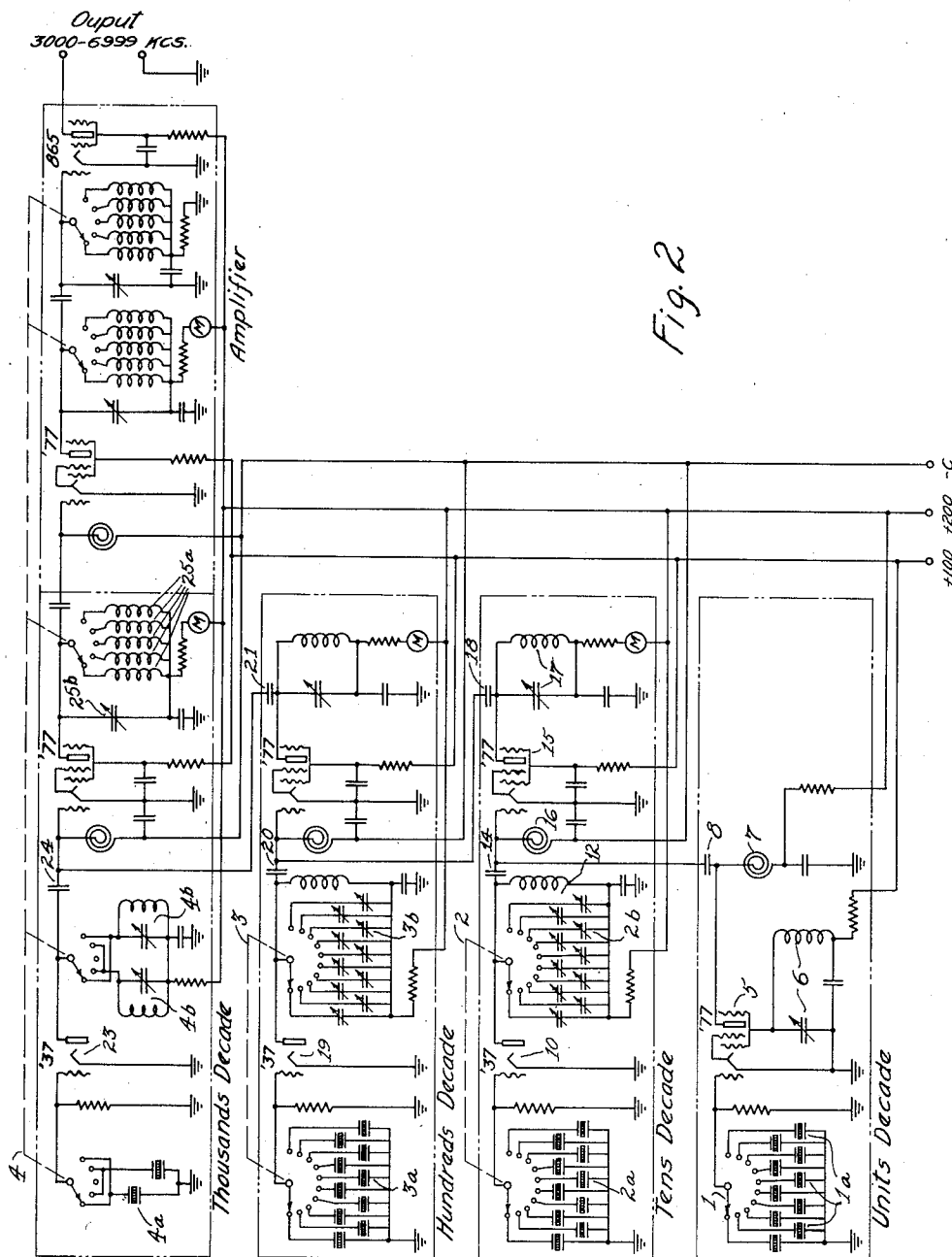
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7 Sheets-Sheet 2



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7 Sheets-Sheet 3

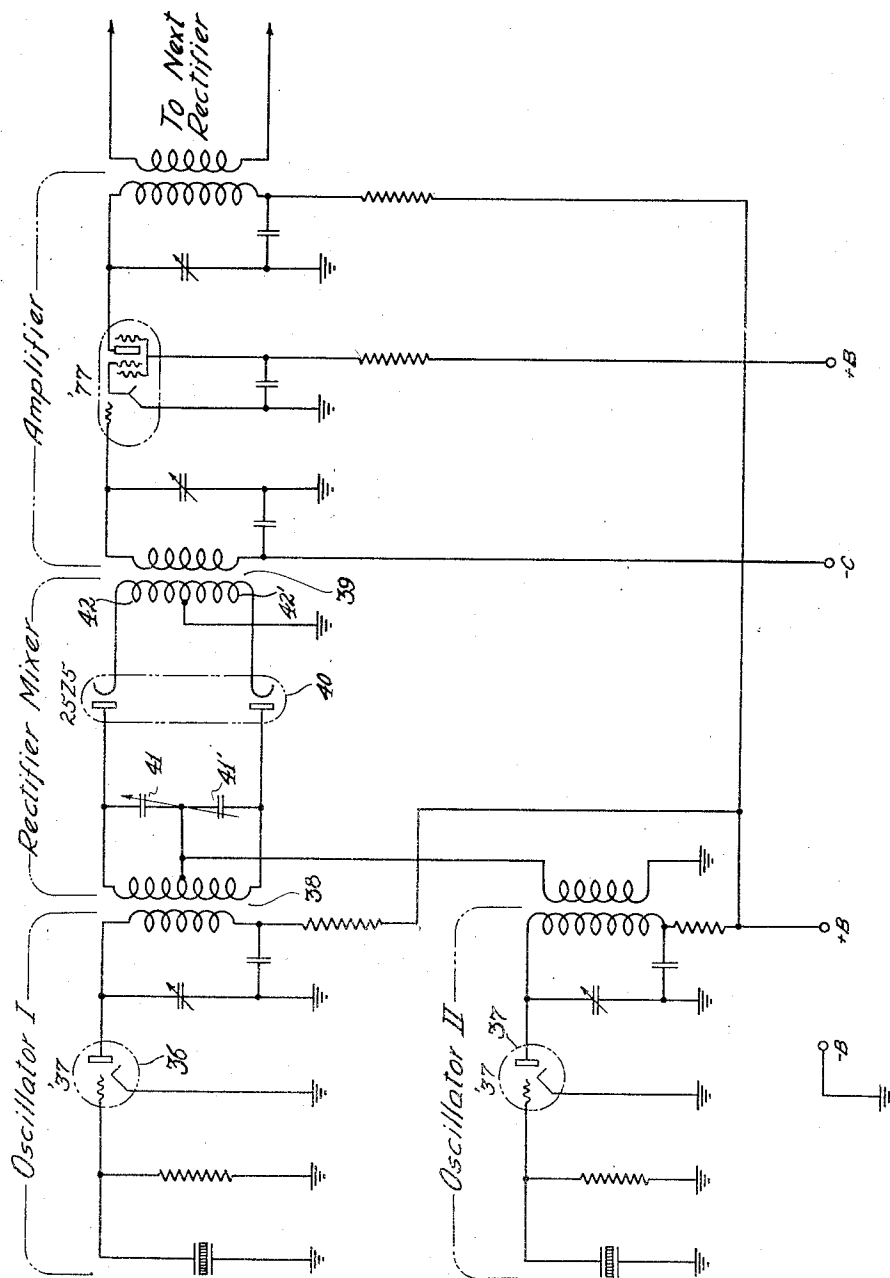


Fig. 3

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7 Sheets-Sheet 4

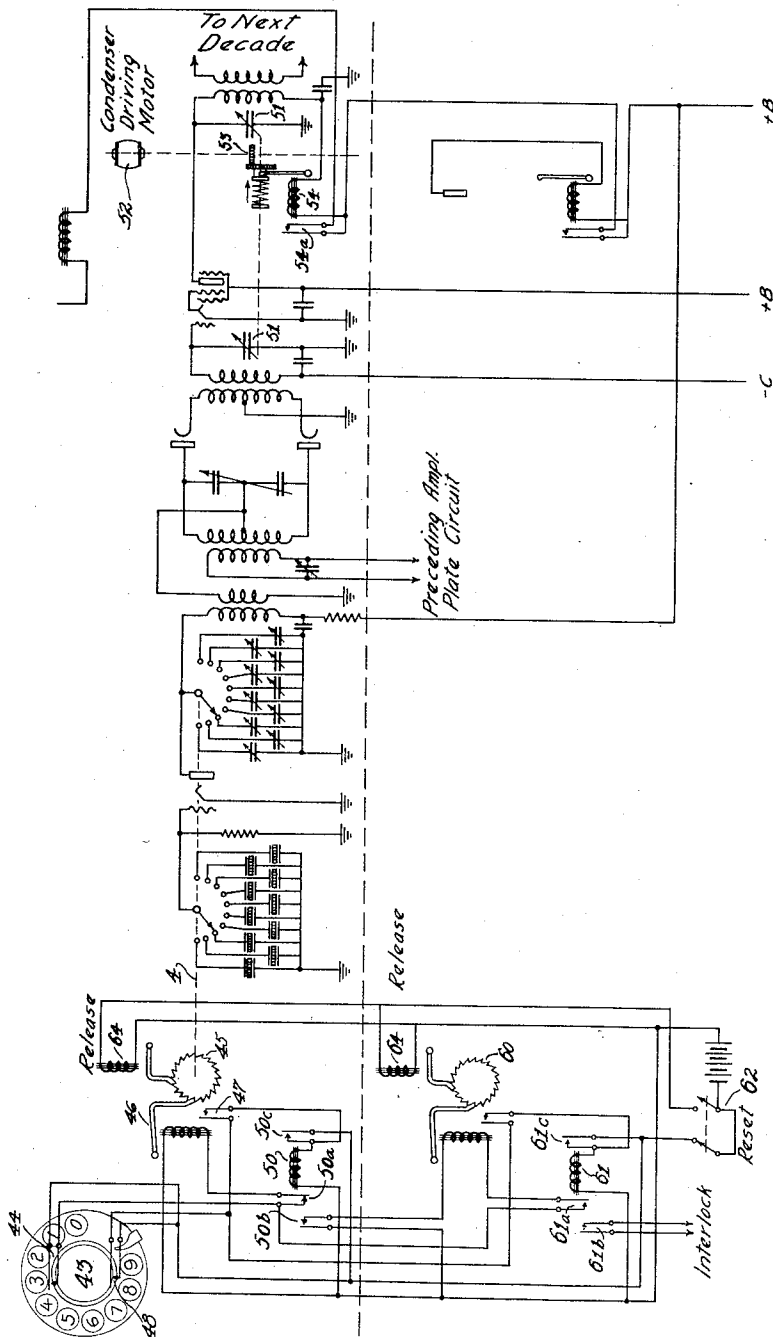


Fig. 4

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7 Sheets-Sheet 5

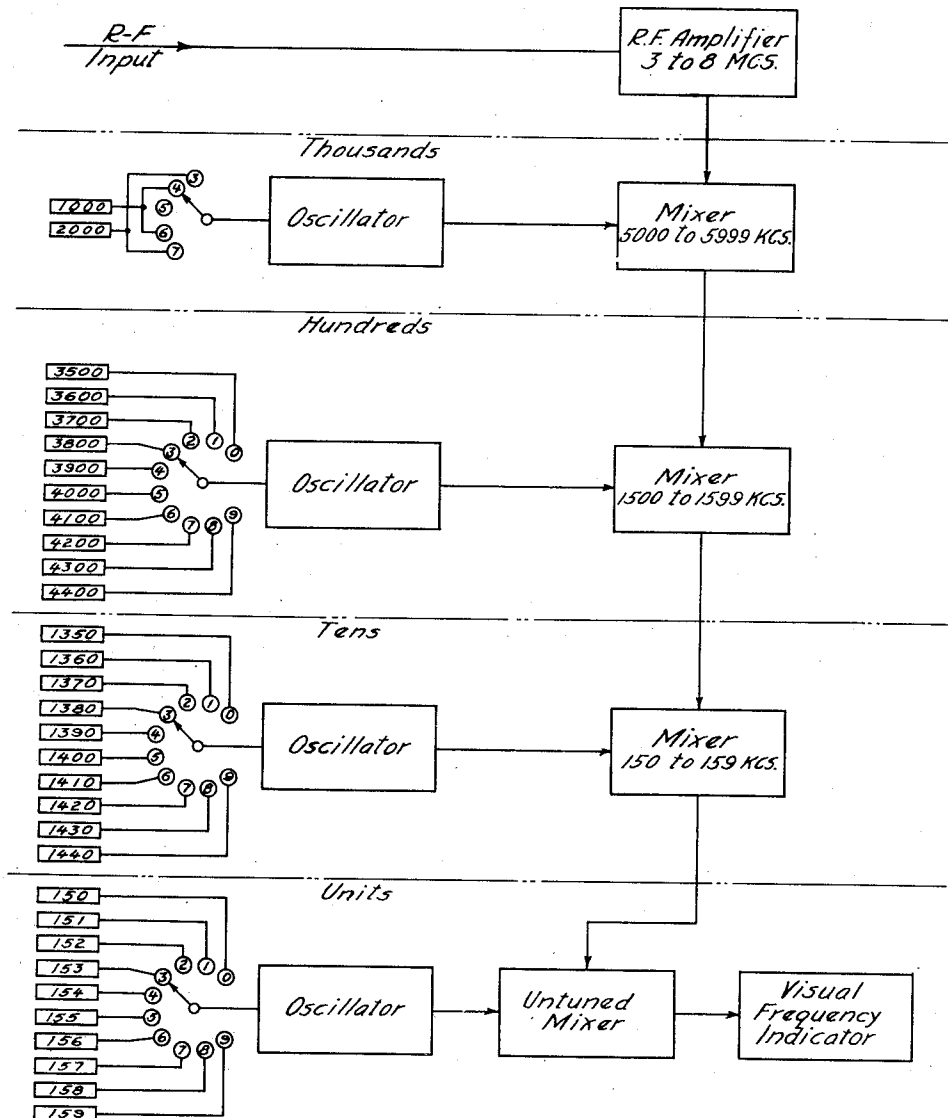


Fig. 5

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7 Sheets-Sheet 6

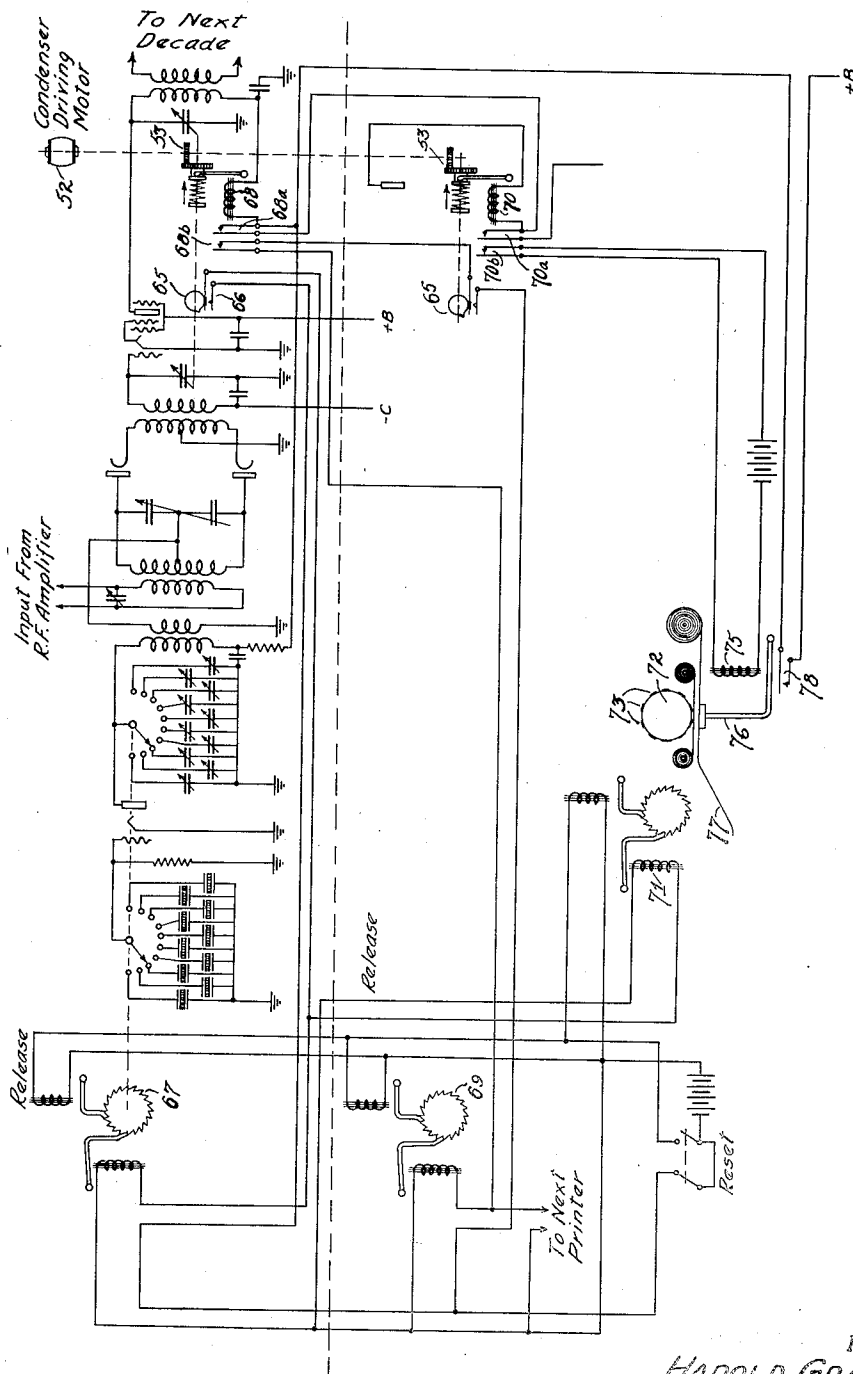


Fig. 0

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SELECTIVE HIGH FREQUENCY OSCILLATOR SYSTEM

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7 Sheets-Sheet 7

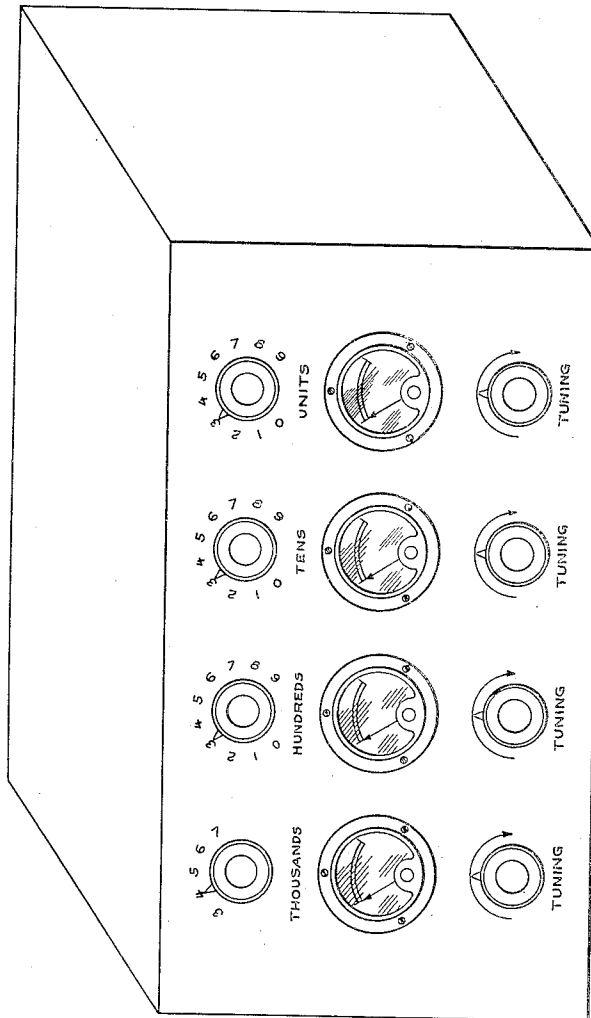


Fig. 7

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UNITED STATES PATENT OFFICE

2,131,558

SELECTIVE HIGH FREQUENCY OSCILLATOR
SYSTEM

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mesne assignments, to Bendix Radio Corpora-
tion, New York, N. Y., a corporation of Dela-
ware

Application July 27, 1934, Serial No. 737,309

12 Claims. (Cl. 250—36)

My invention relates broadly to high frequency systems and more particularly to selective systems for generating, controlling or measuring any one of a plurality of different frequencies.

5 One of the objects of my invention is to provide a decade arrangement of frequency determining elements in association with a plurality of oscillation circuits wherein decade multiples of the available frequencies may be readily derived.

10 Another object of my invention is to provide a plurality of switching arrangements whereby one frequency determining element in each decade may be selected to control an associated oscillator circuit.

15 Still another object of my invention is to provide automatic means for connecting desired frequency determining elements for control of an associated oscillator circuit.

20 A further object of my invention is to provide a balanced mixer circuit for combining two frequencies wherein undesired components of one of the frequencies are opposed and canceled in the output thereof.

25 A still further object of my invention is to provide a system for checking and determining the frequency of an electrical oscillation with a high degree of precision.

30 Another object of my invention is to provide an automatic arrangement whereby the frequency of an electrical oscillation may be measured and a permanent record made of such frequency.

35 Still another object of my invention is to provide a system for synthesizing a desired frequency or determining the frequency of a given oscillation, operative over a desired wide range of frequencies.

40 Other and further objects of my invention reside in the circuits and arrangements as disclosed more clearly in the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 diagrammatically represents the arrangement of the decade frequency generation, 45 or control system of my invention; Fig. 2 is a schematic diagram of the circuit connections in the various units of the frequency generation or control system of my invention; Fig. 3 is a schematic diagram of the balanced rectifier circuit employed in the mixer circuits in my invention; 50 Fig. 4 is a schematic diagram of the connections in the automatic frequency synthesizing and selection system of my invention; Fig. 5 diagrammatically represents an arrangement of the decades of frequency determining elements for the

measurement of a given frequency; Fig. 6 is a schematic diagram of the connections in an automatic frequency measuring and recording system embodying the circuits of my invention; and Fig. 7 is a perspective view of one form of cabinet for 5 mounting the controls in the manual arrangements of my invention.

My invention is directed to a compact construction of apparatus which may be conveniently transported and installed and which will serve 10 as a transmitter frequency control device, a frequency measuring apparatus, or as a heterodyne system for signal receivers. The apparatus of my invention is particularly characterized by the wide and varied frequency range over which the 15 apparatus is designed to function.

Referring to the block diagram of the decade frequency synthesizing system, Fig. 1 of the drawings, units, tens, hundreds and thousands decades are shown.

The units decade consists of an oscillator tube circuit associated with ten piezo-electric crystals having natural vibration frequencies ranging from 150 kilocycles to 159 kilocycles in steps of 1 kilocycle. Any one of these crystals may be connected 25 to the oscillator tube by means of a manually operated switch having ten positions numbered from 0 to 9 inclusive, the zero position connecting the 150 kilocycle crystal and the 9 position connecting the 159 kilocycle crystal with the intermediate crystals connected to the corresponding successive positions.

The tens decade, as shown in the block diagram, immediately above the units decade, consists of an oscillator associated with ten piezo-electric 35 crystals having natural vibration frequencies ranging from 1350 kilocycles to 1440 kilocycles in steps of ten kilocycles. Any one of these crystals may be selected and placed in the circuit for operation in the same manner as accomplished in the units decade. The ten position switch is numbered from 0 to 9 inclusive, and the frequency corresponding to each position is indicated in the block diagram. The tens decade oscillator is fed 40 to a mixer circuit whose tuning range is 1500 to 1599 kilocycles inclusive, and is there mixed with the output of the units oscillator to produce a frequency which is the sum of the frequency of the operating crystal in the tens decade and that of the operating crystal in the units decade.

The hundreds decade is similar to the units and tens decades except that the natural vibration frequencies of the crystals range from 3500 kilocycles to 4400 kilocycles in steps of 100 kilocycles and that the tuning range of the mixer cir- 55

cuit is 5000 to 5999 kilocycles. The output of the hundreds decade oscillator is fed to the hundreds decade mixer and combined with the output of the tens decade mixer. The output frequency of the hundreds decade mixer being the sum of the frequency of the operating crystal in the hundreds decade and the output frequency of the tens decade mixer.

The output frequency of the hundreds decade mixer is then fed to the thousands decade mixer and combined with the output of the thousands decade oscillator. The frequencies of the crystals in the thousands decade unit are determined by the range desired in the system. In this case, as shown in the block diagram, the thousands decade contains a thousand kilocycle crystal and a two thousand kilocycle crystal.

The thousands decade mixer has a continuous tuning range of from 3,000 to 7,999 kilocycles, inclusive. The output frequency of the thousands decade oscillator may, therefore, be either added to or subtracted from the output of the hundreds decade mixer. The amplifiers shown are ordinary class "C" amplifiers and are used merely to increase the amplitude of the oscillation to such amplitude at which it may be used to control a transmitter.

In order to explain the operation of this system, assume that it is desired to produce a frequency of 3763 kilocycles. The following procedure is in order:

Set units on 3, then	153 kc. oscillation is fed to tens mixer
Set tens on 6, then	1410 kc. oscillation is fed to tens mixer
	then 1563 kc. oscillation is output of tens mixer
Set hundreds on 7, then	4200 kc. oscillation is fed to 100's mixer
Tens mixer output	1563 kc. oscillation is fed to 100's mixer
	then 5763 kc. oscillation is output of 100's mixer
Set thousands on 3, then	2000 kc. oscillation is fed to 1000's mixer
Hundreds mixer output, 5763 kc.	oscillation is fed to 1000's mixer
	then 3763 kc. oscillation is output of 1000's mixer and is fed to amplifier.

This last result is obtained when the output of the thousands mixer is tuned to the difference beat between 5763 and 2000 kilocycles which is the condition when the thousands switch is on 3.

The circuit of the system operates in the same manner on all other frequencies less than 5,000 kilocycles. Frequencies between 5,000 kilocycles and 5,999 kilocycles, inclusive, are derived directly from the hundreds decade mixer. Frequencies of 6,000 kilocycles and above are obtained by adding the output of the thousands decade oscillator to the output of the hundreds decade mixer.

Fig. 2 is a schematic circuit diagram of the decade frequency synthesizing system of my invention. The units decade oscillator in the lower portion of the figure includes screen grid electron tube 5. Piezo-electric crystals 1a are selectively connected in the grid circuit to determine

the frequency at which the tube 5 will oscillate. Tuned circuit 6 connected to the screen grid of tube 5 has a band width of ten kilocycles in order to be responsive to any one of the crystals 1a. The anode circuit of tube 5 is connected through radio frequency choke coil 7 to the source of anode potential and through condenser 8 to the input of the tens decade mixer.

The tens decade oscillator, shown just above the units decade oscillator in Fig. 2, includes the electron tube 10 having piezo-electric crystals 2a selectively connected in the grid circuit thereof and tuned circuit 12 connected in the anode output circuit thereof. This tuned circuit includes selective branches 2b for rendering the tuned circuit 12 responsive to the crystal frequency selected in the grid circuit. The band width of the frequencies available in the tens decade oscillator being 100 kilocycles, a single tuned circuit responsive to any frequency in that range is inadvisable and selective circuits are, therefore, provided. The anode of electron tube 10 in the tens decade oscillator is connected through condenser 14 to the input of the tens decade mixer.

The tens decade mixer as shown comprises electron tube 15 biased for amplifier operation through choke coil 16. The outputs from the units and tens decade oscillators are combined on the grid of the tube 15. Tuned output circuit 17, connected to the anode of tube 15, is variable over a range of frequencies including the sums of the minimum and maximum frequencies available in the units and tens decade oscillators. The anode of amplifier tube 15 is connected through condenser 18 to the input of the hundreds decade mixer.

The hundreds decade oscillator is similar to the tens decade oscillator, differing only in the frequencies available. The anode of electron tube 19 in the hundreds decade oscillator is connected through condenser 20 to the input of the hundreds decade mixer where it is combined with the output of the tens decade mixer.

The hundreds decade mixer is similar to the tens decade mixer differing only in that the tuned output circuit is variable over a range of frequencies including the sums of the minimum and maximum frequencies available from the tens decade mixer and the hundreds decade oscillator. The output of the hundreds decade mixer is connected through condenser 21 to the input of the thousands decade mixer.

The thousands decade oscillator comprises electron tube 23 having piezo-electric crystals 4a connected to the grid thereof. As set forth hereinbefore, the output of the thousands decade oscillator may be added to or subtracted from the output of the hundreds decade mixer. This is effected in the output of the thousands decade mixer by selection of a proper tuned circuit. In order to maintain consistent switching operation and convenient selection of the desired frequency by means of numbered taps as shown in Fig. 1, a pair of taps is provided for each crystal. These taps are numbered for selective cooperation with the outputs of the other decade oscillators and the tuned circuits in the output of the thousands decade mixer, and associated amplifiers.

Tuned circuits 4b in the output of the oscillator tube 23 are likewise provided with double taps for consistent cooperation with the selected crystal. The anode of tube 23 is connected through condenser 24 to the input of the thousands decade mixer.

Between the sum and difference outputs of the thousands decade mixer, there is a band of frequencies available from the hundreds decade mixer only. For this band, there are blank taps in the input and output circuits of the thousand decade oscillator, and correspondingly suitable tuned circuits in the output of the thousands decade mixer, and associated amplifiers.

The outputs of the hundreds decade mixer and the thousands decade oscillator are combined in the input of the thousands decade mixer. The output of the thousands decade mixer includes a plurality of tunable circuits 25, dependent upon the range desired or available in the instrument since a single combination of condenser and coil cannot cover the broad range of frequencies possible in the system of my invention. A plurality of coils 25a are selectively associated with a single variable condenser 25b as the more convenient arrangement preferred in this embodiment of my invention.

The output of the thousands decade mixer is connected to suitable amplifying circuits including correspondingly selective tunable circuits. The output of the amplifiers may be employed for any of the purposes already set forth in this specification or for any purpose requiring a stable frequency of any magnitude within the range of the instrument at hand.

In Fig. 2, it is seen that while the units decade switch 1 selects only the crystal 1a to be used, the tens and hundreds decade switches 2 and 3 respectively, also select the proper tuned circuits 2b and 3b in the outputs of the oscillators for cooperation with the crystals 2a and 3a employed at each step. The thousands decade switch 4 selects the proper crystal 4a, proper tuned circuit 4b for cooperation with the crystal, and the desired tuning coil in the thousands decade mixer and in subsequent amplifiers.

The ranges of the hundreds decade mixer and the tens decade mixer are such that it is impossible to tune to anything but the desired frequency which in all cases is the sum of the two frequencies fed to the mixer under consideration. In the thousands decade, however, a wide range of frequencies must necessarily be covered, and it is possible in some cases with the circuit shown in Fig. 2, to tune to undesired frequencies such as the fundamental of one of the oscillator frequencies or to a difference frequency when a sum frequency is desired.

To eliminate any such undesired frequencies, I provide a circuit which may be termed a balanced rectifier circuit. This circuit is used as a mixer, and is shown schematically in Fig. 3 of the drawings.

Oscillator circuits I and II each comprise an electron tube having a piezo-electric element in the grid circuit thereof and tuning elements in the anode circuit. Oscillator I is coupled through a transformer 38 to a mixer circuit which includes a rectifier tube 40 which contains a pair of anode electrodes and a pair of cathode electrodes. The terminals of the secondary of transformer 38 connect to the two anodes in a balanced relation. The two cathodes of the electron tube 40 connect to the terminals of the primary of transformer 39 which constitutes the output of the mixer circuit. The secondary of transformer 39 connects to the input of the amplifier circuits.

Oscillator II is connected to the mixer circuit at the mid-tap of the secondary of the input transformer 38 and the mid-tap of the primary

of the output transformer 39. The sections of the primary of transformer 39, on either side of the center tap, are indicated by reference characters 42 and 42'. The secondary of the input transformer is tuned by a pair of simultaneously variable condensers 41 and 41' connected across the two halves of the secondary from the mid-tap.

The outputs of the two tubes 36 and 37 and associated circuits labeled as oscillators I and II, respectively, are fed to a rectifier mixer 40 and the output of the mixer is amplified, as shown. The output of oscillator II is coupled to the rectifier in such a manner that the two plates are in phase and, therefore, the currents flowing in coils 42 and 42', due to the action of the output of oscillator II, cancel (providing adjustments have been made with respect to the characteristics of each half wave rectifier and potential distribution). In this manner, the possibility of tuning to the fundamental of oscillator II or any of its harmonics is eliminated.

Oscillator I is coupled to the rectifier in such a manner that each plate of the rectifier circuit becomes alternately positive and negative. With both oscillators coupled to the rectifier, as indicated, the output circuit of the rectifier may be tuned to the sum of the two oscillator frequencies, the difference frequency or the fundamental of oscillator I. In actual practice, however, the frequency of oscillator I would be such that the tuned circuits in the amplifier would not tune to the fundamental. Therefore, the possible number of frequencies to which the mixer output circuit may be tuned is materially reduced. This is particularly advantageous in the automatic systems hereinafter described in connection with Figs. 4 and 6. As shown in Fig. 3, the output circuit of the mixer is tuned by reflection. In other words, the grid circuit of the amplifier is tuned and being coupled tightly to the output of the mixer, tuning results in that circuit also.

A refinement of the decade frequency synthesizing system shown in Fig. 2 is disclosed in Fig. 4 wherein all tuning and selection of component frequencies are effected automatically, the only manual control being by means of the telephone dial 43 such as is used on dial systems in land wire communication.

The dial 43, when rotated to a selected position and released, causes impulses of direct current to be produced by contacts 44. These impulses actuate a Strowger relay 45 which, in turn, rotates the selector switch 4 by means of a pawl and ratchet arrangement 46 to a position determined by the number of impulses transmitted by the operation of the dial 43. When the dial has completed the number of impulses determined by the amount of rotation, contacts 48 are closed. Contacts 47, having closed immediately as the Strowger relay 45 advanced the switch arms to the first contacts, and contacts 48 being closed in the home position of the dial, the relay 50 is closed, which, in turn, opens contacts 50a and closes contacts 50b and 50c. This operation removes all possibility of the first Strowger relay 45 acting after the first number is dialed, and also prepares the magnetic circuit of the Strowger relay 60 for operation on the second number dialed.

When the second number is dialed, the Strowger relay 60 is actuated, which, in turn, controls a selector switch 3 in the same manner as shown in connection with relay 45 and selector switch 4. Relay 61 and its associated contacts are actu-

ated in the same manner as relay 50. This system could be extended for any number of decades and the arrangement made so that the first number dialed would actuate the switches on the first decade, the second number dialed would actuate the switches on the second decade, etc.

After the last decade has been dialed, contacts sub *b* of the relay in the last decade group actuate a master relay which closes the "B" plus circuit to the amplifiers, and thus prepares the amplifier circuits for operation.

The tuning condensers 51 and the tuning condensers in all other amplifiers are caused to rotate by means of a motor 52 with reduction gearing, driving through a series of friction clutches 53 which may be disengaged magnetically. When resonance occurs in the first mixer circuit, a relay as shown at 54 is actuated and, in turn, disengages a friction clutch 53, stopping rotation of the tuning condensers 51 on resonance, and also closes auxiliary contacts 54*a* which supply plate voltage to the next amplifier. When this next amplifier is tuned to resonance, the same sequence occurs and when all amplifiers and mixer circuits are automatically tuned to the proper frequencies, all friction clutches will have been disengaged and no condensers will be rotating.

The desired frequency is thus produced, the only control being the numbered dial 43. For instance, if it is desired to produce 3445 kilocycles, it is only necessary to dial 3, 4, 4, 5. The apparatus is adjusted so that the operation of producing a frequency is completed in approximately five seconds after the last number is dialed.

After four numbers have been dialed, further dialing will result in no change in the set-up due to the interlocking system described. Therefore, if an error has been made in dialing, or if it is desired to produce a different frequency, or to cease operation of the instrument, a reset switch 62 is provided to automatically return the instrument to its normal condition for synthesizing a desired frequency. This switch breaks the circuit through the coils of the Strowger relays which actuate the switches 4, 3, 2 and 1, and supplies current to the release coils 64 of the Strowger relays, which allows the switches, by means of spring actions, to return to their initial positions. This destroys the tuned relation of the amplifier and mixer circuits and deenergizes the relays 54 etc., which, in turn, open the several "B" circuits and automatically engage the friction clutches 53 so that all the tuning condensers once more are rotating and the instrument is in condition for the synthesizing or production of another desired frequency.

The circuit of this automatic frequency control system is not shown completely but the essential details are illustrated to demonstrate the operation and the principles involved. The mixer circuit, as in Fig. 4 in the automatic frequency control system, is of the balanced rectifier type and tuning of the mixer output circuit is accomplished by tuning the input circuit of the amplifier.

In Fig. 6, there is disclosed an automatic decade frequency measuring system. In this circuit, the component parts are, in most cases identical in construction with those in the system shown in Fig. 4. However, no dial is used in this system and a printing apparatus actuated by the output of the system is included. A motor 52 is provided, which rotates the tuning condensers in each decade amplifier by means of friction

clutches 53 which may be disengaged magnetically. The motor also drives, through each clutch, a cam arrangement 65 which operates contacts 66. When contacts 66 are closed, Strowger relay 67 is energized and operates to advance the crystal selector switch and tuned circuit switch one tap. Condensers continue to rotate and tune through the range. If no beat frequency within the range of the tuning cycle is produced, the cam 65 again operates contacts 68, and energizes relay 67 to advance the selector switches another tap. This operation takes place until a beat frequency occurs between the incoming signal from the radio frequency amplifier and the crystal frequency which is being used. At this position of the condensers, there is an increase in the plate current in the amplifier which operates relay 68, releasing the friction clutch 53 and closing contacts 68*a* and 68*b*. Contacts 68*a* supply plate potential to the next amplifier and contacts 68*b* prepare Strowger relay 69 for operation.

The controls in the next decade continue to rotate and at each revolution advance the crystal selector and tuned circuit switches one tap until a beat frequency occurs. The relay 70 is then energized closing contacts 70*a* and 70*b*. This interconnection extends to include controls in each decade frequency unit.

In the arrangement shown in Fig. 6, the relay 70 is considered as connected in the units decade control, that is, the final selecting group, and contacts 70*a* are not employed. Contacts 70*b* on the other hand, are used to actuate mechanism necessary to automatically print the frequency measured on a tape to automatically record the frequency. As shown in Fig. 6, Strowger relay 71 is connected in parallel with Strowger relay 67 so that the angular motion at 71 is equal to that at 67 and is employed to rotate a drum 72 having on its periphery number dies 73 corresponding to the numbers on manually operated decade switches, as shown in the block diagram of the decade frequency unit in Fig. 5. Leads from Strowger relay coil 69 are shown "to next printer," indicating that they would actuate another relay and mechanism identical with that at 71 so that the number in the second frequency decade would be automatically printed when the entire operation of measuring had been completed. Each decade frequency section is thus provided with a printer unit, and when contacts 70*b* are closed, relay 75 is energized, and actuates the arm 76 which prints the numbers aligned on the several drums on a tape 77. At the same time, relay 75 also opens contacts 78 opening the plate circuits of the several amplifiers and returning the tuning mechanism to its original condition where all controls are rotating.

To measure a frequency between 3,000 and 7,999 kilocycles, a decade system with crystal frequencies and oscillators, as shown in Fig. 5, would be employed and could be embodied in either a manual or an automatic system. Consider a frequency of 4135 kilocycles. In order that the hundreds decade transmit energy, it is necessary to secure a beat frequency between the signal frequency, 4135 kilocycles, and some crystal frequency of the thousands decade oscillator which would be between 5,000 and 5,999 kilocycles. The only crystal frequency of the thousands decade oscillator which will give such a beat frequency is the thousand kilocycle crystal which, when using the sum frequency, will produce the beat frequency of 5135 kilocycles. Referring again to the

block diagram in Fig. 5, it is seen that when the 1,000 kilocycles crystal is in use in the thousands decade, the crystal selector switch or decade switch is set on 4 or 6. The connection in this case is the reverse of that in the frequency building system wherein, when the switch is on contact 4, the 1000 kilocycles oscillation is connected to give the difference frequency between itself and the incoming oscillation from the hundreds decade mixer. Four, then, is the tap selected and 4,000 is the measurement given by the thousands decade. Next, it is necessary to mix a frequency with 5135 kilocycles to produce a frequency between the limits of 1500 and 1599 kilocycles, the tuning range of the tens decade mixer. 3600 kilocycles, when mixed with 5135 kilocycles will produce a difference frequency of 1535 kilocycles. 3600 kilocycles in the hundreds decade corresponds to 1 on the crystal selector switch and thus, we have 4100 as the measurement by the thousands and the hundreds decades.

It is now necessary to mix a frequency with 1535 kilocycles to produce a frequency between the limits of 150 and 159 kilocycles, the range of the units decade. 1380 kilocycles in the tens decade oscillator will produce, when mixed with 1535 kilocycles, a difference frequency of 155 kilocycles. 1380 kilocycles corresponds to 3 on the decade switch in the tens decade and thus 3 is the third number in the measured frequency and we have 4130 as the measurement at this stage. The 150 kilocycle oscillation is now mixed with a frequency from the units decade to produce the lowest audible beat note. In this case, the 155 kilocycle crystal in the units decade corresponding to 5 on the decade switch will produce a zero beat frequency and the original input frequency has been measured as being 4135. While the zero "audio" frequency cannot be heard, it is found at tap 5 between 1000 cycle notes on taps 4 and 6, 2000 cycle notes on taps 3 and 7, etc., and is thus easily identified.

In the manual system, the correct tuning to obtain the beat frequency in the range of the unit is indicated by the deflection of the needle in the meter in the output circuit of the respective mixer. In the automatic system, the relay in the output circuit automatically responds to the increase of current at the position of correct tuning, or resonance.

The automatic decade frequency measuring system operates electrically in approximately the reverse of the manner of operation of the dialing system for producing frequencies, the main differences being that changes in crystal frequencies are initiated automatically and that the usable range is automatically searched, with the energy progressing to the printing recorder.

The signal receiver has incident on its antenna all frequencies transmitted, but will be resonant only to the beat between 1600 and 3000 kilocycles (1400 kilocycles) since the tuning in the unit is fixed for 1400 kilocycles. The fixed tuning at the station shown, is, therefore, in the control receiver for 3000 kilocycles and in the signal receiver for 1400 kilocycles. Another station may be resonant to 3020 kilocycles having the control receiver tuned to 3020 kilocycles and the signal receiver tuned to 1420 kilocycles.

The signal transmitters at the called stations are, fundamentally, standard 1800 kilocycle transmitters (1800 for purposes of illustration). This frequency, beating with the control frequency of 3000 kilocycles, gives a 1200 kilocycle carrier from this station. The single alternative case cited

would employ a 3020 minus 1800 or 1220 kilocycle carrier.

At the signal receiver at the central station, the incoming carrier frequency, 1200 kilocycles, is heterodyned by the control frequency dialed, 3000 kilocycles, to give an 1800 kilocycle carrier, to which the tuning in the receiver is fixed. The control frequency of 3020 kilocycles would beat with the carrier frequency of 1220 kilocycles to give the same 1800 kilocycle carrier. Thus, the signal receiver, at the central station may be permanently tuned to 1800 kilocycles.

Then, to call any station in the system, it is only necessary to dial its "number" (the control frequency to which the control receiver at the desired station is resonant). No other adjustment is made anywhere, in either transmitter or receiver. Scrambling or other suitable means for obtaining secrecy may be employed, if desired. Actuating the reset switch breaks the "connection".

Fig. 7 shows a perspective view of a cabinet structure showing the arrangement of the selective controls and indicating meters in the manual systems of my invention.

I have shown my invention particularly adapted for operation with piezoelectric crystals, but I desire that it be understood that my invention is equally adaptable to magnetostriction and other types of constant frequency devices.

While I have described my invention in certain of its preferred embodiments, I desire it to be understood that modifications may be made and that no limitations upon my invention are intended other than may be imposed by 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. An oscillation generator adapted to produce any one of a plurality of predetermined frequencies comprising a plurality of auxiliary oscillation generators, said auxiliary oscillation generators being arranged in a series such that the first oscillation generator is adapted to produce a plurality of frequencies increasing in steps of one thousand frequency units; an indicator for said first oscillation generator, said indicator having a plurality of digits each corresponding to a different frequency generated; the second oscillation generator is adapted to produce a plurality of frequencies increasing in steps of one hundred frequency units; the third oscillation generator is adapted to produce a plurality of frequencies increasing in steps of ten frequency units and the fourth oscillation generator is adapted to produce a plurality of frequencies increasing in steps of one frequency unit; an indicator for each of said second, third, and fourth oscillation generators, each of said last mentioned indicators having a plurality of digits thereon, each digit corresponding to a different frequency produced by the corresponding generator, means including a mixer circuit connected to each of said generators except said fourth generator for mixing the frequencies derived from selected ones of said oscillation generators for producing a certain predetermined desired frequency, the digits of said indicators being so arranged with respect to the frequencies of said first, second, third, and fourth oscillation generators that the value of the certain desired frequency is given by said indicators direct by collecting the digits indicated by said dials corresponding only to the frequencies of said oscillation generators used to obtain said desired frequency.

quency, the frequencies generated by said oscillation generator being other than harmonically related.

2. An oscillation generator adapted to produce
5 any one of a plurality of predetermined frequencies comprising a plurality of oscillation generators, one of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one thousand frequencies
10 quency units, a second of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one hundred frequency units, a third of said oscillation generators including means for producing
15 a plurality of frequencies increasing in steps of ten frequency units and a fourth of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one frequency unit, mixer circuits for said first,
20 second, and third generators, an indicator for each of said oscillations derived from said generators to said mixer circuits for producing a desired frequency of predetermined value through the combined efforts of said generators, an indicator for each
25 of said oscillation generators, each of said indicators having a plurality of digits corresponding to the number of frequencies to be developed by the corresponding generator, the digits of each of said indicators being so arranged with
30 respect to each of the frequency selectors of each of said first, second, third, and fourth oscillation generators that the value of the desired frequency produced by the combined efforts of said generators is given by said indicators direct
35 by collecting the digits indicated by said indicators corresponding only to the frequencies of said oscillation generators used to obtain said desired frequency, the frequencies generated by said oscillation generator being other than harmonically related.
40

3. An oscillation generator adapted to produce any one of a plurality of predetermined frequencies comprising a plurality of oscillation generators, one of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one thousand frequency units, a second of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one hundred frequency units, a third of said oscillation generators including means for producing
45 a plurality of frequencies increasing in steps of ten frequency units and a fourth of said oscillation generators including means for producing a plurality of frequencies increasing in steps of one frequency unit, a mixer circuit for said first generator, means for feeding oscillations derived from the combined efforts of said second, third,
50 and fourth oscillation generators to said mixer circuit to develop oscillations of a predetermined desired frequency means for indicating the value of said desired frequency when said desired frequency is being generated, said last mentioned means including an indicator for each of said
55 oscillation generators, each of said indicators having a digit corresponding to each of the frequencies the generator may develop, the digits of each of said indicators being so arranged with respect to each of the frequency selectors of
60 each of said first, second, third, and fourth oscillation generators that the value of the desired frequency oscillations is given by said indicators direct when said desired frequency is generated, by collecting the digits indicated by said indicators
65 corresponding only to the frequencies of

said oscillation generators used to obtain the desired frequency, the frequencies generated by said oscillation generator being other than harmonically related.

4. An oscillation generator system comprising
5 first, second, third, and fourth sets of electromechanically vibratile standard frequency elements, said second, third, and fourth sets each including ten elements, the frequencies of the elements of each of said sets being arranged to
10 increase progressively by predetermined steps, an indicator device for each of said sets of electromechanically vibratile elements, each of said indicator devices for said second, third, and fourth sets having ten digits 0 to 9, inclusive
15 thereon corresponding to the ten standard frequency elements included in the corresponding set, means for deriving any one of a plurality of predetermined desired frequencies from said oscillation generator system, the digits on said indicators being so arranged with respect to the
20 frequencies of said first, second, third, and fourth sets of electromechanically vibratile elements that the value of the desired frequency is given direct by said indicators when said desired frequency is produced by collecting the digits corresponding to the elements used in each of said sets and arranging the collected digits in the order of said sets of elements, the frequencies generated by said sets of electromechanically
25 vibratile standard frequency elements being other than harmonically related.
30

5. An oscillation system comprising at least three oscillation generating units, each of said units including an electric discharge device and
35 a set of ten vibratory members of different frequencies, the frequencies of each of said sets of vibratory members being arranged in an arithmetical progression, selecting means for connecting selected ones of said vibratory members to said electric discharge devices, means connected to said electric discharge devices for mixing the oscillations produced by different ones of said vibratory members and said discharge devices for producing oscillations of any frequency
45 of a plurality of predetermined frequencies, and indicating means for said selecting means for designating each of said vibratory members in each of said sets by a predetermined digit from 0 to 9 inclusive, said digits being arranged with respect to said vibratory members in a manner such that the frequency of the desired frequency being produced is given direct by collecting the digits corresponding to the vibratory members used to produce the desired frequency from said
50 indicating means in a predetermined order, the frequencies generated by each of said oscillation generator units being other than harmonically related.
55

6. An oscillation system comprising a multiplicity of oscillator elements divided into several groups, a plurality of selector means, each of said selector means being associated with one of said groups of said oscillator elements, a decade of oscillator elements constituting one of said
65 groups associated with one of said selector means, said decade of elements being adapted to generate a series of frequencies having a constant difference of one unit of the order of frequencies employed, a second decade of oscillator elements constituting a second one of said groups associated with the second of said selector means, said second decade of elements being adapted to generate a series of frequencies having a constant
70 difference of ten units of the order of frequencies
75

employed, a third decade of oscillator elements constituting a third one of said groups associated with a third of said selector means, said third decade of elements being adapted to generate a series of frequencies having a constant difference of one hundred units of the order of frequencies employed, each successive decade of said groups of elements being adapted to generate series of frequencies having constant differences in the same ratio, means for combining the selected frequencies produced in said decade groups of oscillator elements for generating the desired frequency, and indicating means for each of said oscillator elements and associated with each of said selector means, said indicating means for said first, second, and third decades including digits 0 to 9 inclusive, one digit for each frequency value in each decade, said digits being arranged in an order such that a predetermined desired frequency may be produced by the oscillation system by setting said selector means on predetermined ones of said digits corresponding to the numbers of the value of the frequency desired, the frequencies generated by each of said groups of oscillator elements being other than harmonically related.

7. In an oscillation system adapted automatically to synthesize a desired frequency, a multiplicity of oscillator elements divided into several groups, a plurality of selector means each connected to the oscillator elements of one of said groups, oscillation means connected to each of said groups of elements, mixer circuits connected to said oscillation generator means, tuning means included in said mixer circuits, means for automatically varying said tuning means, means for generating current impulses, means connected to said last mentioned means for automatically actuating each of said selector means, means whereby successive series of current impulses separately actuate different ones of said selector means, automatic means for each of said mixer circuits for stopping the varying of said tuning means when said tuning means is resonant to the selected frequency and an output circuit for receiving the frequency developed by the combined effects of said oscillation generators.

8. In an oscillation system adapted automatically to produce a desired frequency, a multiplicity of oscillator elements, selector means connected to each of said oscillator elements, an electric discharge device oscillation generator, a mixer circuit connected to said oscillation generator tuning means included in said mixer circuit, means for automatically varying said tuning means, means for generating current impulses, means connected to said last mentioned means for automatically actuating said selector means, and automatic means for said mixer circuit for stopping the varying of said tuning means when said tuning means is resonant to a selected frequency.

9. In an oscillation system adapted automatically to produce a desired frequency, a mul-

tiplicity of oscillator elements, selector means connected to each of said oscillator elements, an electric discharge device oscillation generator, a mixer circuit connected to said oscillation generator, tuning means included in said mixer circuit, means for continuously varying said tuning means, manually controlled means for generating current impulses, means connected to said last mentioned means for automatically actuating said selector means, and automatic means for said mixer circuit for stopping the varying of said tuning means when said tuning means is resonant to a selected frequency.

10. In an oscillation system adapted automatically to synthesize a desired frequency, a multiplicity of oscillator elements divided into several groups, a plurality of selector means each connected to the oscillator elements of one of said groups, oscillation generator means connected to said oscillator elements, tuning means connected to said oscillation generator means, means for automatically varying said tuning means, means for generating current impulses, means connected to said last mentioned means for automatically actuating each of said selector means, means whereby successive series of current impulses separately actuate different ones of said selector means, automatic means for stopping the varying of said tuning means when said tuning means is resonant to the selected frequency and an output circuit for receiving the desired synthesized frequency.

11. A system for generating radio frequency oscillations comprising several decades of oscillating circuits, oscillation mixing circuits connected between any two decades, means for selecting particular oscillating circuits in each decade, means for indicating by digits the particular oscillating circuit selected in each decade, the mixed oscillations of all the decades giving a final oscillation, said final oscillation being numerically equivalent to the number represented by the digits collected from each indicating means in a predetermined order, the frequencies generated by said several decades of oscillating circuits being other than harmonically related.

12. In a system for synthesizing a radio frequency oscillation of a predetermined value, a series of oscillator decades, mixing circuits connected between any two decades, selector means associated with each of said decades, said selector means having indicating means carrying digits representative of the value of each oscillator selected within a decade, means for manually selecting a certain digit from each decade indicating means, collection of the digits selected in a predetermined order being representative of the numerical value of the oscillation frequency desired, the frequencies generated by said series of oscillator decades being other than harmonically related, and means associated with said decades for automatically synthesizing the oscillation frequency desired.

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