

May 28, 1946.

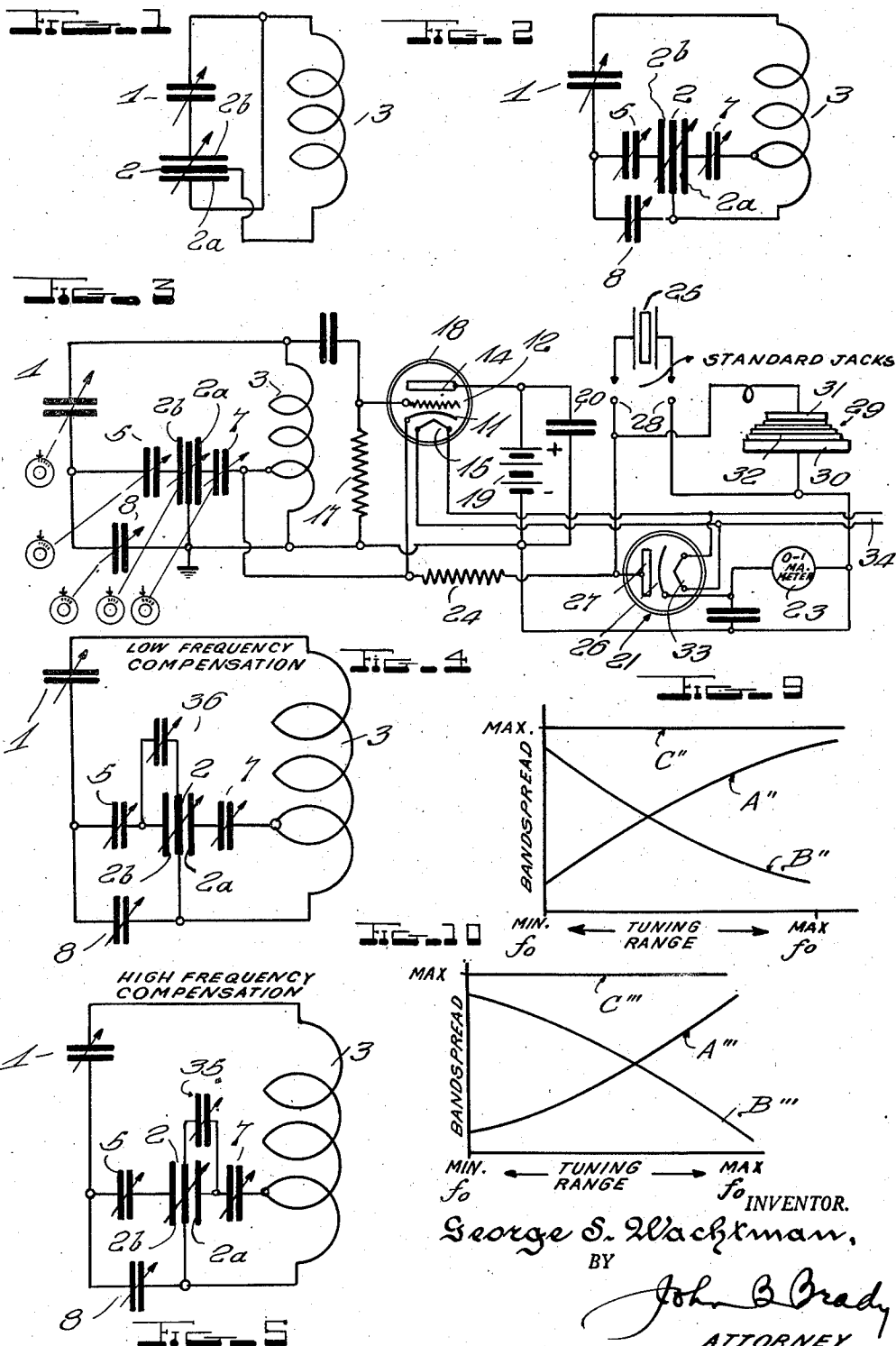
G. S. WACHTMAN

2,400,895

ELECTRON TUBE APPARATUS

Filed Oct. 5, 1943

3 Sheets-Sheet 1



May 28, 1946.

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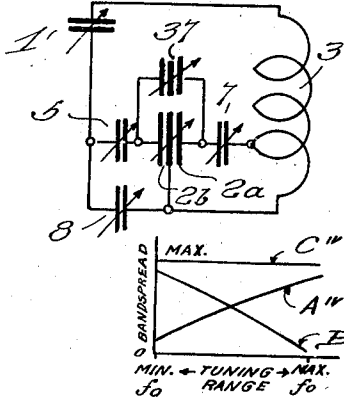
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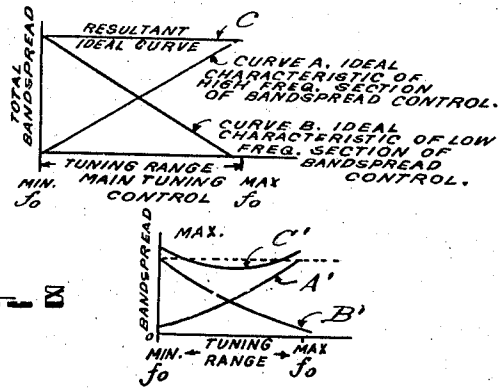
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Fig. 6 HIGH AND LOW FREQUENCY COMPENSATION

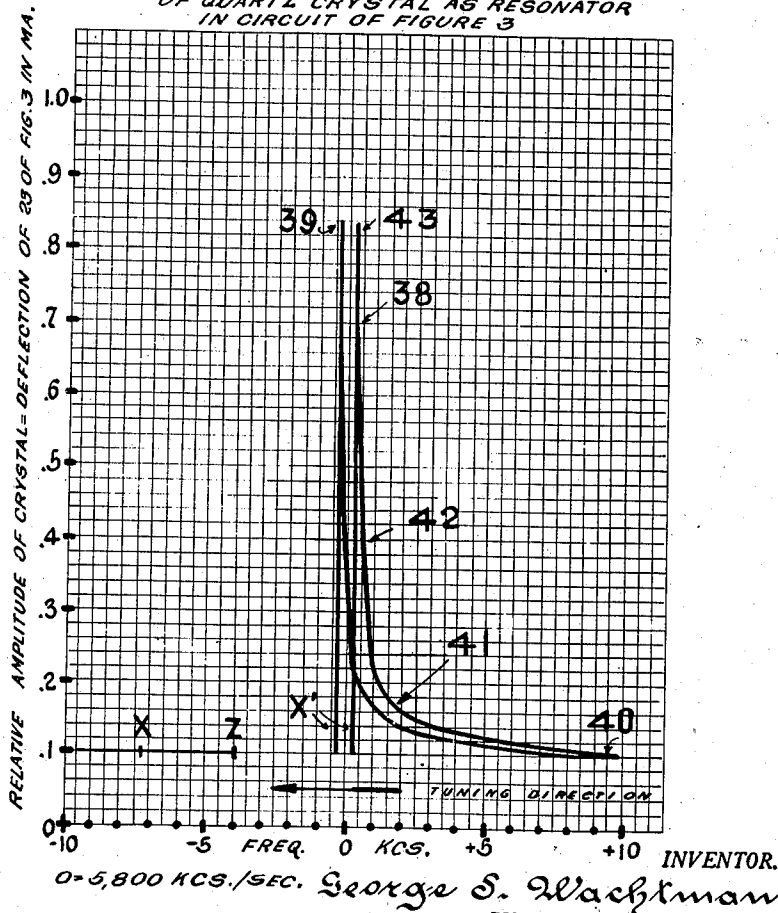


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AMPLITUDE - FREQUENCY CHARACTERISTIC
OF QUARTZ CRYSTAL AS RESONATOR
IN CIRCUIT OF FIGURE 3



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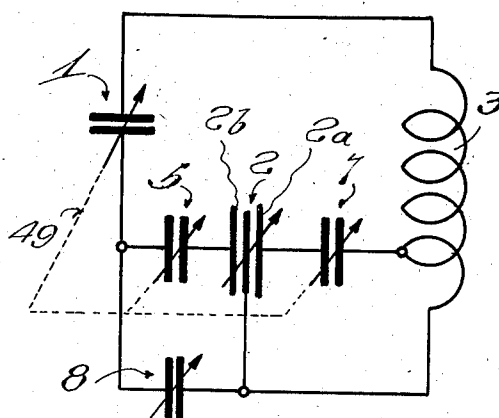
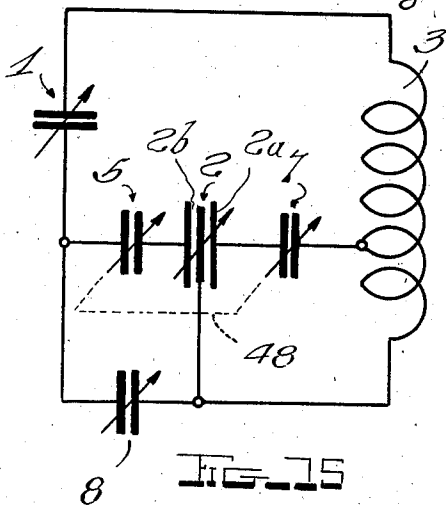
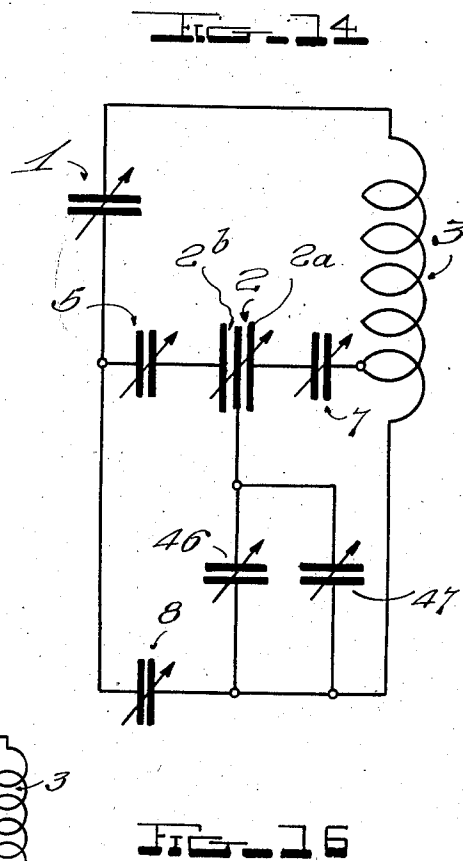
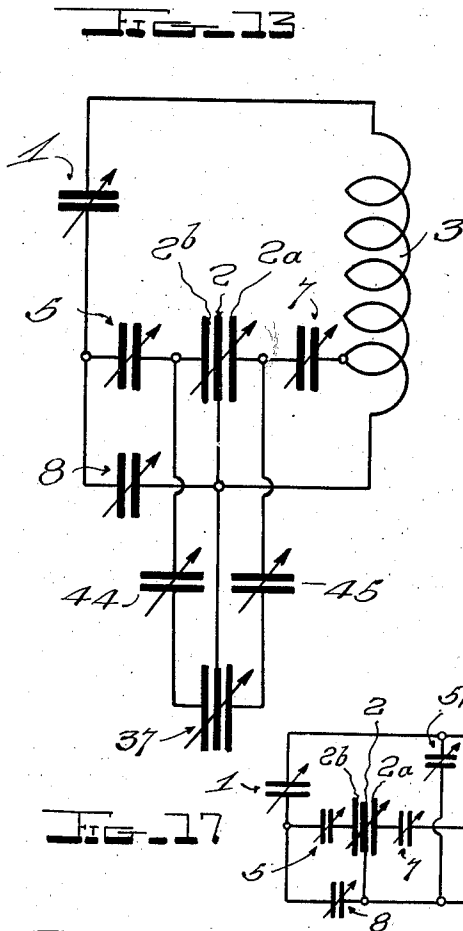
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,400,895

ELECTRON TUBE APPARATUS

George S. Wachtman, Harrisburg, Pa.

Application October 5, 1943, Serial No. 505,048

8 Claims. (Cl. 250—40)

My invention relates broadly to circuit arrangements for electron tube apparatus and more particularly to circuits for controlling the resonant frequency of tunable circuits over a variable frequency range.

One of the objects of my invention is to provide an improved circuit arrangement for controlling the resonant frequency of electrically tunable circuits over a predetermined frequency range by coacting broad and fine frequency control means.

Another object of my invention is to provide a compensating control system for tunable circuits by which broad and fine frequency adjusting means operate integrally in the control of the resonant frequency of the circuit for securing substantially linear frequency changes over a relatively wide band spread.

Still another object of my invention is to provide a circuit arrangement for applying the frequency compensating control circuit of my invention to production test circuits in the manufacture of piezo electric crystal frequency control elements.

A further object of my invention is to provide a circuit arrangement for comparing the frequency of rapid production piezo electric crystals with a frequency standard for producing crystals of selected frequency on a quantity basis with minimum expenditure of time.

Other and further objects of my invention reside in improved electric circuit systems for testing piezo electric crystals as set forth more fully in the specification hereinafter following, in which:

Figure 1 schematically illustrates a resonant circuit embodying the broad and fine tuning control arrangement of my invention; Fig. 2 shows a modified arrangement of tuning control system embodying my invention; Fig. 3 schematically shows the application of the circuit of Fig. 2 to a system for testing piezo electric crystals in accordance with my invention; Fig. 4 shows a further form of frequency control circuit embodying my invention and illustrating the application of low frequency compensation means in the circuit; Fig. 5 shows the circuit arrangement of my invention with high frequency compensation means added to the circuit of my invention; Fig. 6 illustrates a further modification of the frequency control circuit having both high and low frequency compensation means added to the frequency control circuit; Fig. 7 is a curve diagram showing the ideal characteristic curves of the circuit arrangements of my invention; Fig. 8 illustrates practical conditions which may be encountered

unless high precision operation is secured in the frequency control system of my invention; Fig. 9 shows the characteristic curves obtainable upon adjustment of the high frequency compensation means illustrated in the circuit arrangement of Fig. 5, all other components remaining the same as in Fig. 2; Fig. 10 illustrates the characteristic curves obtainable when the low frequency compensation means is employed in the circuit arrangement shown in Fig. 4, all other circuit components remaining the same as in Fig. 2; Fig. 11 illustrates the characteristic curves obtainable in the circuit of Fig. 6 embodying both high and low frequency compensation, all other components remaining the same as in Fig. 2; Fig. 12 is a graph diagram explaining the theory of operation of the circuit of my invention as in Fig. 3; Fig. 13 shows a further modified form of precision adjustment circuit embodying my invention; Fig. 14 illustrates another modified form of circuit embodying my invention; Fig. 15 shows still another modified form of circuit embodying my invention; Fig. 16 is a circuit diagram of a further modification of the circuit of my invention; and Fig. 17 shows a further modified circuit embodying my invention in which the maximum frequency to which the system is tunable may be adjusted with precision.

My invention provides means for controlling the resonant frequency of electrically tuned circuits over a predetermined frequency range by a broad tuning control and over a smaller but constant frequency range by a fine tuning control at any setting of the broad tuning control. My invention is applicable to many different kinds of electrical systems and is illustrated in this specification in conjunction with an electron discharge device and an indicating meter for testing piezo electric crystal elements for activity and frequency.

Figure 1 illustrates in the simplest schematic form a resonant circuit embodying such control elements, 1 being the broad tuning control, 2 being the fine tuning control, and 3 the associated impedance or impedances necessary to resonate the circuit. 2 of Fig. 1 is a split-stator or dual-section variable condenser, or two or more variable condensers ganged together and controlled from one control. By "ganged" I mean that the condensers are arranged so that their capacities vary in the same direction. One section of the split-stator or dual condenser or one or more of the ganged condensers is connected effectively in series with the main tuning con-

trol 1, and the impedance 3, and the other section or ganged condensers is connected effectively in parallel with the main control 1 and the impedance 3. The serially connected section of 2 is chosen so that it has as much control of the resonant frequency at maximum capacity setting of 1 as the parallelly connected section has at the minimum capacity setting of 1, the resultant action being that 2 exerts a practically constant control of the frequency at any setting between and including minimum and maximum capacity of 1 with any one impedance or lumped impedances.

Fig. 2 illustrates a practical control circuit, the action of which is basically the same as that of Fig. 1. 1 is the broad tuning condenser and 2 is the fine tuning condenser, 3 being the impedance. 5 and 7 are trimmer condensers, whereby the control action of the fine tuning control 2 may be adjusted, and 8 is a condenser whereby the minimum or lowest tunable frequency of the combination may be adjusted.

Fig. 3 illustrates one use of the circuit of Fig. 2 with an electron discharge device 18 as a generator or oscillator connected through a common impedance or reactance 24 to another electron discharge device 21, used in conjunction with a meter 23 as an indicating device to indicate the point or points of resonance and maximum activity of either a standard piezo-element or a piezo-element which it is desired to test. The resonant circuit elements in Figs. 2 and 3 are represented by similar reference characters. Electron discharge device 18 includes cathode 11, control grid 12 and anode 14 with provision for heating cathode 11 from filament heater 15. High potential source 19 connects to anode 14 as shown. Condenser 20 connects between the input and output circuits of the oscillator constituted by electron discharge device 18, as illustrated. Electron discharge device 21 includes cathode 26 and anode 27 connected in a series path through meter 23 across the circuit through jacks 28 into which the standard piezo electric crystal 25 may be plugged and also across the test jig 29. Test jig 29 has a fixed plate 30 serving as a support for the crystal 32 to be tested and a movable plate 31 adapted to be placed in contact with the upper face of the crystal 32 to be tested. Cathode 26 of electron discharge device 21 is heated by filament heater 33 connected in parallel with filament heater 15 to suitable source 34 as shown. Essentially, Fig. 3 is comprised of two units connected through a common impedance or reactance, the one being a generator comprising tube 18 and the other a diode vacuum-tube voltmeter comprising tube 21, across the input of which the piezo elements 32 are inserted and tested by varying the resonant frequency of the generator to correspond to any of the resonant frequencies of the piezo-element under test. The accuracy of control of frequency is determined by (a) the stability of the oscillator, (b) the calibration, (c) the accuracy of standardization against a known standard frequency, and (d) the accuracy of the known standard. These four factors may be held to a close minimum, thereby allowing very fine control of frequency.

For purposes of understanding the operation of the system of my invention illustrated in Fig. 3, the values of the elements employed in one of the practical forms of the circuit of my invention are as follows:

Variable condenser 1	325 micro-microfarads
Split stator variable condenser 2	Each section 25 micro-microfarads
5 Trimmer condenser 5	5-50 micro-microfarads
Trimmer condenser 7	5-50 micro-microfarads
Fixed condenser 8	70 micro-microfarads
10 Fixed condenser 16	250 micro-microfarads
Fixed condenser 20	0.1 microfarad
Fixed condenser 22	0.1 microfarad
Inductance 3	8.5 microhenries — 20 turns 1.5" in diameter x 1.375" long tapped 1/3 the distance from the grounded end
Resistance 17	6,000 ohms
20 Resistance 24	10,000 to 30,000 ohms

In the arrangement shown in Fig. 3, the frequency is continuously variable from 5,400 kcs./sec. to 9,200 kcs./sec. by varying condenser 1 and is also variable over a 100 kcs./sec. range by varying condenser 2 regardless of the setting of condenser 1. 2a and 2b are the two sections of the dual-section, ganged variable condenser 2 controlled by one dial or knob, or other control. The range covered by the bandspread control may be varied by adjusting trimmer condensers 5 and 7. Condensers 5 controls the amount of spread at the lower frequencies while trimmer condenser 7 controls the spread at the higher frequencies. The control action exerted by both is approximately equal at mid-frequency.

The capacity of condenser 8 directly affects the range covered or tuned by condenser 1, more capacity increasing the range and less capacity decreasing the range.

The operation of the oscillator embodying the tube 18 is as follows: The necessary voltages are applied to the cathodes and other elements of the tubes 18 and 21, and the movable electrode 31 of the "test jig" 29 insulated from the supporting stage 30 by some good low-loss dielectric. The bandspread control is set at mid-range and a standard crystal 25 i. e., a finished quartz crystal plate that has been standardized for frequency against a primary or secondary frequency standard in a suitable holder, is inserted into the "standard jacks."

Now condenser 1 is varied until the 0-1 milliammeter shows maximum deflection. (Incidentally, resistance 24 is chosen so the milliammeter is just deflected full scale with a good crystal plugged into the "standard jacks" 28 and the oscillator tuned to the crystal's main or fundamental response.) This process is known as "standardizing an oscillator" or just "standardizing" and can be done equally as well with a primary or secondary frequency standard and receiver in conjunction with the oscillator. When the oscillator is "standardized" the crystal is removed from the "standard jacks" and the low-loss insulator from the "test jig" 29 and a blank unfinished but lapped quartz plate inserted between the movable electrode and the plate. If the main or fundamental frequency or response of the blank lies within ± 50 kcs./sec. of the frequency of the "standard crystal" it may be determined by rotating condenser 2, meanwhile letting condenser 1 remain as it was when standardized, until the milliammeter 23 shows maximum deflection and the reading taken from a precalibrated

dial or scale under a pointer carried by the bandspread tuning control either added to or subtracted from the frequency of the standard crystal. The bandspread dial or scale may be calibrated as desired, the equipment in the example herein described being calibrated 0 to 50 kcs./sec. plus and minus for mid-frequency range and 0-100 kcs./sec from right to left in 5 kcs./sec. intervals.

By properly "standardizing" and calibrating the bandspread range and dial or scale, the overall error may be kept down to 2.5% or less of the bandspread range or .066 of 1% or less of the range covered by condenser 1 constituting the main tuning control in the circuit arrangement illustrated in Fig. 3.

The above mentioned inherent accuracy of measurement and the fact that the bandspread range is constant within the small amount mentioned above at any setting of condenser 1 are the oscillator's two most unique features and coupled with the fact that the crystal is driven or excited by the radio frequency voltage generated by the oscillator, and appearing at the "standard jacks" or the electrodes of the "test jig" at the crystal's resonant frequency adapts it very effectively for the production testing of rough, unfinished, lapped blanks to a close tolerance.

Due to the fact that the two sections of the bandspread control 2 of Fig. 2 always exert some control over the resonant frequency of the circuit, regardless of the setting of the main tuning control 1 of Fig. 2, the ideal control characteristic for each section of the bandspread control (as illustrated by curves A and B of Fig. 7) is never realized. Instead curves A' and B' of Fig. 8 actually obtain for the circuit of Fig. 2, curve C' being the resultant. Consequently some means of compensating for the non-linearity of curve C', Fig. 8, must be employed if accurate work is to be done with the circuit. This is accomplished by employing one or more variable condensers, or a dual-section or split-stator variable condenser in parallel with one or more sections of the bandspread control. The action of the compensating condensers is to adjust the minimum and maximum capacity of the parallel combination, thereby effectively controlling the tuning range of the bandspread control.

The foregoing compensating controls are illustrated in Figs. 4, 5 and 6 whereby the ideal resultant curve C of Fig. 7 may be approached very nearly, as shown by the curves C'', C''' and C^{IV} of Figs. 9, 10 and 11. In Figs. 7, 8, 9, 10 and 11, the curves A, A', A'', A''' and A^{IV} represent the control action of the high-frequency control section of the bandspread control, curves B, B', B'', B''' and B^{IV} represent the control action of the low-frequency control section 2b of the bandspread control, and since the effects of the two sections 2a and 2b are additive, curves C, C', C'', C''' and C^{IV} represent the resultant action of curves A, B; A', B'; A'', B''; A''', B''' and A^{IV}, B^{IV}, respectively.

The curves of Fig. 9 illustrate the control actions and the resultant action where a variable condenser 35 is employed as the high frequency compensating control in the circuit of Fig. 5, all other components remaining the same as in Fig. 2.

The curves of Fig. 10 illustrate the control actions and the resultant action where a variable condenser 36 is employed as the low frequency compensating control in the circuit of Fig. 7.

4, all other components remaining the same as in Fig. 2.

The curves of Fig. 11 illustrate the control actions and the resultant action where a split-stator or dual-section variable condenser 37 is employed as the compensating control for both high and low frequencies in the circuit of Fig. 6, all other components remaining the same as in Fig. 2.

As may readily be seen from the curves of Figs. 9, 10 and 11, the resultant curves C'', C''' and C^{IV} are identical with curve C of Fig. 7, but the separate control curves A'', A''', A^{IV} and B'', B''' and B^{IV} only approximate curves A and B of Fig. 7, curves A^{IV} and B^{IV} of Fig. 11 most nearly approaching the ideal.

The uses to which the above-described control circuits can be put are manifold. For example, it can be applied to various circuits of the kind shown in Fig. 3, wherein it is used to test lapped quartz blanks for activity and frequency to a close tolerance before they are hand-finished and put in holders. It can be used in receivers where it is desired to have a continuous bandspread of frequency; i. e., one that is constant at any setting of the main tuning control. In conjunction with a local piezo-oscillator (frequency to be determined by type of use) and a receiver, and used in a stable variable frequency generator circuit by "standardizing" at time of use, it can be used to determine the frequency of another signal within a few cycles. This is done by heterodyning the signal emitted by the generator against the unknown signal and detecting the heterodyne beat by audible or electrical or electromechanical means and then reading frequency by interpolation from a known standard signal (local piezo oscillator) and the calibration on the dial of the fine-tuning control. It can also be used to control the frequency of the emitted radiation of a radio transmitter, allowing the frequency to be varied over a wide range, and yet, by means of the fine-tuning control and pre-standardization against a local piezo-oscillator or other primary or secondary frequency standard, control the frequency within a few cycles of the desired frequency.

The applications of this invention, as can be seen from the foregoing, are almost limitless. The control circuit can be applied to any device wherein the resonant frequency is desired to be variable. It can be applied to capacity-inductance or capacity-resistance or other impedance-tuned generator or oscillators, to tuned circuits, such as radio frequency, intermediate frequency or audio frequency stages in amplifiers, receivers, filters, etc., or to other tuned circuits wherein any combination of capacity, inductance, resistance, or reactance is used.

It will be observed by referring to Fig. 3 of the drawings that the variable tuned circuit, composed of condensers, 1, 2, 5, 7, and 8, inductance 3, and the tube 13, are so connected that they form an oscillating circuit of the self-excited or electron-coupled type. This circuit is designed to oscillate with or without a crystal in the "standard jacks" 28 or "test jig" 29.

A radio frequency voltage is taken from the self-excited oscillator at an appropriate point on the inductance coil 3 (usually at the point where the cathode 11 of the tube 13 connects to the coil 3), and fed into a voltage divider which is comprised of the impedance or reactance 24 and the inter-electrode-capacity and input ad-

mittance or resistance of the diode 21 plus the electrode capacity of the crystal when it is connected in the circuit either by inserting it in a holder into the "standard jacks" 28 or inserting the crystal blank into the "test jig" 29. The voltage appearing at the low end of the impedance 24 is fed to the crystal via the "standard jacks" 28 or the "test jig" 29 and drives the crystal when the frequency generated by the oscillator is the same as the resonant frequency of the crystal. The amplitude of oscillation of the crystal is indicated by the meter 23 which is a direct indication of its quality as an oscillator. Theoretically, the impedance was designed not only as one leg of the voltage-divider, but also to isolate the crystal from the tuned circuit of the self-excited oscillator. Actually, the isolation is not complete and consequently the crystal exerts some control over the resonant frequency of the system.

The graph in Fig. 12 illustrates this action for a typical crystal, curve 38 representing the action for the crystal in a typical holder and inserted into the "standard jacks" 28, curve 39 representing the action for the same crystal between the electrodes of the "test jig" 29, the frequency difference being due to the fact that the electrodes between which the crystal is clamped in the holder, and which in turn is inserted into the "standard jacks" 28, have a predetermined air-gap, thereby effectively raising the resonant frequency of the crystal above what it would be if the electrodes were plane or flat as are those of the "test jig" 29. Incidentally, there is a steady deflection of the meter 23 of approximately 0.1 ma., due to contact voltage in the diode 21 and the radio frequency voltage from the divider when the oscillator is tuned off resonance of the crystal, or even when there is no crystal in the circuit.

Now, as in the graph, operating about a central frequency of 5800 kcs./sec., let us follow the curve 38 with reference to the various points indicated and moving in the direction indicated by the arrow. Beginning at the point 40, the amplitude increases very gradually to a point 41, $\frac{1}{10}$ of the distance or frequency of point 40 from the limit of curve 38 at 43, beyond which point it begins to rise at a more rapid rate until at a point 42, $\frac{1}{2}$ of the distance 41 from the limit of curve 38 at 43, it rises very rapidly to a maximum at point 43. Any attempt to tune for more amplitude or a lower frequency only results in the crystal amplitude falling almost instantaneously to zero (X¹), and the frequency of the self-excited oscillator jumping to the point X. Now, however, if the oscillator is tuned in the reverse direction, higher in frequency, at point Z the frequency will again jump, this time to the point 42, the amplitude of the crystal rising at the same time to this same point. It is evident, as stated before, that the crystal exercises some control over the resonant frequency of the self-excited oscillator, there being some pulling action present between the crystal and the tuned circuit.

When the frequency of the voltage generated by the oscillator is the same as the resonant frequency of either the standard or test crystal, provided one or the other is connected into the circuit, the crystal will oscillate, and, due to resonant step-up, and because of the variation of impedance across the crystal electrodes, the radio frequency voltage will increase to a maximum, thereby increasing the rectified direct current

through the diode 21, and the meter 23, causing the meter to indicate a current maximum at maximum resonance of the crystal. The voltage indicated by the meter is that generated by the self-excited oscillator in all cases.

The procedure in using the circuit of Fig. 3 to compare a rough blank or other crystal against a standard crystal is as follows:

1. Insert the standard crystal 25 into the circuit either via the "standard jacks" 28 or the "test jig" 29.
2. Set the bandspread control 2 at mid-point on its dial calibration.
3. Tune or adjust the main tuning control 1 until the meter 23 indicates a maximum current.
4. Remove the standard crystal 25 from the circuit.
5. Do not touch the main tuning control after completion of step 3 above.
6. As to any crystal the frequency of which is within the range of the bandspread control's range on either side of the standard crystal's frequency, its frequency may be determined by rotating the bandspread control and adding or subtracting from the standard crystal frequency, as the case may be, the amount indicated on the calibration under the pointer on the control knob. Of course the calibration and range of the main tuning and bandspread controls are determined and set according to the use to which it is to be put.

7. If the instrument has a means of compensation of bandspread range such as condensers 35, 36, 37 of Figs. 4, 5 and 6, then this control should be set before step #2 to a point determined by the frequency of the standard crystal and the appropriate calibration of the dial or scale of the control.

Fig. 13 discloses a modified form of the circuit of my invention for obtaining greater precision in bandspread control. In this arrangement the parts of the circuit as described in Fig. 6 are employed with the addition of variable condensers 44, and 45, interposed in series between the dual control condenser 2 and the dual control condenser 37. The function of condensers 44 and 45 is to adjust the amount of control condenser 37 exerts with respect to dual condenser 2. By independently adjusting condensers 44 and 45 a greater precision adjustment of the electrically tunable circuit is secured.

In Fig. 14 I have shown a further modification of the circuit of my invention wherein the elements illustrated in Fig. 2 are provided with the addition of a variable capacity control at 46 in series between the rotor of the dual condenser 2 and the impedance device 3. The variable condenser 46 is provided with a pad or trimmer condenser 47 in parallel therewith for increasing the precision adjustment of the circuit. Condenser 47 is set or adjusted so that condenser 46 has that variation in capacity required for compensating for the lack of linearity in dual condenser 2 as shown in characteristic curve C' in Fig. 8.

In Fig. 15 I have shown a further modification of my precision adjustment circuit in which components are employed similar to those illustrated in Fig. 2 except that the trimmer condensers 5 and 7 are connected together or ganged as schematically represented at 48 so that a simultaneous capacity change occurs upon adjustment of condensers 5 and 7 with respect to dual condenser 2. Actually condensers 5 and 7 vary the range of

capacity variation of the various sections of the dual condenser 2 and correspondingly control the resonant frequency of the circuit.

Fig. 16 illustrates a further modified form of the circuit of my invention in which the condenser constituting the main tuning control 1 is ganged to operate simultaneously with condensers 5 and 7 through gang connection represented at 49 so as to automatically compensate for any variation in control exercised by dual condenser 2.

In Fig. 17 I have shown a further modified circuit arrangement for the tuning system of my invention having provision for adjusting the maximum tunable frequency to which the electrical tuning system is responsive. I provide a tuning condenser 51 which is variable in operation and is connected in parallel with the inductance 3 for precisely adjusting the electrical system to maximum frequency for which the system is tunable. This maximum frequency adjustment is provided in addition to all of the other cooperative adjusting means as heretofore explained and particularly shown in Figs. 2 and 3.

Features of my invention shown but not claimed herein are set forth in my co-pending divisional applications Serial No. 563,383, for Tuning system, filed November 14, 1944; Serial No. 563,384, for Electrical tuning system, filed November 14, 1934, and Serial No. 563,385, for Selective tuning system, filed November 14, 1944.

While I have described my invention in certain of its preferred embodiments, I realize that modifications may be made and 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 electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being connected in parallel with the said variable tuning condenser and in parallel with said impedance device.

2. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being connected effectively in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, the capacity of the serially connected section of said dual condenser having a capacity exerting as much control of the resonant frequency at maximum capacity setting of said variable tuning condenser as the parallelly connected section of said dual condenser exerts at the minimum capacity setting of said

variable condenser whereby said dual condenser exerts substantially constant control of the frequency at any setting between and including minimum and maximum capacity of said variable tuning condenser.

3. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being connected effectively in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, and independently adjustable variable capacity means connected in series with each of the condenser sections of said dual condenser.

4. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being effectively connected in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, independently adjustable variable capacity means connected in series with each of the condenser sections of said dual condenser, and a separate variable condenser connected between said central rotor and a point between one of said independently adjustable variable condensers and said variable tuning condenser for adjusting the minimum tunable frequency of the electrical tuning system.

5. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being effectively connected in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, independently adjustable variable capacity means connected in series with each of the condenser sections of said dual condenser, and means connected with one section of said dual condenser and with said variable tuning condenser for adjusting said electrical tuning system to a minimum tunable frequency.

6. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof con-

ected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being connected effectively in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, separate variable capacity means connected in series with each of the condenser sections of said dual condenser, and means for simultaneously adjusting said separate variable capacity means.

7. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being connected effectively in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, separate variable capacity means connected in series with each of the condenser sections of said dual condenser, and means for simultaneously adjusting

the effective capacity of each of said separate variable capacity means and said first mentioned variable tuning condenser.

8. An electrical tuning system comprising in combination with an impedance device, a variable tuning condenser having one side thereof connected with a point on said impedance device, a dual condenser including a central rotor and a pair of variably related capacity areas constituting a pair of condenser sections whose capacities vary simultaneously in the same direction, said rotor being electrically connected with another point of said impedance device, one of the condenser sections of said pair being disposed in series with said variable tuning condenser and the other of the condenser sections of said pair being effectively connected in parallel with the said variable tuning condenser and effectively in parallel with said impedance device, independently adjustable variable capacity means connected in series with each of the condenser sections of said dual condenser, and a separate variable condenser connected between said central rotor and a point between one of said independently adjustable variable condensers and said variable tuning condenser, and another variable condenser connected in parallel with said impedance device and with the series parallel combination, comprising said variable tuning condenser one section of said dual condenser and the independently adjustable variable capacity means connected in series with it, for adjusting said electrical tuning system to maximum tunable frequency.

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