Dec. 17, 1929. W. L. CARLSON 1,740,331

TUNING OF HIGH FREQUENCY CIRCUITS

Filed Oct. 4, 1928

Fig. 1.

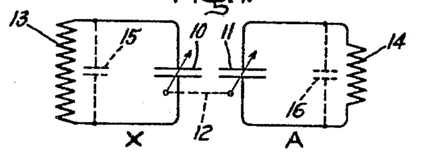


Fig. 2.

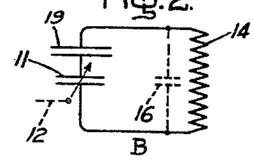


Fig. 5.

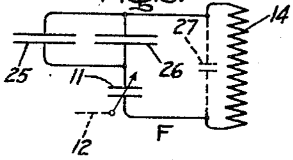


Fig. 3.

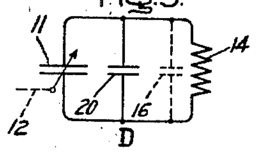


Fig. 4.

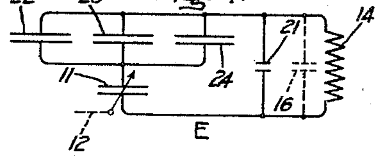


Fig. 6.

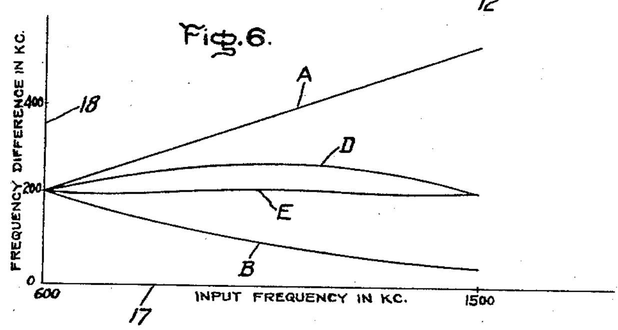


Fig. 7.

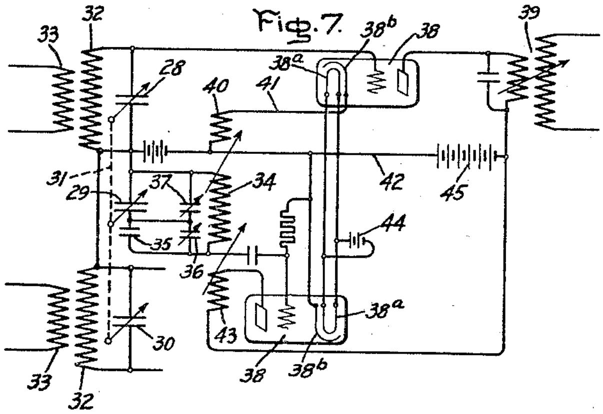
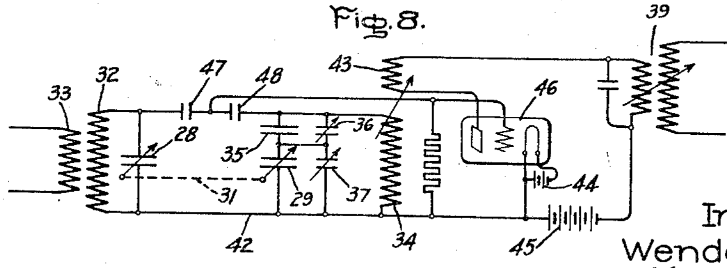


Fig. 8.



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UNITED STATES PATENT OFFICE

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TUNING OF HIGH-FREQUENCY CIRCUITS

Application filed October 4, 1928. Serial No. 310,298.

The present invention relates to the unicontrol tuning of a plurality of high frequency electrical apparatus circuits over a relatively wide band of frequencies, such as the radio broadcast band for example, and more particularly to the unicontrol tuning of such circuits at a constant frequency difference with respect to each other throughout the tuning range. An arrangement of this character is particularly desirable in tuning two or more circuits to receive different signal or broadcast channels simultaneously at a constant frequency difference, or in obtaining a constant frequency output from a received signal and a local oscillator in a superheterodyne receiver for example.

As is well understood in the art, unicontrol or single control tuning refers to the simultaneous operation of several tuning devices, usually each in a separate circuit, by the same operating means, such as an indicating dial or knob, connected therewith by a common shaft or other suitable operating connection. In accordance with present practice, tuning of high frequency circuits is accomplished by variable capacities or condensers in connection with fixed inductances having fixed distributed capacities. The unicontrol tuning of a plurality of circuits to the same frequency is thus comparatively easy since it involves merely a duplication of the tuning means and other constants in each circuit and operating the tuning means simultaneously through the same tuning and movement range.

The problem of providing a constant difference in frequency response between two unicontrolled circuits over a relatively wide tuning range is more difficult of solution and as ordinarily carried out involves not only duplicate tuning means but equal changes in frequency for equal angular or linear movements of the tuning means, known as a straight line frequency tuning characteristic. This involves a fixed angular or linear displacement of the moving or fixed parts of the tuning means of the two circuits between which a constant frequency difference is desired. Thus heretofore it has been considered necessary to employ tuning condensers of the usual rotary plate type having the plates shaped to give a straight line frequency tuning characteristic, with an angular degree shift between rotors on the same shaft to make the circuits connected therewith hold the desired constant frequency difference over a relatively wide tuning range or band of frequencies.

Straight line frequency condensers of the usual rotary plate type are relatively costly, being confined to an accurate plate shape, and occupy a larger space than other more easily manufactured types, such as straight line capacity or straight line wave length types. Furthermore, the angular shift between the rotors for unicontrol operation not only requires an angular adjustment means between the condensers, but limits the normal 180 degree movement of each condenser to some lesser value in which to cover the full tuning range.

In a superheterodyne for example, in order to cover the broadcast band and make one circuit follow the other at a wide frequency separation, such as 200 k. c. for example, the rotors of straight line frequency condensers would be locked together out of step or synchronism at a substantially 30 degree angular displacement, with identical inductances and distributed capacities in each circuit. The total allowable rotation is thereby reduced from 180 degrees to 150 degrees and it is necessary to cover the broadcast range in a 150 degree movement of the tuning means instead of a full 180 degree movement. Thus in addition to disadvantages in size and manufacturing cost, straight line frequency condensers utilized in the unicontrol tuning of two circuits having a relatively wide frequency difference, have the added disadvantage of a limited movement range for a given frequency band to be covered.

In a unicontrol tuning means, it is desirable for manufacturing reasons to provide a unicontrol condenser unit comprising a plurality of variable condensers with the rotors integral with the shaft and without angular displacement, that is, with the rotors in step or synchronism, and for reasons of compactness the rotors are preferably not of the straight line frequency type. With this unit type of tuning means, all the rotors are electrically connected with the shaft and frame and also often with a common bus wire in the set such as the ground bus, although the condensers may be insulated from each other if desirable or necessary for isolating the circuits connected therewith.

The principal object of the present invention is to provide an improved unicontrol circuit arrangement which permits the use of a simple, easily manufactured variable condenser unit or tuning means of the above described type, in tuning two or more high frequency circuits, at least one of which it is desired to operate at a constant frequency difference with respect to the others.

Although the circuit arrangement and tuning means of the present invention are not limited thereto, they are particularly adapted for use in a superheterodyne receiver, and a further object of the invention is to provide a circuit of that type which permits the use of a common grounded rotor condenser unit of the above type or its equivalent in a unicontrolled superheterodyne.

The invention will now be described more fully in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is an elementary diagram of two unicontrolled tuning circuits; Figs. 2 to 5 are similar diagrams of one of said circuits with various values of inductance and capacity substituted therein; Fig. 6 is a curve diagram showing the difference in frequency response between the two unicontrolled circuits illustrated by Figs. 1 to 5; Fig. 7 is a circuit diagram of the tuned circuits of unicontrolled receiver embodying the invention, and Fig. 8 is a similar circuit diagram showing a modification.

Referring to Fig. 1, X is a tuned radio frequency circuit which may be considered as representing one or more such circuits with which a similar circuit A is tuned by unicontrol means at a certain frequency difference which is desired to be substantially constant. The circuits shown comprise two variable capacities or condensers 10 and 11 which have the same plate shape or tuning characteristic and movement range, have the same capacity range within the limits of their movements and are coupled for unicontrol or simultaneous operation as indicated by dotted connection 12. In a multituned circuit arrangement, such condensers are preferably on the same shaft in a gang unit. Connected in shunt with condensers 10 and 11 respectively to complete the circuits are two inductances 13 and 14, together with the distributed capacities of the inductances and connecting leads thereto indicated by 15 and 16.

With one of the circuits, such as circuit X, designed to cover the frequency band desired with movement of the condenser 10 between its maximum and minimum capacity positions, circuit A may be designed to provide the desired difference in frequency response by winding inductance or coil 14 to a higher or lower value than inductance or coil 13. In the present example, inductance 14 may be considered to be wound to a lower value whereby circuit A is the higher frequency circuit, the relative values of the inductances and capacities being roughly indicated by their size in the figure.

A simple circuit arrangement of this character will not however provide a constant frequency difference between circuits X and A throughout the tuning range. This is indicated by the curve A in Fig. 6 which is plotted between input frequency or frequency to which circuit X is tuned along abscissa 17 and frequency difference between the two circuits along ordinate 18. In this curve, a frequency difference of 200 k. c. is assumed by way of example and inductance 14 is designed to provide the difference in frequency at the lower end of the tuning range in k. c. which is assumed for purposes of illustration to be approximately the broadcast band, from 600 k. c. to 1500 k. c.

It will be seen that while the desired frequency separation is obtained at 600 k. c., the separation increases to a wider value at 1500 k. c., thus making a circuit of this character unsuitable for use in a receiver requiring a constant frequency difference between certain tuned circuits, such as a superheterodyne receiver for example, in which circuit X would preferably be utilized for the radio frequency input to the heterodyne and circuit A for the oscillator.

Modifications B, D, E and F of circuit A, with no changes in circuit X, are shown in Figs. 2 to 5 inclusive in each of which circuit X has been omitted and in which the same reference numerals are used for the same parts.

Referring to Figs. 2 and 6, the effect of adding a series condenser 19 in the circuit with other constants indentical with those in circuit X of Fig. 1 is shown. The series capacity is adjusted to provide the desired frequency difference at one point, such as the lower end of the tuning range as before. It will be seen by referring to curve B that the frequency difference is now reduced, in moving the tuning means through the range to the maximum frequency, thus making this circuit arrangement also unsuitable for the purposes intended. As indicated in the figure by the size of the units, the added series capacity is greater than the maximum capacity of condenser 11.

Curve D in Fig. 6 shows the effect of an added shunt capacity 20, as indicated by Fig. 3, in the circuit with the same tuning condenser 11 and distributed capacity 16. The inductance and shunt condenser values in this case can be designed to bring the frequency separation to the desired substantially constant value at each end of the range. It will be seen that this arrangement has a somewhat opposite effect from that of Fig. 2 using the series condenser, and that while it is possible to obtain the desired result at the ends of the tuning range, the frequency separation varies widely therebetween. In this circuit, the added shunt capacity is less than the maximum of condenser 11, but larger than the distributed capacity 16, while the inductance 14 is slightly less than that in circuit A, of Fig. 1.

From a consideration of the curves resulting from the circuits of Figs. 1, 2 and 3 and with the idea of keeping condenser 11 the same, an acceptable and almost ideal curve E is produced by the design of the circuit of Fig. 4, in which only a slight added shunt capacity 21 and a relatively large series capacity 22—23—24 are used, together with a corresponding change in the design of inductance 14.

In this circuit inductance 14 is less than the corresponding inductance of tuned circuit X of Fig. 1, and greater than inductance 14 in circuits A and D of Figs. 1 and 3 respectively, while the variable tuning capacities in each circuit are the same as is desirable. The added shunt capacity is relatively small and may consist of a slight increase of distributed capacity or a small fixed capacity. The added series capacity is substantially three times the value of the maximum of tuning condenser 11. The series capacity is shown in three sections 22—23—24 to illustrate its relative size.

Substantially the same curve as E, may be obtained by changing the constants of the circuit. One design involving the use of a larger inductance for coil 14 than coil 13 in Fig. 1, is shown in Fig. 5. With a larger inductance the total capacity, represented by the series and tuning condensers and distributed capacity, are reduced proportionately to maintain the tuning range and frequency difference as before. Thus in the circuit of Fig. 5, the series capacity represented by two units 25 and 26 is substantially two-thirds of the total value employed in the circuit of Fig. 4, and the tuning capacity 11 is likewise reduced substantially one-third as is also the distributed capacity 27.

The change in the capacity of the tuning condenser does not complicate the construction of a gang or multiple condenser unit of the unicontrol, common shaft type, since it involves no change in plate shape but only the omission of a certain number of rotor or stator plates, or both, when the condenser is assembled.

The tuning variation in k. c. between the higher and lower frequency circuits should be substantially constant and is preferably less than 5 k. c. from a certain constant value, such as 200 k. c. in the present example, for use in a superheterodyne type of receiver, in order that the selectivity of the receiver may be maintained, as is well understood. The curve shown at E in Fig. 6 and the corresponding circuits in Figs. 4 and 5 are such that the intermediate frequency or frequency difference is maintained within the permissible variation limits of 10 k. c., that is, 5 k. c. on either side of the desired constant frequency difference.

Referring now to Fig. 7, a practical application of the above-described unicontrol circuit to a receiver is shown, being by way of example, a superheterodyne type of receiver having three tuned circuits. In this figure, only these circuits and the associated circuits are shown, as the remainder of such a receiver does not concern the invention.

These three tuned circuits, which may be considered to represent a plurality of tuned circuits for any receiver or high frequency electrical apparatus, are tuned by a unit condenser, having three sections 28, 29 and 30 arranged for unicontrol operation as indicated by the dotted connection 31. These condensers have plates of the same shape whereby they have the same tuning characteristic and are arranged in step or synchronism, that is, with no angular displacement, so that the capacity change for a given movement of the tuning means is the same with respect to the maximum for each condenser in each circuit. The condensers may be and preferably are all of the same capacity range as permitted by the limits of their unicontrolled movement.

In the present example, condensers 28 and 30 are arranged to control two radio-frequency circuits comprising the secondaries 32 of radio frequency transformers 33 which are tuned thereby to substantially the same frequency, while condenser 29 is arranged to control at a certain higher frequency and at substantially a constant frequency difference, an oscillator circuit comprising an inductance or oscillator grid coil 34, a series capacity 35—36, the latter portion of which is adjustable, and an adjustable shunt capacity 37 for adjusting the overall distributed capacity of the circuit. It will be noted that the oscillator circuit follows the arrangement of Figs. 4 and 5 and may be utilized to produce the desired frequency difference between it and the other tuned circuits in either of the ways described in connection with said figures.

In actual practice the series capacity is divided as shown between a single large capacity 35 and a smaller adjustable capacity 36, while the added shunt capacity is made adjustable and placed in parallel with the tuning capacity, although it is in effect in shunt with the distributed capacity of the coil because of the relatively large size of the series capacity 35—36 with respect to it. This arrangement of total shunt capacity across the inductance, having the variable tuning and adjustable distributed capacity in parallel, and series connected with a fixed and variable capacity 35—36 across the inductance, permits of a rapid and accurate factory adjustment when aligning the tuned circuits to the same frequency, an adjustment of the distributed capacity 37 being most effective in bringing the frequency difference to the desired value at the high frequency end of the tuning range and an adjustment of the series capacity 36 being most effective for bringing the frequency difference to the desired value at the low frequency end of the tuning range. These capacities are then fixed and require no further adjustment.

In the present example one radio frequency circuit is connected with the detector or frequency changer tube, indicated at 38, while the other may be connected with another tube (not shown) for other purposes such as radio frequency amplification. Tube 38 is of the heater type having a heater 38^a for the cathode 38^b. The detector outputs to the remainder of the set through the usual intermediate frequency transformer indicated at 39 and is coupled to the oscillator by an inductance or coil 40 in the cathode lead 41. This coupling arrangement permits the use of a common shaft or grounded rotor type of condenser unit, that is, a common bus connection for all units as indicated by connection of each unit with a common circuit wire 42. This connection is not possible with the usual oscillator-frequency changer circuit except by placing the coupling coil in the frequency changer grid lead, and is particularly adapted for use with a heater type, separate cathode tube as indicated in the drawing, since the cathode circuit then carries no heating current and may be returned to any desired part of the circuit such as to the common bus 42 to which the condenser units are connected.

The oscillator tube may be of the same type, as indicated, and as an oscillator is provided with the usual plate coil 43 inductively coupled with grid coil 34. Both tubes may have a suitable common cathode heating current supply source 44 and anode voltage supply source 45 represented by simple batteries, although any suitable source of energy for the cathode and anode circuits may be used.

Referring now to Fig. 8, a modification of the circuit of Fig. 7 is shown, in which the oscillator and frequency changer functions are combined by connecting a single tube 46 with both the radio frequency and oscillator tuning circuits, the elements of which bear the same reference numerals as in the preceding figure, circuit 30—32 being omitted.

In this arrangement the tube is a three element type having its grid connected with both tuned circuits through coupling condensers 47 and 48, and having its plate circuit connected with output transformer 39 and oscillator plate coil 43. This arrangement permits the grid of the tube to be controlled through condenser 47 in response to the signal frequency tuned in by radio frequency circuit 28—32, and to respond to the oscillation frequency in the adjusted oscillator circuit 29—35—34, which is unicontrolled with the radio frequency circuit through connection 31.

This circuit arrangement does not differ in practical operation from that of Fig. 7 and is particularly adapted for use in a portable receiver in which a reduction in the number of tubes is of primary importance. In this circuit, the coupling condenser 47 is made larger in capacity than coupling condenser 48, if it is desired to provide a low voltage drop to the grid while condenser 48 is of such capacity that the grid connection forms no appreciable load on the oscillatory circuit. Both capacities are preferably each greater than the grid to cathode capacity of the tube.

In the circuits shown in Figs. 7 and 8, the oscillator circuit is preferably the one having the series and shunt capacities, for the reason that with a plurality of tuned radio frequency circuits all except the oscillator circuit may then be identical and comprise merely a simple inductance and capacity, although of course the oscillator circuit may comprise only such simple inductance and capacity, but this would necessitate providing the series and shunt capacities in each of the tuned radio frequency circuits in order to maintain the same frequency difference. Thus in any case it is preferable to have the frequency difference set up by the use of the series and shunt capacities in a minimum number of the circuits, which in the present example is the one circuit for the oscillator.

Thus it will be seen that by providing the circuit arangement of the present invention, a simple unicontrol tuning condenser means or unit may be employed to tune one of more circuits to the same frequency and one or more circuits associated therewith to a different frequency over a wide range of frequencies, thus eliminating the necessity for condensers of special shape, such as those of the straight line frequency type heretofore used, and an angularity adjustment between each condenser or other mechanical expedient for setting up the frequency difference.

In general, it may be stated that each circuit should have a variable capacity which for any position of the control means or value of the variable capacity in the other circuit, with which capacity it is unicontrolled, its value will be the same percentage of its total or maximum operating value as permitted by movement limit of the control means, as the value of the other capacity is to its total or maximum operating value as permitted by movement limit of the control means. This means that the tuning capacities must have the same tuning characteristic, which is provided in the case of rotary plate condensers by having the plates of all of a unicontrolled series, of the same shape.

The tuning capacities are preferably provided by identical condensers, or condensers having a differing number of plates but all of the same shape, and with no angularity spacing or displacement between rotors when using the ordinary rotary type of variable condenser. Stated in another way the tuning capacities not only have the same tuning characteristic as above mentioned, but are operated in step or in synchronism with each other. This preferred arrangement for such tuned circuit for practical production is an inductance shunted by the tuning and series capacities in series, and with the series capacity adjustable as by a trimmer or adjustable capacity in shunt therewith, and with the overall distributed capacity adjustable as by a trimmer or adjustable capacity in shunt with the inductance or preferably with the tuning capacity.

Previous mention was made of the fact that adjustment of the series condenser by such means as a compensating condenser will affect the low frequency end of the range considerably more than the high frequency end of the range, and likewise that adjustment of the shunt distributed or fixed capacity either directly across the inductance or only across the variable tuning condenser has a predominant effect only at the high frequency end of the range. This variably tuned circuit has therefore a distinct advantage over the customary simple circuit in that alignment of cascade circuits is greatly facilitated by these two adjustments, while the ordinary circuit without the series condenser can have only the one adjustment of distributed capacity which affects mainly the high frequency alignment. It, therefore, follows that this new circuit, substantially as shown in Fig. 7, may be employed to advantage in radio frequency amplifiers where it may be desired to have two compensating adjustments on each resonant circuit to improve unicontrol alignment of the circuits.

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

1. In an electrical apparatus, the combination with a pair of tuned radio frequency circuits each comprising an inductance and a variable tuning capacity, said capacities having the same tuning characteristic and being connected for simultaneous operation through the same tuning movement range, of means for maintaining said circuits at substantially a constant difference in frequency throughout said range, said means comprising a capacity connected in series with one of said tuning capacities and having a value greater than the maximum value of said tuning capacity, and a capacity connected in shunt to said tuning capacity and having a value less than the minimum value of said tuning capacity.

2. In an electrical apparatus, the combination with a pair of tuned radio frequency circuits each comprising an inductance and a variable tuning capacity, said capacities having the same tuning characteristic and being connected for simultaneous operation in synchronism with each other through the same tuning movement range, of means for maintaining said circuits at substantially a constant difference in frequency throughout said range, said means comprising a capacity connected in series with one of said tuning capacities, and having a value substantially three times the maximum value of said tuning capacity, and a capacity connected in shunt to said tuning capacity and having value less than the minimum value of said tuning capacity.

3. In an electrical apparatus, the combination with a plurality of tuned radio frequency circuits each comprising an inductance and variable tuning capacity connected therewith, said capacities having the same tuning characteristic and being connected for simultaneous operation through the same tuning movement range, of means for maintaining one of said tuned circuits at a substantially constant difference in frequency from at least one of the other tuned circuits throughout the tuning range of the variable capacities, said means comprising a fixed capacity connected in series with the variable tuning capacity of one of said circuits, an adjustable capacity connected in shunt with said series capacity for aligning the circuit to a desired frequency difference with respect to said other tuned circuits at the lower frequency end of the tuning range, said fixed and adjustable capacities having a combined capacity greater than the maximum operating value of the variable tuning capacity, and means for adjusting the distributed capacity of said circuit for aligning the same to the desired frequency difference with respect to said other tuned circuits at the higher frequency end of the tuning range.

4. In an electrical apparatus, the combination with a plurality of tuned radio frequency circuits each comprising an inductance and a variable tuning capacity connected therewith, said capacities having the

same tuning characteristic and being connected for simultaneous operation through the same tuning movement range, of means for maintaining one of said tuned circuits at substantially a constant difference in frequency from at least one of the other tuned circuits throughout the tuning range of the variable capacities, said means comprising a fixed capacity connected in series with the variable tuning capacity of one of said circuits, an adjustable capacity connected in shunt with said series capacity for aligning the circuit to a desired frequency difference with respect to said other tuned circuits at the lower frequency end of the tuning range, said fixed and adjustable capacities having a combined capacity greater than the maximum operating value of the variable tuning capacity, and means for adjusting the capacity of said circuit for aligning the same to the desired frequency difference with respect to said other tuned circuits at the higher frequency end of the tuning range, said means comprising an adjustable capacity in shunt with the variable tuning capacity and having a maximum value less than the minimum operating value of said tuning capacity.

5. In an electrical apparatus, the combination with a pair of tuned radio frequency circuits, each comprising an inductance and a variable tuning capacity, said capacities having the same tuning characteristic and being connected for simultaneous operation through the same tuning movement range, of means for maintaining said circuits at substantially a constant difference in frequency throughout said range, said means comprising an adjustable capacity connected in series with one of said tuning capacities and having a value greater than the maximum value of said tuning capacity, and an adjustable capacity connected in shunt to said tuning capacity and having a value less than the minimum value of said tuning capacity.

6. In an electrical apparatus, a plurality of tuned radio frequency circuits having similar inductances and variable capacities, means for varying said capacities simultaneously, said capacities being so related that for any position of said capacity varying means the value of one capacity is the same percentage of its maximum value as the value of the other capacity is of its maximum value and the inductance and capacity of one of said circuits being so related to each other that said circuit is tuned to substantially a constant difference in frequency with respect to another of said circuits throughout the movement range of said capacity varying means.

7. In an electrical apparatus, a plurality of tuned radio frequency circuits including inductances and variable tuning condensers said condensers being interconnected for unicontrol operation and having the same plate shape and tuning movement range, and a circuit connected with one of said condensers including inductance, shunt capacity and series capacity values such that its frequency response period is maintained at substantially a constant difference with respect to that of the other radio frequency circuit throughout said range.

8. In a tuned radio frequency apparatus, the combination of a plurality of unicontrolled circuit-tuning variable condensers having the same tuning characteristic whereby they are operable with the same percentage of maximum change in capacity in each for a given unicontrolled movement, a series capacity connected in circuit with one of said condensers and having a value greater than the maximum operating capacity value of the condenser with which it is connected, and means connected in circuit with said capacity and condenser including a distributed capacity of a value less than the minimum operating capacity value of said condenser.

9. In a superheterodyne receiver, the combination with a tuned radio frequency circuit including an inductance and a rotary variable tuning condenser connected therewith, of an oscillator circuit, a rotary variable tuning condenser for said oscillator circuit having the same plate shape and movement range as said first-named condenser, means for operating said condensers in step simultaneously through said movement range, said oscillator circuit including an inductance, a capacity in series therewith and a capacity in shunt therewith, said series and shunt capacities being so related to each other and to the capacity range of said tuning condenser that said circuit is tuned to a frequency differing from that of the tuned radio frequency circuit by substantially a constant frequency throughout the movement range of said operating means.

10. In an electrical apparatus embodying electric discharge devices, an oscillator circuit connected with one of said devices and comprising a variable condenser for tuning said circuit, an inductance, a capacity greater than the maximum capacity of said condenser connected in series with said condenser, and a capacity less than the minimum capacity of the condenser connected in shunt with said condenser.

11. The combination in an electrical apparatus embodying electric discharge devices, of an oscillator circuit connected with one of said devices and comprising a variable condenser for tuning said circuit, an inductance, and adjustable capacity connected in series with the condenser and having substantially three times the maximum capacity of the condenser, and an adjustable capacity less than the minimum capacity of the condenser connected in shunt with said condenser.

12. In an electrical apparatus embodying electric discharge devices, an oscillator cir-

cuit connected with one of said devices and including a variable condenser for tuning said oscillator circuit, an inductance, and a capacity connected in series with said condenser and having a greater value than the maximum capacity of said condenser, said circuit having a distributed capacity less than the minimum capacity of said condenser, a tuned radio frequency circuit connected with another of said electric discharge devices, a second variable condenser having the same tuning characteristic as said first condenser for tuning said tuned radio frequency circuit, and means connecting said condensers for simultaneous operation in step through the same movement range.

13. In an electrical apparatus embodying electric discharge devices, an oscillator circuit connected with one of said devices and comprising a variable condenser for tuning said oscillator circuit, an inductance, a capacity connected in series with the condenser, and having a value greater than the maximum capacity of said condenser, the distributed capacity of said oscillator circuit being less than the minimum capacity of said condenser, a tuned radio frequency circuit connected with another of said electric discharge devices, a second variable condenser having the same tuning characteristic as the first for tuning said radio frequency circuit, means connecting said condensers for simultaneous operation in step through the same movement range, an inductance connected in the cathode circuit of the last-named electric discharge device, said inductance being coupled electromagnetically with the inductance of said oscillator circuit, and a common circuit connection for each of said condensers.

14. In an electrical apparatus embodying electric discharge devices, the combination of a unicontrolled tuning means comprising a plurality of variable condensers having the same tuning characteristic and operable simultaneously through the same tuning movement range in synchronism with each other, a plurality of radio frequency circuits connected with said electric discharge devices and with certain of said condensers and having substantially the same inductance and distributed capacity whereby they are tuned to substantially the same frequency throughout the movement range of the condensers, a coupling coil connected with one of said circuits in a cathode lead of one of said electric discharge devices and externally of the tuned circuit of said device, an oscillator circuit connected with another of said variable condensers and including an inductance electromagnetically coupled with said coil, a capacity greater than the maximum operating capacity of the last-named variable condenser connected in series therewith in the oscillator circuit, and a capacity connected in the oscillator circuit and having a value less than the minimum operating capacity of said variable condenser, said capacities and inductance being so related that the oscillator circuit is tuned by simultaneous movement of its variable condenser with those of the radio frequency circuits to substantially a constant frequency difference throughout the tuning range with respect to the frequency to which said radio frequency circuits are tuned.

15. In an electrical apparatus embodying electric discharge devices, an oscillator circuit connected with one of said devices and including a variable condenser providing a tuning capacity therein, an inductance, an adjustable capacity connected in series with said condenser, and being greater than the maximum capacity of the condenser, and an adjustable capacity in said circuit less than the minimum capacity of the condenser, a tuned radio frequency circuit connected with another of said electric discharge devices, a second variable condenser having the same tuning characteristic as the first for tuning said radio-frequency circuit, and means connecting said condensers for simultaneous operation in step through the same movement range.

16. The combination with a variable condenser unit comprising a plurality of condensers having the same tuning characteristic and connected for simultaneous operation through the same movement range in synchronism, of a high frequency circuit connected with each of said condensers, and means in at least one of said circuits including a relatively large series capacity and a relatively small shunt capacity for changing the frequency response thereof by substantially a constant difference with respect to that of the remaining circuits throughout the tuning range of the condenser unit.

17. In an electrical apparatus, an oscillator circuit, said circuit comprising a variable condenser providing a tuning capacity therein, an inductance, a capacity in series with the condenser, said capacity being greater than the maximum capacity of the condenser, and a distributed capacity in said circuit less than the minimum capacity of the condenser, a tuned radio frequency circuit, a second variable condenser having the same tuning characteristic as the first providing a tuning capacity in said radio-frequency circuit, means connecting said condensers for simultaneous operation thereof in step through the same movement range, a combined oscillator and frequency changer tube, and means for coupling said tube with each of said circuits, said means comprising a pair of series-connected capacities, each connected with one of said tuned circuits and a grid connection for said tube between said capacities.

18. In an electrical apparatus embodying electric discharge devices, an oscillator circuit, said circuit comprising a variable con-

denser providing a tuning capacity therein, an inductance, a capacity in series with the condenser, said capacity being greater than the maximum capacity of the condenser, and a distributed capacity in said circuit less than the minimum capacity of the condenser, a tuned radio frequency circuit, a second variable condenser having the same tuning characteristic as the first providing a tuning capacity in said radio-frequency circuit, means connecting said condensers for simultaneous operation in step through the same movement range, a combined oscillator and frequency changer tube, and means for coupling the grid of said tube with each of said circuits, said means comprising a pair of series-connected capacities, each connected with one of said tuned circuits and a grid connection for said tube between said capacities, the cpacity connected with the oscillator circuit being less in value than the capacity connected with the radio-frequency circuit and both capacities being greater in value than the grid to cathode capacity of the tube.

In witness whereof, I have hereunto set my hand this 2nd day of October, 1928.

WENDELL L. CARLSON.