April 12, 1932. H. I. BECKER 1,853,953

TUNED ELECTRICAL CIRCUITS

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Fig. 1.

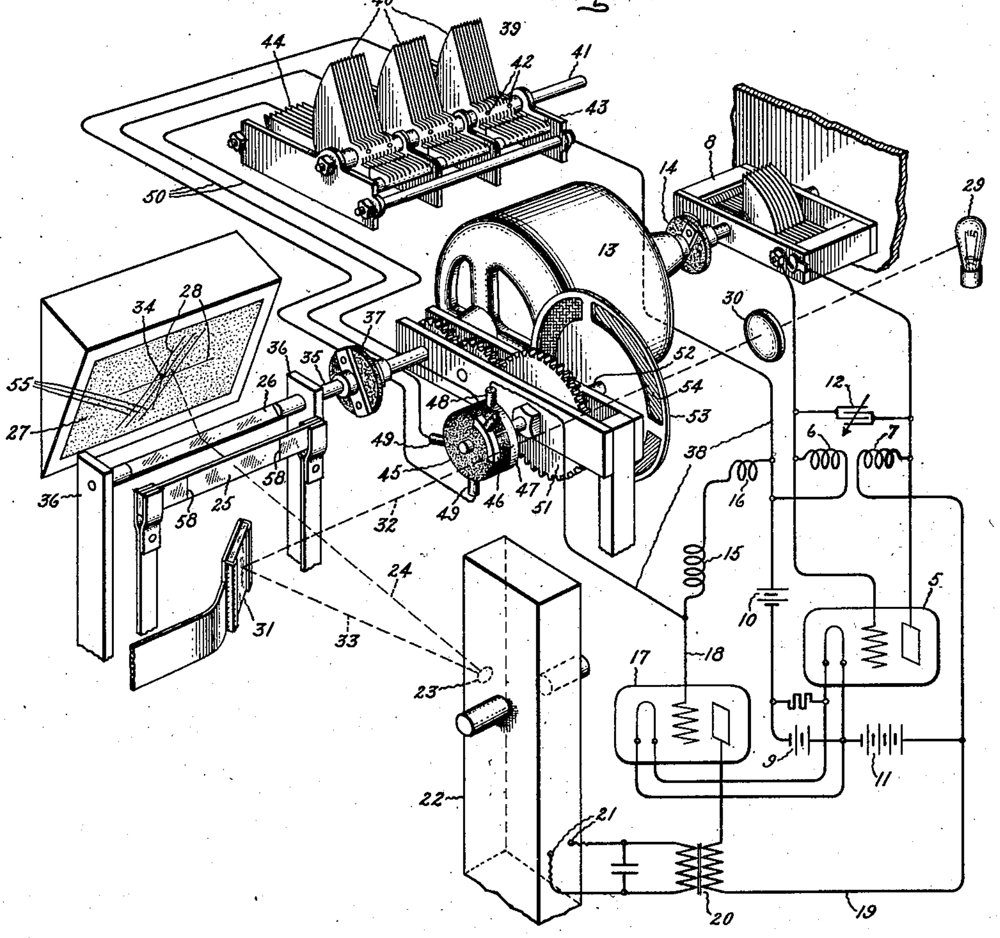

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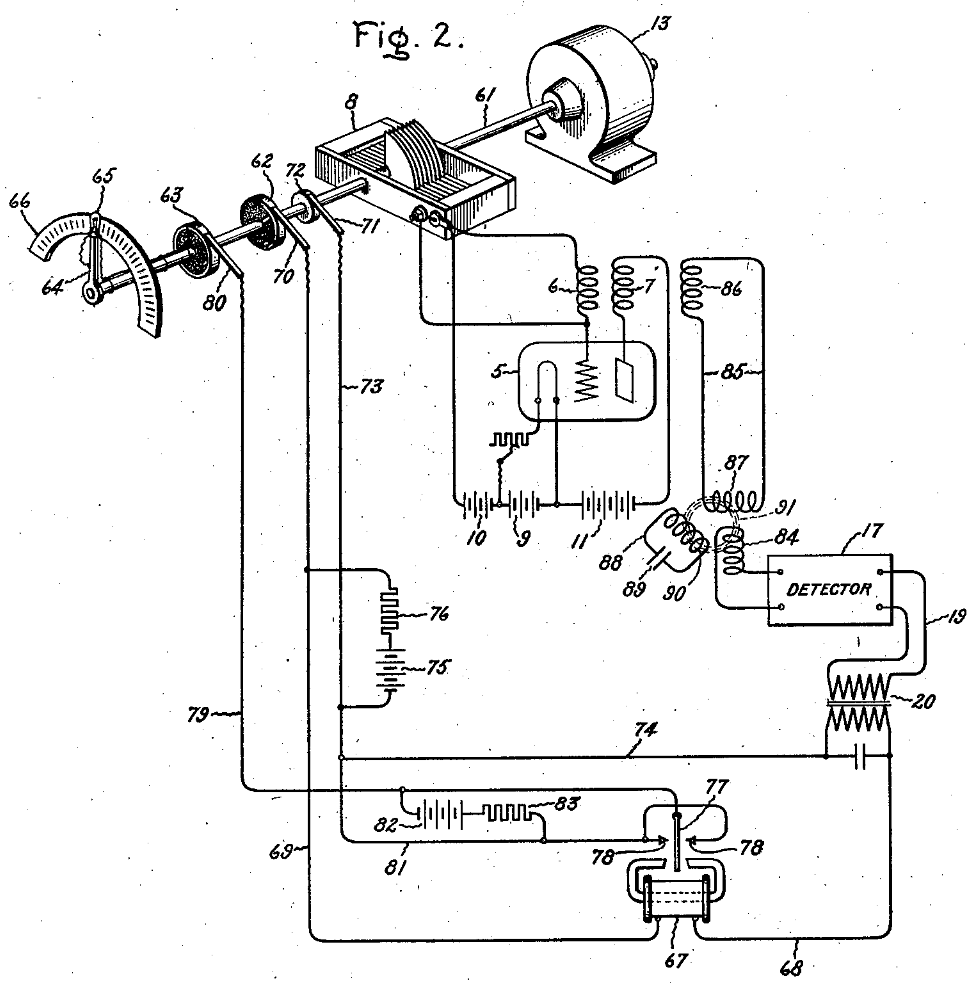
Fig. 2.



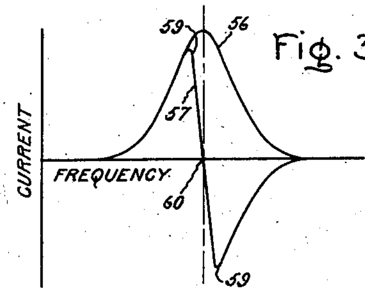


Fig. 3.

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UNITED STATES PATENT OFFICE

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TUNED ELECTRICAL CIRCUITS

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The present invention relates to tuned electrical circuits, and has for its principal object to provide an improved apparatus and method of operation whereby the resonance frequency response or resonant peak of such tuned circuits may be quickly and easily determined independently of their sharpness of resonance and of the amplitude of their response.

The method and means of the present invention are particularly adapted to the testing of resonant circuits and component parts thereof, such as the coils and tuning condensers of radio broadcast receivers for example, in large quantity production, although it is not limited thereto, but may be applied to the testing of any tuned circuit or component thereof.

The invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings Fig. 1 is a diagrammatic representation of an apparatus embodying the invention and arranged for testing a 3-element tuning condenser such as is used as a tuning component of a broadcast receiver; Fig. 2 is a similar diagrammatic representation of a modification; and Fig. 3 is a curve diagram illustrating one phase of the operation of the apparatus of Figs. 1 and 2.

Referring to Fig. 1, 5 is an electric discharge device having associated grid and anode coils 6 and 7 respectively, which are tuned by a rotary variable condenser 8 to provide a common form of oscillator or oscillation generator having a frequency range determined by the relation between the inductance of the coils and the capacity of condenser 8. In the present example the electric discharge device is of the 3-element type and is supplied with operating voltages from suitable means such as a cathode heating battery 9, grid bias battery 10 and anode battery 11. Condenser 8 is shunted by a variable condenser 12 by which its range may be adjusted for purposes hereinafter described.

The above described oscillation generator or oscillator having a variable tuning means such as condenser 8, whereby its frequency output may be varied through a desired frequency range, represents any suitable source of electrical impulses or alternating current, the frequency of which may be varied through a desired range.

In connection with the oscillator shown, the tuning means is most easily provided by a rotary variable condenser which is of a well-known type having 180 degree tuning movement. This should however be taken as representing any suitable means for varying the source of alternating current through its range of frequencies.

The oscillator tuning means is continuously rotated by a suitable small electric motor 13 which is connected with the condenser shaft by an insulated coupling 14. The oscillator or source of alternating current is thus caused to generate a frequency which is continuously varying between certain higher and lower limits as determined in the present example by the relative sizes of inductance and capacity used therein.

Coupled to the oscillator through a divided coil 15—16 as hereinafter described, is a detector or rectifier 17. In the present example the detector is an electric discharge device of the same type as oscillator 5 and is supplied from the same voltage and current sources as the oscillator, as indicated, although it may be of any suitable type and receive operating current and voltages from other sources.

In this arrangement energy received from the oscillator by coil 15—16 is applied directly to the grid of the detector through a grid lead 18 connected with the high potential end of the coil and providing conductive coupling therewith, although any other suitable coupling between the detector and the tuned circuit may be used.

In the anode or output circuit of the detector, which is indicated at 19, is connected a transformer 20, the secondary of which is connected with the terminals 21 of a galvanometer 22 representing any suitable current responsive device adapted for responding to current variations in the output circuit 19 of the detector. The transformer operates to apply the detector energy output to the current responsive device.

The galvanometer is provided with the usual reflecting mirror 23 as an indicating means, which is adapted to throw a beam of light 24 through a lens 25 on to a rotating mirror 26 from which it is reflected to the surface of a translucent screen 27, the center of which is indicated by cross lines 28.

The beam of light from mirror 23 of the galvanometer originates in a suitable source such as a lamp 29 and is directed on mirror 23 through a lens 30 and a stationary deflecting mirror 31, as indicated by dotted lines 32—33. When the galvanometer is unexcited, with its mirror 23 in a normal centered position and with the rotating mirror 26 in a mid position relative to its rotation, the beam of light 24 is adjusted in such a manner that it is directed upon the center of the screen at the junction 34 of the lines 28.

Mirror 26 is mounted on a shaft 35 carried in suitable bearings 36 and coupled with the variable tuning means for the oscillator through a coupling 37 with the motor, to rotate in synchronism with the former. The mirror rotates in the direction of the light beam and the angular relation between the oscillator tuning means or rotor of condenser 8, and the mirror 26, is such that the mirror meets the beam of light 24 and reflects it on to screen 27 while the oscillator tuning means passes through its tuning range which in the present example is 180 degrees, but is turned away from the beam while the tuning means is returning through the remaining 180 degrees to the starting point.

Mirror 26 is thus in effect a cut-off means which operates in synchronism with the oscillator tuning means to prevent the current responsive means or galvanometer from indicating a response except during the time when the oscillator tuning means is varying the oscillator through its frequency range in the desired direction such as from a minimum frequency to the maximum frequency. It is obvious that other suitable cut-off means may be used with other forms of current responsive devices, although the arrangement shown in the present example is that now preferred because of its simplicity and ready adaptability for coupling with a rotary oscillator tuning means such as condenser 8.

Coil 15—16 is the inductance forming one component of a tuned circuit 38. When this circuit, including inductance 15—16, is connected with a tuning means such as a variable capacity indicated at 39 a resonant tuned circuit is provided, and with the arrangement shown this circuit then becomes a selective coupling means between the source of alternating current or the oscillator and the detector or rectifier. Energy is then transmitted to the latter only at the frequency to which the resonant circuit is tuned by the means connected with the inductance 15—16.

Circuit 38 may thus represent a tuned circuit to be tested for resonance or a test circuit in which the adjustment of either the inductance or capacity components to produce resonance at one point, or over a range of frequencies, may be determined by fixing the one component and adjusting the other.

In the present example, tuned circuit 38 is arranged for testing the capacity component thereof which is the variable capacity 39. This is a standard three-unit variable condenser comprising three separate rotors 40 adjustably secured to a common shaft 41, by set screws 42 or other suitable means whereby their angular relation to each other may be adjusted. The shaft is journaled in a frame 43, which also carries three insulated stators 44 with which the rotors mesh. This tuned capacity is typical of the usual single controlled tuning means at present employed in radio receiving apparatus for tuning a plurality of circuits simultaneously. In such receivers each section of the tuning capacity is arranged to tune a circuit such as circuit 38, including an inductance similar to 15—16, to the same frequency for any angular movement of the shaft 41. Hence each section of the tuning capacity must be substantially identical with the others.

Because of manufacturing variations which are unavoidable, the several sections of a multiple tuning means such as capacity 40 are not electrically identical and require adjustment after manufacture, and in order that production may be rapid it is necessary that adjustment and correction be facilitated. It is to this phase of the manufacture that the apparatus of the present example is particularly adapted, although it is not limited to the testing of the mutiple tuning means or of a condenser tuning means, but may be adapted to test any circuit tuning component located in a tuned circuit such as circuit 38, or in testing the response of the circuit itself.

With the multiple tuning unit shown, an arrangement is provided whereby each section thereof is successively and separately connected into the tuned circuit 38, that is in the present example, in parallel with inductance 15—16. This means comprises a commutator or selective switching means 45 carrying a contact segment 46 which is connected through a ring 47 and a brush 48 with one side of tuned circuit 38 which in this case is the high potential side thereof. Segment 46 occupies substantially ⅓ of the circumference of the commutator. Arranged in the path of segment 46, in equally spaced relation to each other about the circumference of the commutator, are three brushes 49 to each of which is connected one section of the tuned capacity 40 through circuit leads indicated at 50.

The opposite or low potential side of tuned circuit 38 is connected with the frame, shaft and rotors of capacity 40, all of which are electrically connected together, the tuning capacity 40 being what is commonly known as a grounded rotor type.

With this arrangement each section of the capacity 40 is connected with tuned circuit 38 for substantially one-third of the revolution of the commutator 45 which is connected to rotate with mirror 26 and the tuning means 8 for the oscillator through a suitable gearing 51. This gearing provides a 3:1 ratio between the shaft by which the mirror and tuning means 8 is driven and a shaft 52 on which the commutator or selector means is mounted, so that each section of the tuning capacity 40 remains in the tuned circuit 38 while the motor shaft makes one complete revolution, that is, while the oscillator tuning means 8 and the mirror 26 make one revolution.

Connected with the commutator 45, and in this case, mounted on the same shaft with it, is a disc or shutter 53 having elongated openings or windows 54 equal in number to the number of sections of the tuning component 40, and of such length as to divide the surface of the disc adjacent the periphery into three separate equal openings. The shutter is arranged to rotate in a plane at a right angle to the beam of light 32 so that the latter passes successively through the shutter openings as the shutter rotates. Each shutter opening is preferably colored by suitable means such as a piece of colored glass mounted therein, each opening having a different color, whereby the color of the beam of light is changed as the commutator rotates. The shutter is so connected with the commutator that the beam of light 32 passes through a separate opening in the shutter while the commutator connects each section of the tuning capacity with tuned circuit 38.

The operation is as follows: With the inductance of coil 15—16 of a desired value to cooperate with each section of tuning capacity 40 in responding to a certain desired frequency or frequency range, and with the oscillator designed to provide a frequency range which includes any frequency to which coil 15—16 may be tuned by capacity 40, the detector 17 and oscillator 5 are energized together with motor 13 and lamp 29. This causes the oscillator to pass successively through its range of frequencies while the separate sections of the tuning capacity 40 are successively connected with tuned circuit 38. At the same time the beam of light from light source 29 is successively changed in color for each section of the tuning capacity.

As a result of this, there appears on screen 27 three differently colored lines of light 55, one for each section of capacity 40, and if the capacity of each section differs from the other, lines 55 will be spaced as shown, the greater the difference in capacity between the different sections the wider the spacing between the lines. The lines are brought to the center of the screen adjacent the intersection 34 of lines 28 by adjusting auxiliary capacity 12 in the oscillator, and then the capacity of each condenser section is corrected by slightly bending the plates or loosening the set screws 42 and shifting one rotor with respect to another until all three lines coincide on the screen. The condenser unit or tuning capacity 40 is then adjusted for the one frequency, and may be tested for others in its range, or it may be removed from the circuit and another substituted in its place for a similar test, without stopping the operation of the testing means described.

It is obvious that while the above described arrangement is adapted for testing a three-unit tuning means, it is not limited thereto but may be used to test a tuning means having one section or any number of sections, the number of sections determining the number of points on the switching means or commutator and the number of windows on the shutter. It is obvious that the shutter is not entirely necessary but is desirable since it permits the registrations or indications to be allocated to each section of the tuning means being tested by a difference in color of the light on screen 27. Likewise it is obvious to one skilled in the art that since a tuned circuit comprises inductance and capacity, that the means shown is not limited to testing and adjusting a capacity tuning means alone, but that it may be adapted to test in much the same manner, one or more inductive tuning means by suitably interposing the tuned circuit containing such components between the source of alternating current and the detector.

Referring now to Fig. 3 along with Fig. 1, the reason for the above described operating results will be further described. In Fig. 3, curves 56 and 57 are frequency response curves plotted between current and frequency coordinates as indicated. When the oscillator or source of alternating current passes through its frequency range there appears in the anode or output circuit 19 of the detector a current impulse represented by curve 56. This is a usual resonance impulse curve and its nodal point or peak represents the resonance point of circuit 38 tuned by one section of capacity 40. This impulse produces in the secondary of transformer 20 and in the current responsive device 22 an alternating current cycle represented by curve 57. This cycle occurs each time the oscillator passes through the resonance point of the tuned circuit, for each section of the capacity 40 under test. The galvanometer follows the current wave or cycle 57 for the resonance impulse of each section of capacity 40 and throws a beam of light across lens 25 between points which may be indicated at 58—58 Fig. 1 as it follows each current wave. The rotating mirror 26 is so synchronized with tuning means 8 of the oscillator that portion 59—59 only of curve 57 is shown on the screen 27, the remainder of the curve being lost by operation of mirror 26 which as hereinbefore described provides a cut-off means for the galvanometer or current responsive device.

In order that the full length of portion 59—59 of curve 57 may appear on the screen as one of lines 55 for any particular setting of tuning capacity 40, condenser 12 of the oscillator is adjusted until it provides the peak resonant frequency of circuit 38 at the instant when the rotating mirror 26 is in a mid position with respect to its travel in the path of light beam 24. This throws the lines into the center of the screen and gives the full image of the lines thereon, each line being a different color when a suitable color disc or shutter means such as 53 is provided.

By examining the curves in Fig. 3 it will be seen that the peak of curve 56 represents the exact resonance point for tuned circuit 38 and that regardless of its sharpness or amplitude, by the use of transformer 20 in the circuit in which this resonance wave is detected, there will result an alternating current wave 57 having a zero point indicated at 60, which will always directly coincide with the peak frequency of the tuned circuit 38. It serves therefore as an accurate indication of the resonance point of the tuned circuit or of the resonance adjustment of the tuning component therein. Hence, in the present example the simultaneous indication of such resonance points, as by the light lines 55 serves as an indication of the relative adjustment of the tuning components included in capacity 40, and permits the adjustment of each component to the same value or frequency response while viewing the results.

Referring to Fig. 2 in which for like parts, the same reference numerals are used as in Fig. 1, 5 is the oscillator or generator of oscillations which is tuned by condenser 8 connected with its grid coil 6, while 9, 10 and 11 are the sources respectively of filament current, grid bias voltage and anode voltage. The oscillator is caused to pass through its frequency range by motor 13 which is connected with it through shaft 61 on which shaft is also mounted an insulated make and break contact or segment 62, and an insulated collector ring 63 together with an arm 64 carrying a light 65 which as the shaft rotates, passes over a scale 66. The lamp represents any suitable indicating means adapted to be rotated by the shaft in synchronism with tuning means 8. At 17 is the detector or rectifier having an output or anode circuit 19 and an output transformer 20 the secondary of which supplies operating current to a current responsive device 67 through a circuit which may be traced through wires 68—69, a brush 70 bearing on contact 62, through the shaft 61 and returning through a brush 71 bearing on a suitable contact ring 72 on the shaft, and wires 73 and 74.

Shunted across wires 69 and 73 is a source of voltage such as a battery 75 having a series connected current limiting resistor 76 which source supplies current to the current responsive device 67 when the make and break device 62 is open. In the present example this device is shown in its closed position, so that the battery or voltage source is inoperative to affect the circuit containing the current responsive device. The make and break device 62 is synchronized with the oscillator tuning means 8 so that as the oscillator is carried through its operating range the brush 70 is in contact with segment 62 to short circuit the voltage source 75 through resistor 76 which prevents excessive drain from the battery.

In the present example the current responsive device 67 is a polarized relay, and it will be seen that when contact device 62 is open, the current from battery or voltage source 75 will hold the relay in a closed position in one direction. This holding force is sufficiently strong to overcome any signal or indicating impulse received from the detector, whereby the indicating or current responsive device 67 is rendered inoperative during the time when the oscillator is being returned to its zero or starting point for each revolution of the motor. This is similar in its effect to the motor operated cut-off means provided in the apparatus of Fig. 1, and as is obvious, any other suitable cut-off means adapted for use with a current responsive device such as polarized relay 67 may be used.

The relay is arranged to light the lamp 65 by means of its movable armature 77 and two contacts 78 with which the arm engages at either end of its travel. The arm of relay 67 is connected through a lead 79 and a brush 80 with the collector ring 63, which in turn is connected with one side of the lamp 65 as indicated. The opposite side of the lamp connects with the arm 64, shaft 61, contact ring 72, brush 71, lead 73 and with contacts 78 of the relay through a lead 81. Shunted across leads 79 and 81 is a second battery or source of voltage 82 and a series current limiting resistor 83 therefor. This arrangement operates to light the lamp 65 when the relay contact arm is in a mid position between contacts 78 as shown, the current for lighting the lamp being supplied from battery or voltage source 82. When the relay is actuated to move to the closed position in either direction, the lamp is short circuited by arm 77 making contact with one of the contacts 78. This arrangement serves to cause indications received from the transformer 20 by the current responsive device 67 to cause such indication to appear on the scale 66 as a spot of light, the spot of light which normally would occur at 180° therefrom and off the scale, being removed by operation of the contact making device 62 as hereinbefore explained.

The arrangement above described is substantially the same as that described in connection with Fig. 1 except that the present arrangement is simplified for use with a single tuned circuit to be tested instead of a plurality thereof, and employs a different type of current responsive device and cut-off means therefor.

The detector is provided with a pick-up coil 84 which is adapted to receive energy from the oscillator or through a circuit 85 in which a coil 86 is coupled with the oscillator and a coil 87 is coupled with the detector coil 84.

Interposed between the oscillator and the detector, that is, in the present example between coils 87 and 84, is a tuned circuit 88, which is to be tested for resonance, and the components of which are indicated at 89 and 90, the former being the tuning capacity and the latter being the tuning inductance. In the present example as indicated by lines 91, coil 90 is electromagnetically coupled with coils 87 and 84 whereby the tuned circuit provides a coupling means between the oscillator and the detector in a manner similar to that described in connection with Fig. 1.

To test the resonance point of circuit 88 or to test the effect of variation in either of its components, it is brought into position to form a suitable coupling as indicated, between the oscillator and the detector. As the detector receives an impulse through the tuned circuit, and applies through transformer 20 an alternating current cycle to the current responsive device 67, the lamp 65 is lighted as the armature of the device 67 follows the change in current through the zero point of the cycle as indicated at 60 of Fig. 3. The lamp will then appear as a spot of light in the same position on the scale for each revolution of the motor 13.

Supposedly identical circuits or circuit tuning means may then be tested by substituting such circuits or circuit tuning means for those shown in 88, 89 and 90, and observing any change in the location of the spot of light on scale 66.

From the foregoing description of the embodiments of the invention shown in the present example it will be seen that the method for determining the resonance frequency response of a tuned circuit in accordance with the invention is particularly well adapted for testing the manufactured components of tuned circuits such as coils and the condensers in production, and that the method is applicable to the testing of such circuits independently of their sharpness of resonance or of the amplitude of the resonance response.

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

1. The combination with a tuned electrical circuit, of means for generating electrical oscillations having frequencies continuously varying over a certain range at predetermined regular intervals, said range of frequencies including a frequency resonant with the frequency to which said circuit is tuned, means for receiving oscillations from said generating means through said tuned circuit at the resonant frequency of said circuit and for rectifying said oscillations, and means connected with said receiving and rectifying means for indicating the nodal points of said rectified impulses.

2. The combination with a tuned electrical circuit, of means for applying thereto electrical impulses having frequencies continuously varying between predetermined higher and lower limits at predetermined regular intervals, means for receiving and rectifying impulses from said circuit at the resonant frequency thereof, a current responsive device, and transformer means for connecting said receiving and rectifying means with said current responsive device.

3. The combination with a tuned electrical circuit, of means for applying thereto electrical impulses having frequencies continuously varying over a range extending between predetermined higher and lower limits at predetermined regular intervals, said range of frequencies including a frequency resonant with the frequency to which said circuit is tuned, a detector arranged to receive energy from said circuit at the resonant frequency thereof and provided with an output circuit, a current responsive device, indicating means arranged to be actuated thereby, and means for connecting the output circuit of said detector with said device.

4. The combination with a tuned electrical circuit, of an oscillator coupled with said circuit for applying electrical impulses thereto, means for varying the frequency of said impulses continuously between predetermined higher and lower limits at predetermined regular intervals, a detector coupled with said oscillator to receive energy therefrom, an output circuit for said detector, a transformer in said output circuit, and an electro-responsive indicating device connected with said transformer.

5. The combination with a tuned electrical circuit, of an oscillator coupled with said circuits for applying energy thereto, means for varying the output frequency of the oscillator, a detector coupled with said oscillator to receive energy therefrom, an output circuit

for said detector, a transformer in said output circuit, a current responsive device connected with said transformer, indicating means actuated by said current responsive device, and means synchronized with the first named means for periodically cutting off indications produced by said indicating means.

6. In combination, a source of alternating current, a tuned electrical circuit, means for continuously varying the frequency of said source over a certain range at regular intervals, said range of frequencies including a frequency resonant with the frequency of said tuned circuit, means in said circuit for receiving energy from said source of alternating current, a detector coupled with said tuned circuit and provided with an output circuit, a current responsive device, means for connecting said output circuit with said current responsive device, and indicating means arranged to be actuated by said current responsive device.

7. In combination, a source of alternating current, means for varying the frequency of said source, a tuned electrical circuit, means connected in said circuit for receiving energy from said source of alternating current, a detector coupled with said tuned circuit and provided with an output circuit, a current responsive device, means for connecting said output circuit with said current responsive device, indicating means including a mirror arranged to be actuated by said current responsive device, a screen, means for directing a beam of light from said mirror on to said screen, and means synchronized with said first named means for cutting off said beam of light at predetermined intervals.

8. In combination, a source of alternating current, means for varying the frequency of said source, a tuned electrical circuit, means connected in said circuit for receiving energy from said source of alternating current, a detector coupled with said tuned circuit and provided with an output circuit, a current responsive device, means for connecting said output circuit with said current responsive device, and indicating means including a current source arranged to be controlled by said current responsive device, a scale, a lamp arranged to move over said scale in synchronism with said frequency varying means and means including said second-named current source and said current responsive device for controlling the lighting of said lamp.

In witness whereof, I have hereunto set my hand this 12th day of November, 1927.

HOWARD I. BECKER.