

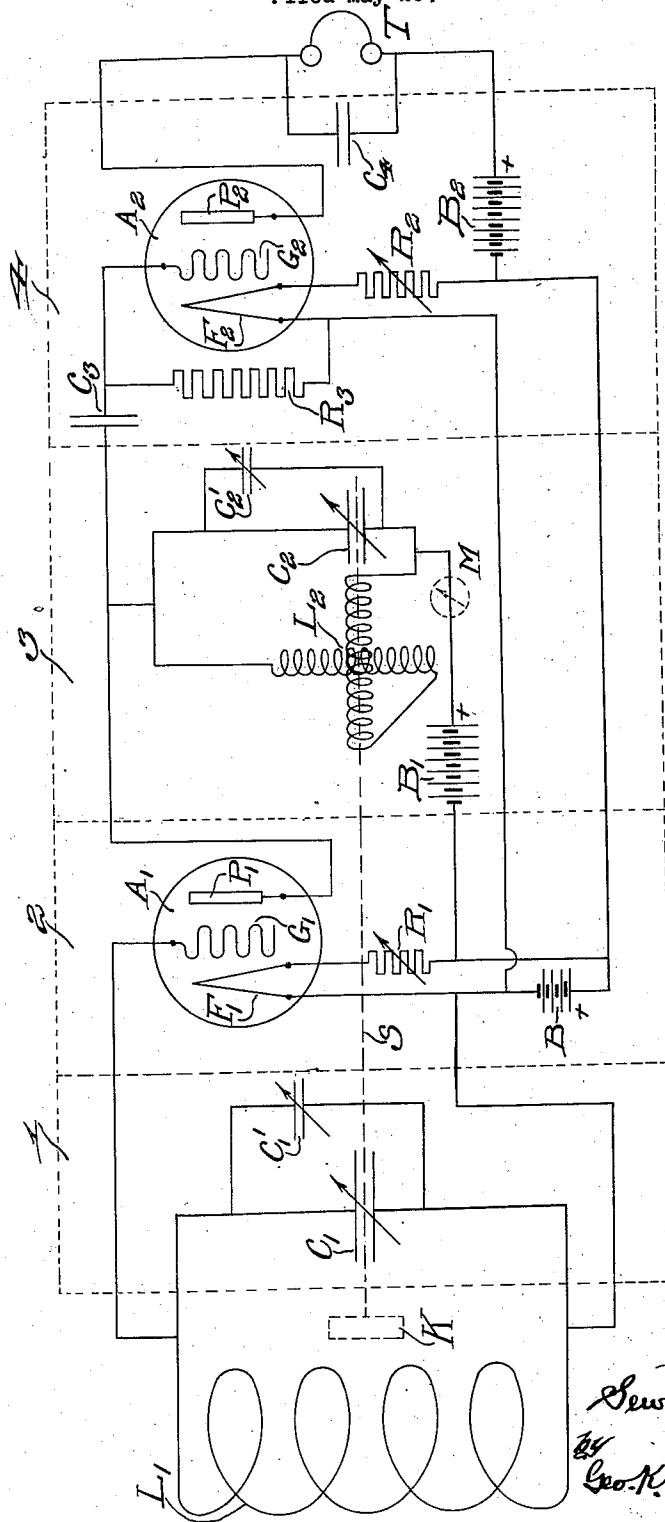
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S. CABOT

ELECTROMAGNETIC WAVE RECEIVING SYSTEM

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ELECTROMAGNETIC-WAVE-RECEIVING SYSTEM.

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To all whom it may concern:

Be it known that I, SEWALL CABOT, a citizen of the United States, and a resident of Brookline, in the county of Norfolk and State of Massachusetts, have invented a new and useful Improvement in Electromagnetic-Wave-Receiving Systems, of which the following is a specification.

My invention relates to electromagnetic-wave receiving-systems and more especially to an apparatus for controlling the oscillatory phenomena in such systems of the radio-frequency amplifier type.

The general object of my invention is to provide an electromagnetic-wave receiving-system of the radio-frequency-amplifier type in which the plate and grid circuits of a three-electrode vacuum tube are not exteriorly coupled or interlinked but are, in fact, shielded from each other, being coupled or interlinked only by the capacity between the plate and the grid, and are not provided with means supplementing the electrostatic coupling of the vacuum tube to facilitate the transfer of energy from the plate to the grid circuit or to increase the effect upon the grid of the high frequency pulsations in the plate circuit.

In the electromagnetic-wave receiving-systems of the regenerative-detector type now in general use, various methods have been employed for controlling the creation of local oscillations, for example, the method of so varying the coupling between the plate and grid circuits that the system is just on the verge of creating such local oscillations, this being the condition in which the system is most sensitive to feeble electrical oscillations.

Such method of so controlling the creation of local oscillations is open to the objection that any variation in the coupling between the plate and grid circuits varies the natural period of the oscillatory receiving-circuit, thereby necessitating the retuning of such circuit for feeble electrical oscillations or weak signals every time the coupling between the plate and grid circuits is varied.

When a tuned radio-frequency amplifier consisting of two parallel-branch circuits each having an inductance in one branch and a condenser in the other and connected, respectively, between the grid and the negative end of the filament, and between the

plate and filament, is so adjusted that said two circuits are approximately in tune, strong local oscillations will be created if the product of inductance by capacity of the first, or grid, circuit slightly exceeds the product of inductance by capacity of the second, or plate, circuit. Such oscillations are detrimental because they are much too strong for advantageous reception of signals, especially weak signals, and various means have heretofore been employed to suppress them, such for example as a biasing potential put on the grid or a relatively large artificial resistance introduced into the circuits.

Such means for suppressing the local oscillations are open to various objections including the unnecessary complication of the system, the difficulty of maintaining such system in permanent adjustment, and diminished sensitiveness.

When a tuned radio-frequency amplifier is adjusted to create strong local oscillations in the manner aforesaid, I have discovered that if a vernier adjustment of either of the tuning elements in the plate circuit be made so that a relatively large movement of its adjusting handle makes only a very small change in the tuning of said plate circuit, said local oscillations may be gradually reduced in amplitude until they finally cease, provided, however, that such adjustment is made so as to increase the value of either of the tuning elements in the plate circuit, and thereby increase the natural period of said circuit from that at which the strongest oscillations are created. When the oscillations have been suppressed by such increase in the natural period of the oscillatory plate-circuit, the system is most sensitive to feeble electrical oscillations or weak signals.

If means are provided for simultaneously adjusting both of said circuits by one motion to approximate resonance to any frequency within their tuning range, the vernier tuning element may be very small, and the adjustment aforesaid may be made without disturbing the tuning of the grid circuit, and in this manner the tuning of the system and the control of the oscillatory phenomena are rendered substantially independent, thereby greatly facilitating the adjustment of a system of this type for receiving feeble electrical oscillations or weak signals.

It is therefore an object of my invention

to provide a method of and means for controlling the creation of local oscillations without varying the natural period of the oscillatory receiving circuit, thereby rendering unnecessary the retuning of such circuit for feeble electrical oscillations of a given frequency, and without having recourse to the use of biasing potentials or artificial resistances.

10 Another object of my invention is to provide means for adjusting an electromagnetic-wave receiving-system to selectively receive feeble electrical oscillations or weak signals by two mutually independent motions only, 15 one motion serving simultaneously to attune the oscillatory circuits approximately to the frequency of the oscillations to be received and the other motion serving to so adjust the system that it is just on the verge of 20 creating local oscillations, this, as aforesaid, being the condition in which the system is most sensitive to feeble electrical oscillations or weak signals.

A further object of my invention is to 25 provide a unitary means whereby one of the tuning elements, for example, the condenser, of each of said oscillatory circuits may be simultaneously varied, and, preferably, whereby the inductance of one of said oscillatory circuits may also be varied at the same 30 time.

A further object of my invention is to provide a micrometer tuning element, for example, a vernier condenser, associated 35 with one of the tuning elements of one of the oscillatory receiving circuits or two such micrometer tuning elements, associated, respectively, with one of the tuning elements of each of the oscillatory receiving circuits, 40 whereby the natural period of such oscillatory circuit or circuits may be very slightly varied without altering the main tuning element or elements thereof.

Inasmuch as the theory underlying the regenerative amplification obtained by my invention is complex and obscure and any explanation thereof would at best be merely tentative. I deem it unnecessary herein to enter into a detailed statement of the probable nature of such action, but believe it to be substantially as follows: The control of the oscillatory phenomena is transferred from the detector circuit to the circuit of the radio-frequency amplifier, in which circuit 55 the control of the oscillatory phenomena, i. e., the property of the system to create internal oscillations, is attained, not by varying the external coupling of the plate and grid circuits of the audion, but by suppressing this coupling and by adjusting the balance between the positive resistance of the circuits through which the local oscillations take place and which may be varied within wide limits by a slight adjustment of the 65 capacity or inductance of said circuits when

the latter are nearly resonant to the frequency of such oscillations, and the negative resistance of the audion which may be varied with the temperature of the filament and which is, in effect, an internal electromotive force in a direction tending to magnify any change in the value of the current flowing in the electron stream within the tube.

With the foregoing objects in view my invention comprises an electromagnetic-wave receiving-system employing two parallel-branch circuits, each having an inductance in one branch and a condenser in the other, one of said inductances acting as a coil antenna, a three-electrode vacuum tube interposed between said parallel-branch circuits, an oscillation detector, which may be a vacuum tube, crystal, etc., associated with the second parallel-branch circuit, a signal-indicating device associated with said oscillation detector, and a vernier tuning element associated with one of the tuning elements of one of said parallel-branch circuits, preferably the second of said parallel-branch circuits, or two such vernier tuning elements associated, respectively, with one of the tuning elements of each of said parallel-branch circuits, whereby the natural period of one or both of said circuits may be very slightly varied without altering the adjustment of the main tuning elements thereof, such vernier tuning element being a condenser, in which case it is connected in parallel with the condenser in one of said parallel-branch circuits, preferably the second parallel-branch circuit, or if two are employed, they are connected, respectively, in parallel with the condensers of each of said parallel-branch circuits.

My invention comprises also a unitary means, such as a rotatable rod, whereby one of the tuning elements, for example, a condenser, of each of said parallel-branch circuits may be simultaneously varied, and whereby at the same time the other tuning element, such as the inductance, of one of the parallel-branch circuits, preferably the second, may be varied.

My invention further comprises a tuned radio frequency amplifier having its vacuum tube and the oscillatory circuits which are connected to its in-put and out-put circuits, respectively, so constructed and arranged that between the maximum and minimum adjustment of a vernier tuning element associated with one of the tuning elements of one of said oscillatory circuits local oscillations will be created and suppressed whereby the system will be put in the most sensitive condition for receiving feeble electrical oscillations without altering the natural period of the receiving oscillatory circuit connected to the grid of said vacuum tube.

My invention further comprises an appa-

ratus for controlling the oscillatory phenomena in an electromagnetic-wave receiving-system of the radio-frequency amplifier type by varying the natural period of one of the two oscillatory circuits connected respectively to the grid and plate of a three-electrode vacuum tube, for example, increasing such natural period in the plate circuit until the local oscillations are suppressed without altering the natural period of the receiving oscillatory circuit, thereby placing the system in the condition in which it is most sensitive to feeble electrical oscillations. In using said apparatus, preferably one motion serves simultaneously to attune the two oscillatory circuits approximately to the frequency of the waves the energy of which is to be received, whereupon the natural period of the plate oscillatory circuit may be slightly reduced by an independent motion until local oscillations are generated, and then such natural period is slightly increased by a reversal of the last mentioned motion without altering that of the other oscillatory circuit until such oscillations are suppressed, thereby attaining the sensitive condition aforesaid; or, the system may be so adjusted that local oscillations will be created at the time the two oscillatory circuits are brought approximately into tune with the signal wave by a single motion on the part of the operator, in which case the local oscillations will be suppressed as before by slightly increasing the natural period of the plate oscillatory circuit without altering that of the other and the aforesaid sensitive condition attained.

The drawing which accompanies and forms a part of this specification represents conventionally and for illustrative purposes only an arrangement of circuits and apparatus embodying my invention, and whereby my method may be realized in practice; but it will be understood that various modifications may be made both in the apparatus and circuit arrangements therein shown without departing from my invention as defined by the appended claims and also that my method is broader than mere apparatus and may be practiced by a multiplicity of electrical means.

In the drawings:—

The figure is a diagram of an electromagnetic-wave receiving-system of the radio-frequency amplifier type embodying my invention.

In the particular drawing selected for more fully disclosing the principle of my invention and which is to be understood as illustrative rather than restrictive, a parallel-branch circuit having an inductance L_1 in one branch and a condenser C_1 in the other is connected to the in-put circuit of the three-electrode vacuum tube or audion A_1 having the filament F_1 , grid G_1 , and

plate P_1 . Preferably the inductance L_1 is a coil aerial consisting of a coil having relatively large area with its turns suitably spaced apart to reduce its resistance, and the condenser C_1 is a variable air condenser, preferably of the rotary-plate type, serving to vary the natural period of the oscillatory circuit $L_1 C_1$, and thereby attune said circuit to the frequency of the oscillations to be received.

The out-put circuit of the amplifier audion A_1 is connected to the parallel-branch having the inductance L_2 in one branch and the condenser C_2 in the other, said inductance being shown in the present instance as a variometer and said condenser as a variable-air-condenser which, preferably, is of the rotary-plate type.

As indicated in the drawings, the in-put circuit of the detector audion A_2 having the filament F_2 , grid G_2 , and plate P_2 is connected to the second parallel-branch circuit $L_2 C_2$, the grid circuit of said audion being provided with the usual condenser C_3 and the usual leak resistance R_3 being connected between the grid and filament; but it will be understood of course that an oscillation detector of any other type, such as a crystal detector, may be suitably connected with said second parallel-branch circuit.

It will be obvious that instead of connecting a detector, such as the tube A_2 , to the second parallel-branch circuit $L_2 C_2$, a second amplifying tube may be connected thereto and a parallel-branch circuit connected to the out-put circuit thereof, to produce a two-stage radio-frequency amplifier, and that the system may be further duplicated to produce a three-stage radio-frequency amplifier or other multi-stage radio-frequency amplifier, each parallel-branch circuit being provided with one of the vernier tuning elements hereinafter described; and that, in such case, a detector will be associated with the parallel-branch circuit which is the most remote from the amplifier tube; and that any suitable audio-frequency amplifier of the single or multi-stage type may be associated with such detector.

In the present instance, a signal-indicating device T of any suitable type, such as a high-resistance telephone, is associated with the oscillation detector A_2 by connecting it to the out-put circuit of said detector, said signal-indicating device being shunted by the usual condenser C_4 .

The battery B is connected through the variable resistances or potentiometers R_1 , R_2 , to the filaments F_1 , F_2 , and the out-put circuits of the tubes include the usual batteries B_1 , B_2 , respectively.

It is desirable to provide a unitary means for simultaneously varying the natural periods of the parallel-branch circuits $L_1 C_1$, $L_2 C_2$, and while it will be obvious to those

skilled in the art that various means may be employed for this purpose, I prefer, as indicated in dotted lines, to mount the rotary plates of the condensers, C_1 , C_2 , on the shaft S rotatable by the knob K . The movable element of the variometer L_2 may be so arranged for relative movement with respect to the stationary element thereof that the inductance of said variometer may be varied simultaneously with the variation in the capacity of the condensers C_1 , C_2 . As indicated in dotted lines, the said movable element of the variometer L_2 is mounted on the shaft S , although it will readily occur to those skilled in the art that a multiplicity of means may be employed for varying the inductance of the circuit L_2 , C_2 , simultaneously with the variation of the capacity of the condensers C_1 , C_2 .

Preferably the maximum inductance of the variometer L_2 , or such other inductance element as may be employed in lieu thereof, is much larger than the inductance of the coil L_1 , and the movable element thereof is so arranged on the shaft S that the inductance of said variometer is a maximum at such position of the shaft as causes the condenser C_1 to have its maximum capacity.

The rotary plates of the condenser C_2 are so shaped that for any given position of the shaft S the product of the inductance of the circuit L_1 , C_1 , by the capacity thereof is equal to the product of the inductance of the circuit L_2 , C_2 by the capacity thereof.

The shape of the rotary plates of the condenser C_2 may be determined approximately from the calibration curve of the variometer L_2 and the final adjustment of such shape may be determined by the fact that the system will oscillate only when the two circuits L_1 , C_1 and L_2 , C_2 are approximately in tune, the presence of oscillations being detectable by a milliammeter M in the out-put circuit of the tube A_1 . The plates of the condenser C_2 preferably are made slightly too large at first and then are pared down to exact shape so that a slight movement of the vernier condenser C'_2 from its half-value position in the direction of a decreased capacity causes oscillations to start.

Associated with one of the tuning elements of one or both of the parallel-branch circuits is a vernier tuning element, and in the present instance I have shown vernier condensers C'_1 , C'_2 , connected, respectively, in parallel with the condensers C_1 , C_2 , of said circuits, although as hereinafter pointed out the condenser C'_1 is not absolutely essential. The vernier condenser C'_2 may have a maximum capacity of about one-tenth of the maximum capacity of the condenser C_2 . Without further description or illustration it will be readily apparent to those skilled in the art that in lieu of said vernier condenser C'_2 , connected in parallel with the

condenser C_2 , a vernier or micrometer inductance may be connected in series with the inductance element L_2 .

When the plates of the condenser C_2 have been given the correct shape by the method above pointed out or by any other suitable method, local oscillations may be created in the receiving system for any position of the shaft S , or, in other words, for any frequency to which it is attuned, by slightly decreasing the capacity of the vernier condenser C'_2 , and such oscillations may be checked by slightly increasing the capacity of said vernier condenser.

A receiving system constructed in accordance with my invention is so highly selective when used in the manner above set forth that a very small movement of the shaft S will quickly detune it. It is therefore advisable to employ a vernier tuning element associated with one of the tuning elements of the parallel-branch circuits L_1 , C_1 . In the present instance, such vernier tuning element is represented as a vernier condenser C'_1 connected in parallel with the condenser C_1 , although it will readily be understood without further explanation or illustration that in lieu of such vernier condenser a vernier or micrometer inductance may be connected in series with the inductance L_1 .

It is not, however, absolutely essential to employ a vernier tuning element in connection with the circuit L_1 , C_1 to make delicate adjustments in the period of said circuit, for, as will be readily apparent to those skilled in the art, the movable plates of the condenser C_1 may be actuated by a reduction-gear driving-handle for rotating the shaft S through a very small arc to make the final adjustment.

Generally speaking, the changes in the natural periods of the parallel-branch circuits L_1 , C_1 , L_2 , C_2 , effected by the vernier tuning elements is of the order of one-half of one per cent.

It is highly desirable to shield the plate and grid circuits of the vacuum tube A_1 from each other, so that there shall be no exterior coupling between said circuits, and if two such vacuum tubes are employed their plate and grid circuits should be similarly shielded. In the present instance the means employed for this purpose are represented diagrammatically as the metallic compartments 1, 2, 3, 4, which enclose respectively the condensers of the first parallel-branch circuit, the tube A_1 , and its associated apparatus, the second parallel-branch circuit and the tube A_2 , and its associated apparatus, although obviously various other arrangements may be employed for this purpose.

If some suitable means for so shielding the elements of the system is not employed, and there is any exterior coupling between the grid and plate circuits of the tube or of

either of the tubes, if two are employed, effective control of the oscillatory phenomena as above set forth becomes impaired, the oscillations having a tendency to start and stop suddenly so that the system either will not oscillate at all or else will oscillate so strongly that its sensitiveness to feeble electrical oscillations is reduced.

I have determined experimentally that when the circuits of the system are attuned in the manner above set forth and the relations above specified between the several elements are obtained, a very considerable amplification is effected and without the use of a receiving antenna relatively feeble electromagnetic signal-waves transmitted over long distances may readily be received.

Having thus described an illustrative embodiment of my invention and electrical means whereby my method may be practiced, without however, limiting the same thereto, what I claim and desire to secure by Letters Patent is:—

1. An electromagnetic-wave receiving-system comprising in combination a parallel-branch circuit having an inductance in one branch and a condenser in the other, a three-electrode vacuum tube having its in-put circuit connected to said parallel-branch circuit, a second parallel-branch circuit having an inductance in one branch and a condenser in the other, means connecting the out-put circuit of said vacuum tube to said second parallel-branch circuit, means for simultaneously adjusting both of said circuits by one motion to approximate resonance to any frequency within their tuning range, and a vernier tuning element associated with one of the tuning elements of one of said parallel-branch circuits for controlling the generation and suppression of local oscillations in the system without altering the natural period of the other of said parallel-branch circuits whereby the tuning of the system and the control of the oscillatory phenomena are substantially independent.

2. An electromagnetic-wave receiving-system comprising in combination a parallel-branch circuit having an inductance in one branch and a condenser in the other, a three-

electrode vacuum tube having its in-put circuit connected to said parallel-branch circuit, a second parallel-branch circuit having an inductance in one branch and a condenser in the other, means connecting the out-put circuit of said vacuum tube to said second parallel-branch circuit, means for simultaneously adjusting both of said circuits by one motion to approximate resonance to any frequency within their tuning range, and a vernier tuning element associated with one of the tuning elements of said second parallel-branch circuit for controlling the generation and suppression of local oscillations in the system without altering the natural period of the first mentioned parallel-branch circuit whereby the tuning of the system and the control of the oscillatory phenomena are substantially independent.

3. An electromagnetic-wave receiving-system comprising in combination a parallel-branch circuit having an inductance in one branch and a condenser in the other, a three-electrode vacuum tube having its in-put circuit connected to said parallel-branch circuit, a second parallel-branch circuit having an inductance in one branch and a condenser in the other, means connecting the out-put circuit of said vacuum tube to said second parallel-branch circuit, movable means for mechanically connecting a tuning element of one of said parallel-branch circuits with a tuning element of the other of said parallel-branch circuits, said tuning elements being so constructed and arranged that for any given position of said movable means both parallel-branch circuits are attuned to substantially the same frequency, and means for slightly varying the natural period of one of said parallel-branch circuits without altering that of the other of said parallel-branch circuits whereby the oscillatory phenomena of said parallel-branch circuits may be controlled independently of the position of said movable means.

In testimony whereof, I have hereunto subscribed my name this 23d day of May, 1922.

SEWALL CABOT.