June 17, 1930. V. D. LANDON 1,764,323

RADIO RECEIVING SYSTEM

Filed Jan. 29, 1927

Fig. 1.

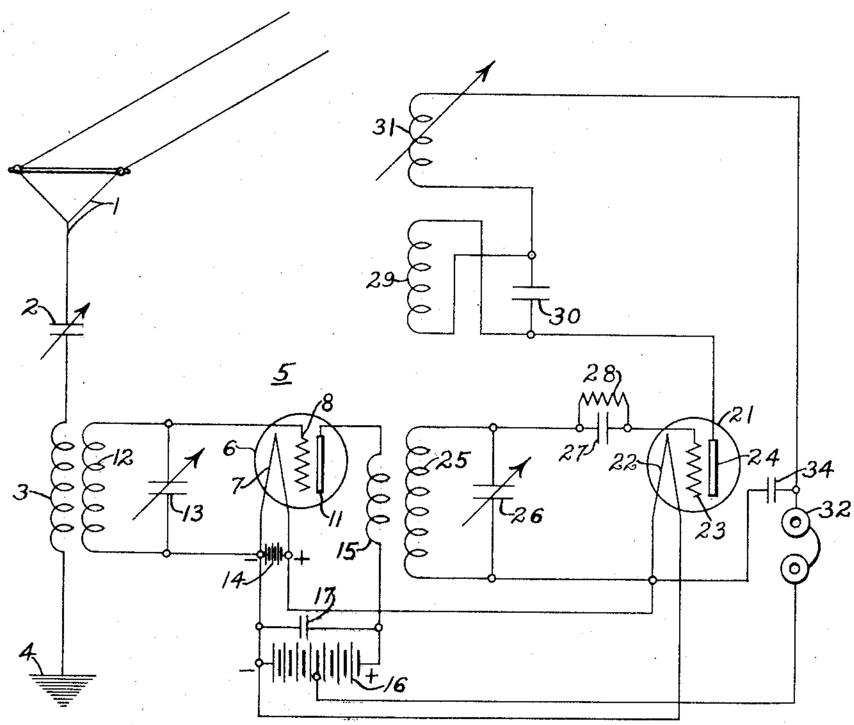


Fig. 2.

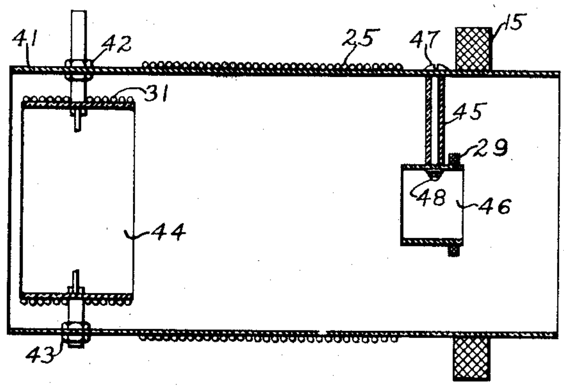
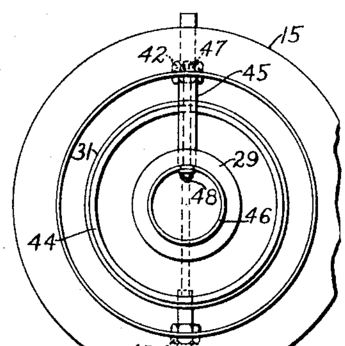


Fig. 3.



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UNITED STATES PATENT OFFICE

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RADIO RECEIVING SYSTEM

Application filed January 29, 1927. Serial No. 164,492.

My invention relates to radio receiving systems, and particularly to systems in which the principle of regeneration is utilized in order to increase the sensitivity and selectivity thereof.

One object of my invention is to provide a system in which critical regeneration may be secured over a wide range of frequencies without the necessity of a multiplicity of controls.

Another object of my invention is to provide a receiving system in which critical regeneration may be obtained over a wide range of frequencies without resorting to constant re-adjustment of the energy feed-back controlling elements.

Another object of my invention is to provide a semi-fixed regeneration-control system for a radio receiving set by which substantially constant regeneration may be obtained over the tuning range without changing the adjustment thereof.

A further object of my invention is to provide an improved inductor-assembly particularly adaptable for use in a radio receiving system.

Heretofore, when it was desired to utilize the principle of regeneration in order to increase the sensitivity or selectivity of a radio receiving system, it has been necessary to provide one or more adjustable elements whereby the amount of feed-back could be accurately adjusted for each frequency it was desired to receive. The adjusting elements have taken various forms, such as rotatable coils, known as "tickler" coils, fixed coils shunted by variable reactors, or variable feed-back condensers between the plate and grid circuits of a thermionic tube, but, with none of the devices of the prior art, has the desideratum of critical regeneration over the entire tuning range been obtained, except by constant and careful adjustment.

In view of the present trend toward simplification of radio controls, it is highly desirable to provide means whereby the usual "tickler" control may be eliminated from a receiving system, or the system at least so modified that constant adjustment of any of the controlling devices is not necessary in order that critical regeneration may be obtained. Accordingly, I have provided a regenerative receiving system in which the amount of regeneration is automatically adjusted to suit the frequency that is being received. Specifically, to obtain the desired results, I cause the feed-back energy to traverse two separate "tickler" systems, one of which is mainly operative to cause regeneration at the higher frequencies and one at the lower frequencies, and I so proportion the relative values of these systems and the amount of magnetic coupling between them and the circuit in which the feed-back energy is to be utilized that the amount of feed-back is always independent of the frequency.

Among the novel features which I consider characteristic of my invention are those set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing, in which,

Figure 1 is a diagrammatic view of a radio receiving system embodying a preferred form of my invention.

Figs. 2 and 3 are, respectively, a longitudinal sectional and an end elevational view of an inductor-assembly that has been found to be advantageous in an actual embodiment of my invention.

Referring specifically to Fig. 1, an energy-receiving structure is shown which comprises an antenna 1, a tuning condenser 2, an inductor 3 and a ground connection 4, and which is inductively coupled to the input circuit of a radio-frequency amplifier 5.

The radio-frequency amplifier comprises a thermionic device 6 having a filament 7, a grid 8 and a plate 11, and is provided with an input circuit comprising an inductor 12 and a tuning condenser 13. The filament 7 is energized from a battery 14. The thermionic device 6 is provided with an output circuit comprising an inductor 15 connected in series between the plate 11 and the positive terminal of a battery 16, the negative terminal of which is connected to the filament 7. The plate-potential battery 16 may be shunted by a condenser 17 of large capacity, if desirable.

A second thermionic device 21 is employed to act as a detector. The thermionic device comprises a filament 22, a grid 23 and a plate 24, and the filament 22 thereof may be energized from the battery 14 which energizes the radio-frequency amplifier device 6. The thermionic device 21 is provided with an input circuit comprising an inductor 25 shunted by a tuning condenser 26. A grid condenser 27 and grid leak 28 are interposed between the inductor 25 and the grid 23, as is customary.

A tuned circuit, comprising an inductor 29 and a condenser 30, in parallel, is connected in series with an additional inductor 31, the series connection extending from the plate 24 to a suitable point on the battery 16. The inductors 29 and 31 are coupled electromagnetically to the input inductor 25. A pair of telephones 32 is included between the inductor 31 and the connection to the battery. The telephones are preferably shunted by a small condenser 34 to provide a path for radio-frequency currents.

With the exception of the circuit comprising the inductor 29 and the condenser 30, the system thus far described will be recognized as the usual "tickler" feed-back regenerative system, now well known to those skilled in the art. Such a system, as has been explained, necessitates constant adjustment of the variable tickler coil in order that critical regeneration shall be obtained at the different frequencies being received. By the inclusion, however, of the tuned circuit comprising the inductor 29 and the condenser 30 in series with the usual "tickler" coil, and by coupling this circuit also to the input circuit of the detector device, I am enabled to attain distinctly new results.

The current in a tickler circuit is evaluated according to the equation

$$I_t = -\frac{yE_g}{R_p + Z_e},$$

in which I=the tickler current; y=the amplification constant of the tube; E_g=the applied grid voltage; R_p=the effective impedance of the tube; and Z_e=the external load, i. e., the impedance of the tickler coils, B-batteries, etc.

In general, R_p is large, as compared with Z_e, and the tickler current is about 180° out of phase with the applied grid voltage and substantially in phase with the effective signal voltage in the plate circuit, $(-y\ E_g.)$

The inductor 29 and the condenser 30 constitute a tuned circuit which is resonant to a frequency preferably below the lowest frequency to which the receiver is designed to be tunable; hence, at any frequency within the tuning range, this circuit will act as a capacitance, the value of which decreases with decrease in the applied frequency.

Designating the voltage drop across the equivalent capacity of the circuit 29—30 by E_c, it is evident that E_c will lag behind I_t by 90°. The current in the inductor 29, I_v, will equal E_c divided by the reactance of the inductor and will lag 90° behind E_c. The current I_v therefore, lags about 180° behind the plate current I_t and is approximately in phase with the applied grid voltage E_g. For this reason, it is necessary to reverse the connections to the inductor 29, as indicated in the drawing, in order that the coupling between it and the inductor 25 shall be in the proper sense to cause regeneration.

Since the current in the inductor 29 increases as the frequency thereof decreases, it is evident that the regenerative effect caused by this current is greater at low than at high frequencies. This compensates for the condition usually encountered in capacitively-tuned receiver circuits, that is, for the decreasing tendency to oscillation at low frequencies. Increasing the capacity of the condenser 30 decreases the inductive effect of the inductor 29 on the inductor 25, without influencing the effect of the inductor 31 thereon, the effect of the latter thus predominating at the higher frequencies. By properly choosing the values of inductors 29 and 31, and that of the condenser 30, a fixed adjustment of the coupling between the tickler system 29—31 and the input inductor 25 will give critical regeneration at both ends of the tuning range.

For frequencies intermediate the high and low ends of the tuning range, it is sometimes necessary to slightly readjust the setting of the tickler inductor 31, though this necessity may be obviated by working over the proper portion of the resonance curve of the compensating circuit 29—30. This curve rises rapidly near the resonance frequency, but, at frequencies remote therefrom, it is nearly a straight line.

The value of the compensating inductor 29 is not critical, though I have found that very good results are obtained if the inductance thereof is approximately twice that of the input inductor 25. If the inductance is too high, the consequent reduction in capacity of the condenser 30 so decreases the A. C. component of the plate current at high frequencies that oscillation is obtainable only with difficulty; if too low, it is difficult to obtain the proper balance.

In a specific embodiment of my invention, the inductor 29 has a value of 500 microhenries and the condenser 30 of 600 microfarads, which gives a resonance frequency of 290 kilocycles.

It is, accordingly, not necessary to continually adjust the angular position of the movable coil 31 in order to obtain critical regeneration over the entire tuning range of the detector input circuit. The values may be adjusted when the receiving apparatus is first built, and the angular position of the movable coil be fixed at that point which gives the best average of regeneration over the tuning range.

To provide, however, for reception by either the homodyne method or by the heterodyne method, it is necessary that the feed-back be increased to the point where the circuit goes into oscillation. To permit of this adjustment, therefore, I prefer to equip the movable coil with manually controllable adjusting means and to so arrange the apparatus that the adjusting means are accessible from the exterior of the cabinet.

It is desirable that the fixed portion of the tickler system shall be so arranged that minimum capacitive coupling exists between it and the tuned input circuit. To this end, I have designed a special type of inductor assembly, Figs. 2 and 3 being respectively sectional and end elevational views thereof.

Referring specifically to Fig. 3, a cylindrical form 41 of insulating material supports the inductor 25, which is preferably a single-layer winding. At one end of the form 41 are provided a plurality of rotatable bearing devices 42 and 43, and supported thereon in the interior of the form 41 is a small cylinder 44 of insulating material carrying the inductor 31.

The inductor 15, which is preferably of the duo-lateral or universal type, is positioned at the end of the cylindrical form 41 opposite to that in which is mounted the rotatable inductor 31.

A small tube 45 of insulating material is mounted radially of the cylindrical form 41 and carries, on its inner end, a small cylindrical form 46, also of insulating material. The tube 45 and the cylindrical form 46 are maintained in position by a bolt 47 provided with a lock nut 48. The cylindrical form 46 carries the inductor 29, which is also preferably of the duo-lateral or universal type, and maintains it in inductive relation to the large duo-lateral inductor 15 and also to the single layer winding 25.

The cylindrical form 46, on which the inductor 29 is mounted, may be rotated by loosening the nut 48, and may be adjusted during manufacture of the apparatus to the position giving the best results.

In the operation of a receiving system incorporating my invention, it is usual and desirable when first energizing the apparatus, to adjust the angular position of the rotatable tickler coil 31 to the position which gives maximum permissible regeneration on any given received frequency. This adjustment once having been made, it is not usually necessary to change the coupling of the movable tickler coil to the tuned circuit over substantially all of the tuning range of the apparatus, provided filament temperature and plate potential are not altered.

Accordingly, I have provided a regenerative receiving system which is very much superior to systems of the prior art and one which is substantially automatic in its operation. The automatic control of regeneration is an extremely desirable feature in modern multi-tube sets, inasmuch as it eliminates one of the heretofore necessary tuning controls and tends to minimize the likelihood of the operator causing interference with near-by reception by inadvertenly placing his receiving apparatus in the oscillatory state.

In some cases, it may be desirable to fix the adjustment of the movable tickler coil when the apparatus is being manufactured and eliminate therefrom the accessible adjustment means, hereinbefore referred to.

It is also believed obvious that my invention may be applied to a multi-tube receiving circuit, in which case, the output circuit of a tube later in the series may be back-coupled to an earlier tube to secure regeneration, instead of coupling the input and output circuits of a single tube.

Although I have illustrated and described a specific embodiment of my invention, such invention is not to be restricted to the embodiment chosen, but is only to be limited by the state of the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a tunable radio system comprising thermionic devices, means for securing critical regeneration over the entire tuning range, said means comprising a plurality of inductors in an output circuit each regeneratively back-coupled to an input circuit, and means whereby one of said inductors is a more efficient feed-back agent at low frequencies than another of said inductors.

2. In a tunable radio system comprising thermionic devices, means for securing critical regeneration over the entire tuning range, said means comprising a plurality of inductors in an output circuit, each inductor being variably coupled to an input circuit in the sense to promote regeneration, and means whereby one of said inductors is a more efficient feed-back agent at high frequencies than another of said inductors.

3. In a tunable radio system comprising thermionic devices, an input circuit for one of said devices, an output circuit for one of said devices, a plurality of inductors in said output circuit each back-coupled to said input circuit in the sense to cause regenera-

tion, and means whereby such regeneration is substantially uniform over the tuning range of said system.

4. In a tunable radio system comprising thermionic devices, an input circuit for one of said devices, an output circuit for one of said devices, a plurality of inductors in said output circuit back-coupled to said input circuit in the sense to promote regeneration, and means whereby one of said inductors has a natural frequency below the tuning range of said system.

5. In a tunable radio system comprising thermionic devices, an input circuit for one of said devices, an output circuit for one of said devices, a plurality of inductors in said output circuit back-coupled to said input circuit in the sense to promote regeneration, means whereby the coupling of certain of said inductors may be manually adjusted, and means for insuring that one of said inductors will be a more efficient feed-back agent at low frequencies than at high frequencies.

6. In a tunable radio system comprising thermionic devices, an input circuit for one of said devices, an output circuit for one of said devices, an inductor in said output circuit back-coupled to said input circuit for securing regeneration chiefly at frequencies toward the high end of the tuning range, and another inductor for securing regeneration chiefly at frequencies toward the low end of the tuning range whereby regeneration at all frequencies is substantially equal.

7. In a tunable radio system comprising thermionic devices, means for securing critical regeneration over the entire tuning range, said means comprising a plurality of inductors, means whereby one of said inductors is given a natural frequency below the tuning range of the system, and means for securing oscillation at any frequency in the range.

8. In a radio receiving system, a thermionic device having a tunable input circuit and an output circuit, a plurality of inductors in said output circuit both of which are back-coupled to said input circuit for securing regeneration, means whereby one of said inductors is a more efficient feed-back agent at low than at high frequencies, and means whereby oscillations may be produced in said system at any frequency in the tuning range thereof.

In testimony whereof, I have hereunto subscribed my name this 28th day of January 1927.

VERNON D. LANDON.