Dec. 22, 1936. H. J. ROUND ET AL 2,064,991

HIGH FREQUENCY AMPLIFYING SYSTEM

Filed June 9, 1931

Fig. 1

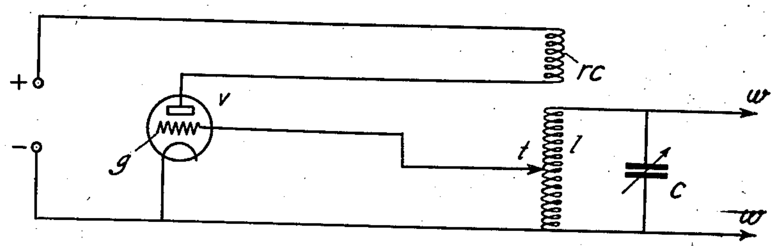


Fig. 2

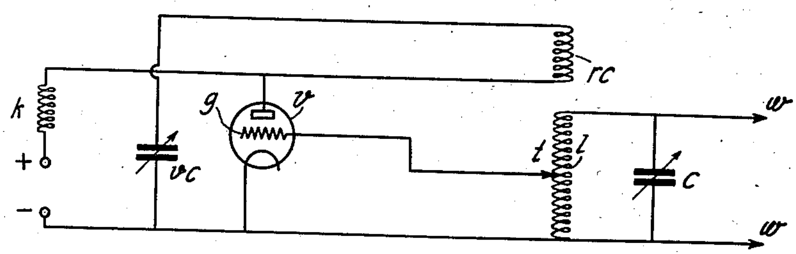
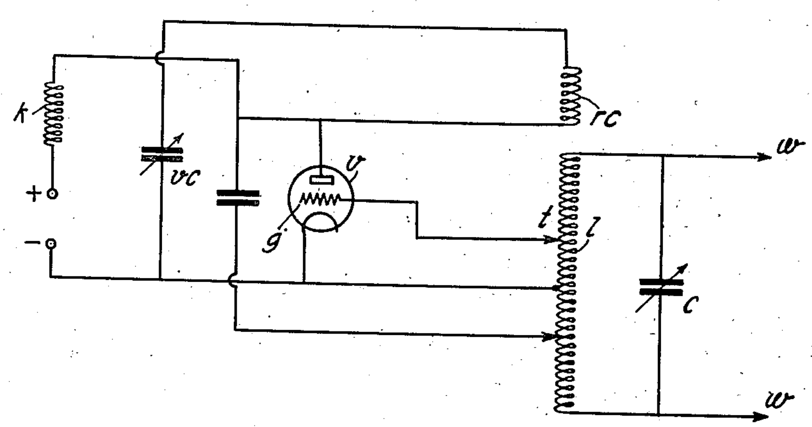


Fig. 3



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Patented Dec. 22, 1936

2,064,991

UNITED STATES PATENT OFFICE

2,064,991

HIGH FREQUENCY AMPLIFYING SYSTEM

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Application June 9, 1931, Serial No. 543,140
In Great Britain June 12, 1930

3 Claims. (Cl. 250—27)

This invention relates to thermionic amplifying systems, and more particularly to such systems employing thermionic valves, and suitable for use in radio receivers and like apparatus.

The invention has for its object to provide an amplifying system wherein great amplification and sharp selectivity may be obtained by the use of what is sometimes termed "retroaction", without the defects normally experienced when an attempt is made with known arrangements to increase retroaction to a large extent.

In the reception of wireless signals with valve apparatus it is very common to employ retroaction, i. e. to feed back energy from the output circuit of one of the valves to the input circuit of a previous valve. If, as is usual, that part of the amplifier which is between the two valves which are retroactively coupled is of a frequency selective nature, e. g., if it includes tuned circuits, the effect of retroaction is not only to increase the apparent amplification, but also the apparent selectivity, the latter effect being often so marked that unless special means be taken to correct for it, serious distortion of any complex modulation which the incoming signals may carry occurs.

The theory underlying such distortion is that since modulation may be regarded as equivalent to the addition to the main sinusoidal radio frequency current (the carrier) of other frequencies (side band frequencies) if the selectivity is unduly sharp the side bands and the carriers are not equally amplified, and the result, after rectification, is that currents of lower modulating frequencies, i. e., those frequencies which, in the complex wave before rectification, are nearest the carrier, are disproportionately large as compared with currents of higher modulating frequencies.

Various methods have been proposed to obviate this defect, one of the best known being to arrange one of the valves following the rectifier as a constant current device (i. e. to arrange its anode circuit to contain so much pure resistance that the total impedance is substantially independent of frequency), to include in the said anode circuit an inductance which is not sufficiently high to prevent the valve in question acting as a substantially constant current device for the highest desired modulating frequency, and to apply to the grid of the valve following the constant current valve the voltage set up across the added inductance, together with the voltage set up across a small part of the pure resistance.

Other arrangements of this kind are known, and such correcting arrangements (which are commonly referred to as "differentiating" arrangements) may be broadly summed up as providing means whereby the voltage applied to one of the valves following the rectifier contains two components properly adjusted in relative magnitude, one component being proportional to the current in the anode circuit of the valve previous to that valve, and the other component being proportional to the time-rate of change of said current.

Theoretically, with such differentiating correcting arrangements, it should be possible to obtain a faithful reproduction of an original modulation, however great the apparent selectivity in the high frequency amplifying parts of the whole apparatus may be, and theoretically also there is no limit other than that set by the occurrence of instability or self-oscillation to the amount of amplification which may be obtained by retroaction. In practice, however, the amount of amplification obtainable by retroaction is severely limited. This will be understood from a consideration of the following brief theoretical exposition:—

A first requirement in obtaining great amplification by retroaction is that the fed back energy shall be strictly proportional to the energy coming in from the external source (e. g. the energy received upon a broadcast receiving aerial), for it is a condition necessary for great amplification that the energy fed back must be nearly, though not quite, sufficient to maintain the appropriate circuit in permanent oscillation. It follows, therefore, that if an increase of input from the external source causes a disproportionately large increase in feed-back, the circuit in question may break into oscillation if the input voltage (e. g. the received strength) be strong. In practice, the obtaining of the required proportionality depends upon the valves having linear characteristics, and, of course, the characteristics of valves are practically never absolutely linear.

According to this invention a thermionic amplifying circuit comprises a thermionic valve of comparatively high mutual conductance, a tuned circuit associated with the input electrodes of said valve in such manner that the voltage transferred to the said electrodes from the said tuned circuit is only a small proportion of the total voltage set up across said tuned circuit, and means for applying reaction between the output and input circuits of said valve, the whole arrangement being such that the action of the valve under impressed signals is substantially linear, and the degree of reaction employed is sufficient to bring the whole circuit arrangement effectively almost to zero resistance.

Obviously a single reaction valve may be replaced by a plurality of valves in parallel.

In this way sufficient reaction may be obtained to bring the reaction valve circuit arrangement to an impedance value which is effectively equivalent to that of a substantially pure resistance approximating to zero, while the resistance of the circuit to input impulses is substantially linear, and the disadvantage commonly met with in known reaction arrangements, namely, that when the reaction is increased to a degree sufficient to bring the effective resistance near to zero for weak signals, a strong signal will cause self oscillation, is avoided.

This arrangement of, what may be termed, a special "reaction" valve (or valves) for the sole purpose of feeding back energy, substantially avoids any low frequency changes being superimposed on high frequency changes, while the effect of possible departure in valves from the desired ideal linear characteristics is rendered negligible by reason of the fact that the radio frequency voltage applied to the reaction valve is relatively small.

For this purpose the grid of the valve is "tapped down" on the tuned input circuit, so that only a portion and preferably only a small portion of the voltage across the said tuned circuit is actually fed down to the grid.

The invention is illustrated in the accompanying diagrammatic drawing, which shows three arrangements in accordance therewith.

Referring to Fig. 1, *v* is a reaction valve receiving voltage from the usual tuned circuit *lc*. The grid *g* of the valve is "tapped down" as shown, by means of a tapping *t* upon the inductance *l* of the tuned circuit. The plate circuit of the valve contains a reaction coil *rc* which is coupled to the coil *l*. Connections *ww* are taken, as shown, from the ends of the tuned circuit *lc*, these connections being led to the input circuit of the usual detector, not shown.

Owing to the fact that the grid is tapped down, the coupling between the coils *l* and *rc* must be closer than would otherwise be the case.

The "tapping down" is carried as far as possible. The higher the mutual conductance of the reaction valve, the lower is it possible to "tap down". It will be seen that with this arrangement, reaction is obtained with greatly reduced liability to distortion, due to lack of linearity, since there will be only a small "swing" along the valve characteristic.

Another requirement for high amplification by retroaction is that the fed back voltage shall be exactly in phase with that existing in the circuit, for if the fed back voltage wave lag or lead by some phase angle upon the voltage wave already present, the maximum amplification obtainable by retroaction can, as may be shown mathematically, never exceed the cosecant of that angle. Thus, if the lag or lead were only 2°, the limiting amplification before self oscillation occurs is approximately 28.5 times.

In known retroactive arrangements this requirement has only accidentally been attained, if at all, and in carrying out the present invention a special circuit is preferably provided for ensuring that the fed back energy shall always be in phase.

An arrangement of this kind is shown in Fig. 2, in which, as will be seen, the steady voltage for the anode of the retroactive valve is supplied through a choke K of high impedance to radio frequency so that substantially all radio frequency currents are diverted to a special circuit consisting of a coil *rc* and variable condenser *vc* in series. This circuit is connected between the anode and filament of the valve and is tuned to the radio frequency so as to offer as nearly as possible zero reactance at that frequency. The coil *rc* in this tuned circuit is weakly coupled to the coil *l* in the input circuit of the valve, so as to induce therein the required feed back voltage.

In some cases, particularly where much amplification at high frequency is required, undesired capacity may give rise to retroactive effects. In such cases this may be avoided by employing in circuits in accordance with this invention ordinary neutralizing arrangements which are well known per se. Such an arrangement is shown in Fig. 3.

Again, where even with the reduced input voltage as above described, non-linearity of valve characteristics gives rise to difficulties, a "push-pull" circuit may be resorted to.

It has been found, in using such tuned circuits of effectively very low damping in arrangements in which they are supplied with energy from high frequency amplifying valves, that, due to the extraordinary low effective resistance of the circuit, their effective shunt resistance is of the order of 20 megohms.

In ordinary practice it is usual to connect the plate of a high frequency valve, e. g., a screened grid valve, either to the top of the following tuning coil or only slightly down the coil. With arrangements employing these low resistance circuits, however, it is possible to "tap down" very excessively, for instance, in the above case employing an ordinary screened grid valve with a μ value of 200 and a resistance of 200,000 ohms it can be "tapped down" to $\frac{1}{10}$ of the coil, i. e., its plate can be connected $\frac{9}{10}$ of the way down the coil in the following tuned circuit and an effective magnification of 1,000 obtained.

Where arrangements in accordance with this invention are employed for radio receiving, it will almost always be necessary to provide for varying the wave length for tuning purposes, and it is important that the arrangement shall be such that the comparatively delicate retroaction adjustment shall not be upset by tuning.

A simple way of meeting this difficulty is to incorporate circuits in accordance with this invention in an intermediate frequency amplifier operating at constant frequency and following a wave changer as in the well known supersonic heterodyne circuit. Alternatively, there may be incorporated a variable resistance or reactance whose control member is mechanically coupled with the tuning control member and which is arranged to apply the necessary compensation to maintain correct retroaction adjustment over the whole tuning frequency band.

In certain cases this effect may be achieved without mechanical coupling. For example, in cases in which tuning is effected by inductance variation alone, the capacity and resistance remaining constant, and the mutual inductance between the tuning and retroaction coils, also remaining constant, constancy of the retroaction adjustment over the whole frequency tuning band will be automatically achieved.

Obviously all the hereinbefore described embodiments may be modified by reversing the reaction connections of the valve in manner well known per se, i. e. the anode of the valve may be tapped down (or its equivalent) upon the tuned circuit and a reaction coil which is coupled to said circuit taken to the grid.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. In combination with a high frequency resonant circuit including an inductance coil, a tube having its input electrodes connected across a portion of said coil, a source of anode potential for the tube, a path between the anode of the tube and its cathode including a coil and a variable condenser, said coils being coupled, connections for connecting said circuit to the input of a detector and a capacitative neutralizing path connected between the anode and resonant circuit.

2. In combination with the resonant input circuit of a high frequency detector, a tube having its input electrodes connected across a part of the circuit, a path coupling the anode circuit of the tube to said resonant circuit whereby high frequency energy is regeneratively fed back from the anode circuit of the tube to said input circuit, means in said path including a coil and a serially connected condenser resonating the path to the frequency of said resonant circuit whereby the voltages of the fed back energy and the resonant circuit energy are in phase, and a capacitative neutralizing path connected between anode and resonant circuit.

3. In combination with the tunable input circuit of a detector, a tube having its cathode connected to an intermediate point on the input circuit inductance and its input electrode connected to said inductance at a point spaced from the cathode connection, a circuit including a coil inductively coupled to the tunable input circuit and a variable condenser, said coil and condenser being serially connected between the anode and cathode of the tube, and a neutralizing condenser connected between the tube anode and a point on the input circuit inductance also spaced from the cathode connection, said condenser and grid connecting points on the inductance being on opposite sides of the cathode connecting point.

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