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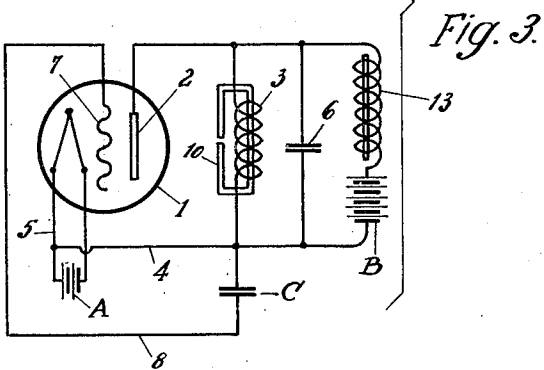
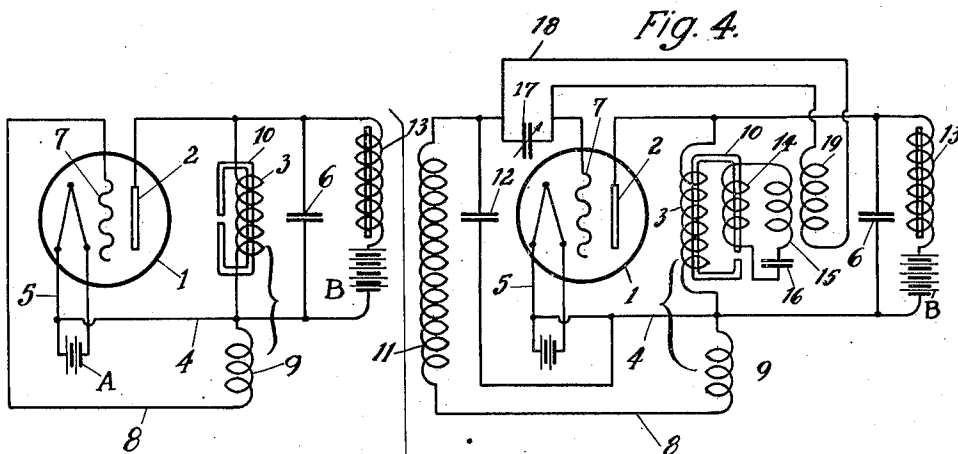
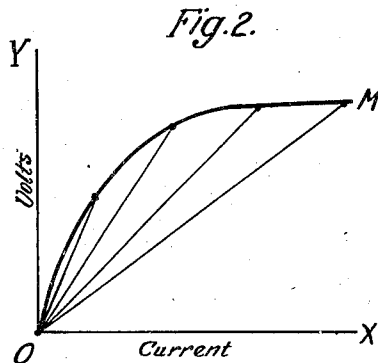
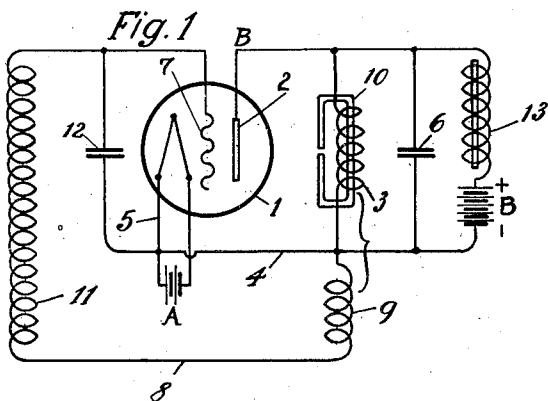
1,697,126

E. MAYER

OSCILLATING APPARATUS

Filed Jan. 9, 1924

2 Sheets-Sheet 1



INVENTOR
EMIL MAYER.

BY
H. R. Van Dewater
ATTORNEY

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2 Sheets-Sheet 2

Fig. 5.

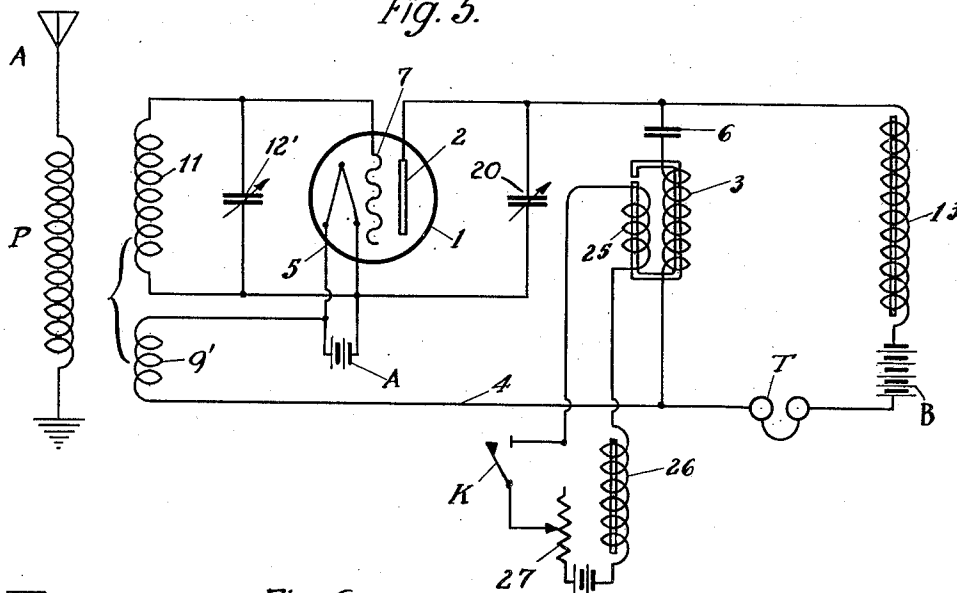
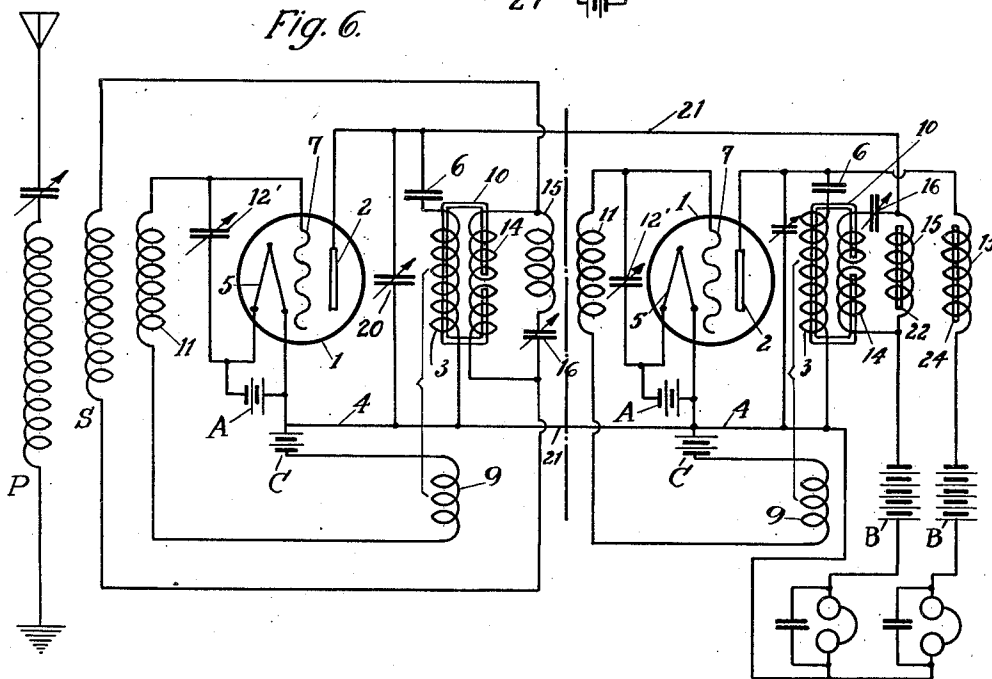


Fig. 6.



INVENTOR
EMIL MAYER

BY
H. Van Severen
ATTORNEY

UNITED STATES PATENT OFFICE.

EMIL MAYER, OF BERLIN, GERMANY.

OSCILLATING APPARATUS.

Application filed January 9, 1924, Serial No. 685,211, and in Germany October 16, 1923.

This invention relates to an improvement in oscillating apparatus, for use in radio and other electrical circuits; and particularly oscillating apparatus adapted for modulating and receiving purposes.

An object of the invention is to provide an oscillating device which will operate through an ordinary electrical valve device having terminals comprising a cathode and a pair of anodes; the anodes being so related that the action of one of them, for example the grid, upon the other, for example the plate, is greatly increased by automatic means, which influences the relations between these two members so as to produce the desired result. Preferably I achieve my purpose by causing the well-known controlling or back-feed action of the grid to be modified by having the phase of its voltage changed with respect to the voltage of the plate. This variation of phase can be accomplished in accordance with this invention by the use of reactance means, such as an electro-magnetic element in the plate circuit, or the grid circuit or both, which controls the current and oscillations in the plate circuit or grid circuit or both, and periodically or in accordance with the signals impressed affects the back-feed action or controlling action of the grid in such a manner that a greatly enhanced output or amplification per stage in the plate circuit is obtained.

In like manner my invention can be practiced with all means for producing oscillations comprising an output circuit and a circuit to control same.

Other objects and advantages of this invention are set forth in the following description, together with the drawings which show electrical constructions by which my invention can be practiced, and the novel features of my oscillating arrangement are defined in the appended claims. This disclosure, however, is illustrative only, and I may change the details of what is actually presented in the drawings, without departing from the principle of this invention, to the full extent indicated by the broad and general meanings of the terms in which the claims are expressed.

In the drawings:—

Fig. 1 shows diagrammatically a circuit comprising terminals, such as a cathode and a pair of anodes, the latter being connected in controlling or feed-back relation, with an electromagnetic element in the circuit of one

of the anodes in accordance with my invention;

Fig. 2 presents a graph showing the effect produced by the presence of this electro-magnetic element;

Fig. 3 presents a pair of diagrams to indicate the manner in which the feed-back action of one of the anodes is modified and its phase altered by the presence of this element;

Fig. 4 shows a complete oscillating device or a unit;

Fig. 5 shows a circuit for receiving purposes in telephony, according to my invention, with key to transmit signals included, if desired; and

Fig. 6 shows how two or more oscillating devices can be connected in cascade to make a complete amplifying apparatus or system in which the principle of my invention is embodied.

The same numerals identify the same parts throughout.

Referring first to Fig. 1, I show an ordinary electrical oscillating or valve device consisting of a simple vacuum tube having a plate 2 connected with reactance means, such as a self-inductive coil 3; this plate having its circuit completed through a conductor 4 leading to one terminal of a filament 5 in the tube, this filament being connected to the usual energizing battery "A". Connected around the coil 3 is a condenser 6. The tube also contains a grid 7, which is joined through a conductor 8 to a coil 9 that may be loosely coupled to the coil 3 and likewise united to the wire 4, so that the grid circuit or controlling circuit extends from member 7 through the filament, the conductor 4, the coil 9 and the wire 8. Contrary to the usual practice, I provide the plate circuit with an iron core 10, associated with the coil 3, and I believe the presence and the action of this core to be new. Between the grid and the coil 9, I may have an inductance coil 11, and the grid circuit also has a condenser 12 between the grid and the filament 5. The iron core 10 can be so designed with reference to the frequencies to be generated in the circuit of the plate or anode 2, that the operation will be attended with only small losses. Hence I employ finely laminated sheet iron for this core or very fine iron wire when very high frequencies are to be obtained. At B is the battery for terminal 2, and a coil 13 with iron core may be inserted between this battery

and the plate, to prevent oscillations reaching the battery B.

We may now consider, independently of the tube 1, the characteristics of a circuit comprising a condenser and a self-induction coil with an iron core. When oscillations are produced in such a circuit, the natural period of or number of oscillations in it is not constant, because the self-induction of the coil depends upon the degree of saturation of the iron. Thus the number of oscillations is variable and changes according to the degree of momentary magnetization which exists or is produced by the influence of the current flowing in the oscillation circuit. The greater the current, the smaller becomes the self-induction and the greater becomes the number of oscillations or frequencies.

Fig. 2 presents a pair of axes, OX and OY, and the curve OM is the well-known curve of magnetization produced by a current flowing around a core of iron. The OY axis will give, for constant frequency, the voltage between the terminals of the coil 3, depending upon the current flowing, which is plotted along the OX axis; while a straight line extending from the point O to any point of the curve gives the voltage between the terminals of the condenser. Since the circuit works at the natural frequency, the voltage of the inductance coil 3 and the condenser voltage must be the same, no matter what the current. Therefore the slope of the line from the point O to any point on the curve OM gives a measure of the generated frequency per second. Obviously, as we go from the point O along the line OM with increasing current, a line from the point O to successive points along the line OM makes a decreasing angle with the horizontal axis, and the cotangent of this angle, as the slope of the line decreases, will increase. Hence increasing the current up to a certain point will cause a material increase of frequency to take place.

With this in mind, one will see, with reference to Fig. 1, that when the tube 1 is working so that current will flow in both the plate circuit and the grid circuit in the well-known manner so as to produce oscillations in the plate circuit, the number of oscillations or frequency in the plate circuit will change from the moment these oscillations begin, according to the amplitude of the current in the coil 3. It is to be assumed that the self-induction produced by the coil 3 containing the iron core 10 is so designed that when current flows in the coil 3, a suitable range of the curve of magnetic saturation will be traversed.

For example, the grid or controlling circuit in Fig. 1 which is in back-feed relation to the plate circuit through the loose coupling between the coils 3 and 9, will be so

designed and tuned that for the initial oscillations and a very small load or output of the tube 1, this circuit will be almost entirely self-inductive in character. Under these circumstances, the condenser 12 of the grid circuit will have a slight effect. The natural number of oscillations or frequency of the grid circuit, too, is smaller than the natural number of oscillations of the plate circuit.

The core 10 is now in a condition of slight or low saturation. However, as the oscillations continue, the current rises and increases in amplitude in the plate circuit of the tube. The iron core 10 becomes more and more saturated, with the result that the effective self-induction in the plate circuit grows less, and consequently the number of oscillations in the plate circuit become greater.

Now the back-coupling to the grid circuit is correct and effective so long only as, with the oscillations generated, the grid circuit remains preponderantly self-inductive. But as soon as, in consequence of the loading or saturation of the iron core, the frequency so increases in the plate circuit, that with a corresponding increase of frequency in the grid circuit through the coupling between coils 3 and 9, a point is reached at which, in consequence of this rise in frequency, resonance is attained and passed, the phase in the grid circuit changes, and this circuit becomes capacitative in character. The phase of the voltage of the grid, as is well known, will alter very quickly with respect to the plate voltage by almost as much as 180° . Now the back-coupling which formerly produced oscillations causes a choking of oscillations. The change of conditions in the grid circuit whereby, upon the point being passed at which the grid circuit finds itself in resonance and the character of the grid circuit becomes changed, is indicated on the two diagrams of Fig. 3, the lower of these two diagrams presenting a condenser C in the place of the coil 9, in order to stress to the eye the point under discussion. The effect so obtained can be utilized according to this invention in many ways, and gives amplification in very high degree. What really is attempted and accomplished is the same as though the tickler coil commonly used and well known were rapidly thrown over from a back-feed to a contrary position.

In practice, the reversal of the phase of the voltage in the back-coupled grid circuit in consequence of the increasing magnetic saturation of the iron core 10, must not be allowed to take place slowly, because a certain stability of oscillations generated may occur; but on the contrary, such reversal of the phase should take place quickly. The plate circuit and the grid circuit must be so designed in relation to one another that the critical point at which the first reversal

takes place, is arrived at by the use of a surplus of energy, for example, by making the back coupling in such a way that oscillations begin very quickly and the critical point is reached before the full capacity of the tube is used. Then no stability results. On the contrary, after the attainment of the critical point, and the corresponding degree of saturation of the iron, the current in the plate circuit will rise somewhat further and then rapidly drop, after the change of phase takes place in the grid circuit, and in consequence of the change of phase.

Due to the hysteresis in the iron at decrease of current, the point at which the oscillations or frequency in the grid circuit runs through the critical or resonance point in reverse direction, is reached at much lower current amplitude. In fact, by proper design, one can make the current in the anode or plate circuit completely die out or stop before it can begin to increase again. Hence, instead of stable oscillations with constant amplitude of current in the plate circuit, a periodical change of the amplitude takes place. The period of this change of amplitude depends, as is easily seen, upon the constants of both circuits, and particularly upon the resistance in the plate circuit and the steepness with which the oscillations of the tube start, that is to say, of the back coupling.

A simple and practical utilization of the phenomena above set forth can be made for receiving purposes in both wireless telegraphy and telephony. In telegraphy, for example, I can utilize the principle of my invention in connection with a circuit for the reception of undamped signals, in place of the heterodyne receiving circuit, and greater sensitiveness can easily be secured. The tube 1 is then so operated that with no voltage impressed upon the grid from without, oscillations commence. The signal thus produces the oscillations and the effect of the iron core audibly modulates the signals.

The auxiliary frequency then introduced can be enhanced by providing in the plate or output circuit, or in the grid circuit, or in both, an element which is tuned to this auxiliary frequency. For instance, one can place one or more auxiliary windings upon the coil 3 with the core 10, and with additional means, such as coils and condensers, make a resonance circuit for the auxiliary frequency, and back-couple this auxiliary resonance circuit, which may include a similarly tuned element. The auxiliary frequency comes from the interruptions, due to the iron core 3, of the oscillations produced by the valve under the influence of the signals.

See, for example, Figure 4. In this view the connections are all as in Figure 1, with the addition that an auxiliary winding 14 is

placed upon the coil 3, and in circuit with this winding are coil 15 and condenser 16, (variable if desired), which will be tuned to the auxiliary frequency, which is different from the frequency of the signal oscillations. Included in the grid circuit may be a condenser 17 united by conductors 18 to a coil 19, that is to carry the auxiliary frequency only, the coil 19 being in inductive relation to the coil 15. By means of the coil 19 and condenser 17, the effect of a further back-coupling is provided for the circuit of the grid or member, and this further back-coupling may be either tuned to the auxiliary frequency or aperiodic, and either capacitative or inductive.

For receiving purposes in telephony, the tube is set to oscillate at the frequency of the incoming signals. It is very easy to adjust the periodic change of the plate current, then, to take place at a frequency above audible limits. If, now, the coil 11 be coupled to an antenna and incoming signals received upon it, and the tube set into operation, the incoming voltages will be impressed upon the grid circuit. The combined action of the feed back, and the incoming signals, and further possible back-feed provided by parts 17 and 19, will modulate the output of the plate circuit, in accordance with the effects which the incoming signals produce in the coil 11. A degree of amplification in the tube is thus obtained which is limited only by the available output capacity of the tube, and is almost completely utilized for the generation of the sounds in the telephone receivers.

A further arrangement according to my invention with the coil 11 coupled to an antenna circuit is presented in Figure 5. Here a telephone receiver is shown in the plate circuit at T. The extra back coupled circuit comprising the condenser 17 and coil 19 is omitted and a coil 9' is utilized in place of the coil 9, in inductive relation to the coil 11; i. e., as a tickler coil being connected to one terminal of the coil 3 and to one terminal of the filament. Except for the omission of the additional back feed, due to condenser 17 and coil 19, the operation of this arrangement, as to the effect of the coil 3 with iron core 10, is the same as above. In parallel with the coil 11 is shown an adjustable condenser 12', with another adjustable condenser 20 between the plate and filament, and the condenser 6 in series with the coil 3. It will be noted that in Figs. 1, 3 and 4 condenser 6 is shown in parallel with winding 3, whereas in Figs. 5 and 6 condenser 6 is disposed in series with coil 3. At a is shown the antenna with coil P in inductive relation to the coil 11. This circuit is untuned and operates to give superregenerative amplification.

My invention can also be advantageously used by feeding the incoming signals into the

modulating coil placed on the iron core self inductance of the plate circuit of the tube, instead of feeding it into the grid circuit.

Figure 6 gives a working diagram of this mode of operation. In order to obtain a high amplifying effect, the tube and the saturation of the iron core of the coil are so set that a minimum change of said saturation will produce a large change in the amplitude of the plate oscillations by changing the phase relation between the grid and the plate circuits.

At the left half of Figure 6, the condenser 12' is across filament and grid. Variable condenser 20 is connected as before, and the terminals of coil S inductively related to the antenna, are joined to the circuit including the parts 14, 15 and 16. Condenser 6 is in series with coil 3, and coil 9, though still loosely coupled to coil 3, has a bias battery C, to influence the grid circuit, so that the variation in oscillations has the maximum rectifying effect.

It is advantageous to set the grid bias so that the maximum change in plate current will be obtained for a certain change of the amplitude of the plate oscillation.

The output of the tube can for purposes of further amplification be fed into another unit made up in the same way, as shown at the right half of Figure 6. This is accomplished by connecting the plate and filament at the left half of Figure 6 to a second unit of the same description as, at the left half of Figure 6; running the conductors 21 from plate and filament as before to the circuit of the condenser 16 and coils 15 and 14 of the second unit. Coil 15 may have an iron core 22, and in the circuit leading from the first unit to the second may be a battery B and a receiver T in series with the coil 15. Another coil 23, with iron core 24, in series with another battery B and receiver T, will be in the plate and filament circuit of the second tube. This second receiver may be operated at audio frequency, while the first joined to the unit at the left, enables the operator to ascertain conditions in the first or left unit, and adjust accordingly.

Depending upon the frequency to be amplified, it may then be decided whether the current fed into the second unit be the rectified current of the first unit as shown in Figure 6, or whether the feeding is done direct at the frequency generated in the first unit. In the latter case, the input circuit of the second unit at the right can be tuned similar to the first unit. If the frequency received be high, it may even be advantageous to rectify before going into the input circuit of the first unit.

My invention will work very well also, if the tuning of the grid circuit be changed in accordance with the signal instead of the tuning of the circuit of the plate or anode terminal 2, and if by these means the phase rela-

tion between the two circuits is shifted in the way described. This may be advantageous inasmuch as much smaller currents flow in the grid circuit than in the plate circuit.

For the utilization of the full effect of the invention for receiving purposes, one may employ a receiving tube with larger emission than is customary. Such larger emissive capacity can be obtained by the use of oxide covered filaments in the tubes, without too much power consumption for the heating of the filaments.

To facilitate the tuning of such apparatus and give a very close adjustment of the point at which phase alteration takes place, one can arrange to give the iron a variable preliminary magnetization with direct current, but the circuit of this direct current must of course be protected against high frequency. See Figure 5, showing a small magnetizing coil 25 on the core 10, in circuit with a battery M, iron-core choke coil 26, and variable resistance 27.

A further advantage in the use of this invention is due to the fact that it permits the making and breaking of large energies with small means. In transmission, if a tube is operated so as to be in stable oscillation, the greater part of its self-induction being, however, provided with an iron core, one can use a small direct current in the auxiliary winding, and thus change the self-induction. Thus very suddenly the false phase of the voltage in the back coupling is produced, and the oscillations are very rapidly choked. For this purpose a key K can be provided, as shown in the circuit of battery as in Figure 5.

Figure 6 shows how my invention can be employed in cascade. In this combination, the first coil 14 is joined by wires 21 to a coil S, which is part of a receiving antenna P. The output circuit of the first tube is connected to a second unit and the output of the first tube is further amplified by the action of the second tube, and so on until the desired degree of amplification is reached. The device as shown in this view has the advantage, that in succeeding steps of amplification the frequencies can be chosen arbitrarily and differing from each other, provided that each one of these frequencies is higher than the frequency of its input.

The vertical dot-and-dash line in Fig. 6 signifies that no inductive relation exists between the coil 15 of the first unit and the adjacent coil 11 of the second unit.

A further advantage is that there is no re-radiation, because only the antenna and first input circuit are tuned to the signals.

Of course any magnetic metal besides iron can be used for the core 10.

While I have described my invention in certain preferred embodiments, I desire that it be understood that modifications may be

made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

Having described my invention what I believe to be new and desire to secure and protect by Letters Patent of the United States is:

1. Radio receiving apparatus comprising an electrical oscillating device having an output circuit, a member for co-operating with said circuit, to be subjected to an electric potential, an electro-magnetic means connected in shunt with said circuit and capable of changes in reactance to influence the phase of the voltage of said member with respect to the voltage in said circuit to cause amplifying action, said changes in reactance depending on values of current passing therethrough, and means for controlling the effect of said electro-magnetic means in accordance with incoming oscillations.

2. An amplifying device comprising an electrical valve device having a plate filament and grid therein, an output circuit connected with said plate, a grid circuit connected in feed-back relation to the plate, and an inductive coil with magnetic core connected in shunt with the plate and filament to influence the phase of the voltage of the grid with respect to the voltage of the plate, and an auxiliary coil for fixing the magnetic condition of the first coil.

3. An amplifying apparatus comprising an electrical valve device having a plate and an output circuit connected thereto, a grid circuit connected in feed-back relation to the plate, an electro-magnetic coil connected in shunt to the output circuit, said coil having a magnetic core, the inductive effect of said coil influencing the phase of the voltage of the grid circuit with respect to that of the plate circuit, an auxiliary coil in inductive relation to said coil, and connections for enabling said auxiliary coil to receive incoming signals for changing the magnetic condition of said first mentioned coil for modulating the output of said valve device.

4. An oscillating device comprising a plate, a filament and a grid electrode, circuits interconnecting said electrodes, a coil with magnetic core connected in shunt with the plate and filament, the grid being in feed-back relation to the plate, an auxiliary coil inductively related too the first coil, means comprising a coil and a condenser connected to the auxiliary coil, and an additional coil associated with the auxiliary coil and connected to provide independent control of the grid circuit.

5. A cascade amplifier consisting of successive units, each comprising an oscillating device with a terminal connected to an output circuit and reactance means in each output circuit, a controlling circuit associated with

each output circuit, a circuit for receiving signals, an auxiliary circuit for each unit associated with the reactance means thereof, the auxiliary circuit of the first unit being connected to the receiving circuit, and the output circuit of the first unit being connected to the auxiliary circuit of the next unit.

6. An electric valve having an output circuit and a control circuit the currents of which have a predetermined or natural phase relation and means for varying said phase relation comprising a magnetized iron core a winding on said core disposed in shunt with said output circuit and a magnetic coupling between said winding and one of said circuits.

7. A vacuum tube comprising a plate circuit and a grid circuit, said grid circuit being connected in feed-back relation to said plate circuit, means connected in shunt with the plate circuit of said tube to alter the phase relation of the currents in said circuits, and auxiliary means magnetically coupled with said first mentioned means for selectively fixing the magnetic condition of said plate circuit.

8. In an amplifying system a plurality of electron tubes each having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, a signal receiving circuit, means coupling the input circuit of one of said electron tubes with said signal receiving circuit, a circuit connected across the output circuit of said last mentioned electron tube and comprising a series connected inductance and capacity, an iron core for said inductance, an auxiliary winding disposed on said iron core, a tuned circuit connected with said auxiliary winding and connections between said tuned circuit and said signal receiving circuit, a coupling between the input circuit of a succeeding electron tube and said last mentioned tuned circuit and a responsive device connected in the output circuit of said last mentioned electron tube.

9. An amplification system comprising a plurality of electron tubes each having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, the output circuit of each of said tubes including a shunt circuit having capacity and inductance elements therein, an iron core for each of said inductance elements, an auxiliary circuit associated with each of said inductance elements, inductances in the input circuits of each of said tubes coupled with the inductance elements in said shunt circuits and a coupling between the input circuit of a succeeding tube and the auxiliary circuit of a preceding tube.

In testimony whereof I affix my signature.

EMIL MAYER.