Experimental Wireless Telegraphy and Telephony—VIII*

Discussing Further the Action of Vacuum Tubes as Applied to Radio Communication

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WHILE acting in the capacity of a detector, the three-element vacuum tube is unlike any other type of detector; for, besides rectifying the current induced in the aerial circuit by the incoming oscillations, it also amplifies, and it is this latter characteristic that makes it the most sensitive detector in existence.

The amplifying action of the vacuum tube is readily explained if the reader will refer to Fig. 1, which accompanies this text. In this sketch it will be noted that an aerial or antenna, and ground are connected to the primary winding of a receiving transformer, and this winding, in turn, is in inductive relationship with a secondary winding *L* shunted by a variable condenser C_1 and then connected to a three-electrode vacuum tube with the necessary filament and plate batteries and other requisites, as already described in another instalment. As the incoming oscillations impinge on the aerial and travel up and down the antenna system on their journey to the ground, these oscillations are induced in the secondary coil *L* and they impress themselves between the *grid* and the filament. These are represented in graphical form in Fig. 2, at *A*.

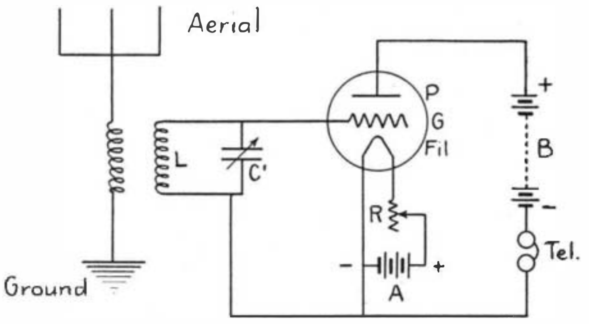

Fig. 1. Method of connecting three-electrode vacuum tube as a simple detector, without a grid condenser

Because of the uni-directional characteristics of the tube, the current in the plate circuit is *positive* only, but is of oscillating nature in direct resonance with the incoming oscillations, and the altitude or height of said oscillations is increased noticeably as shown at *B* in Fig. 2.

The ultimate result in the telephone receivers is shown in Fig. 2 at *C*; the high frequency oscillations are smoothed out by the inductance of the telephone receiver so that each train of high frequency current is a single impulse equivalent to the spark frequency, which is usually audible. The above explanation applies only when no grid condenser is used.

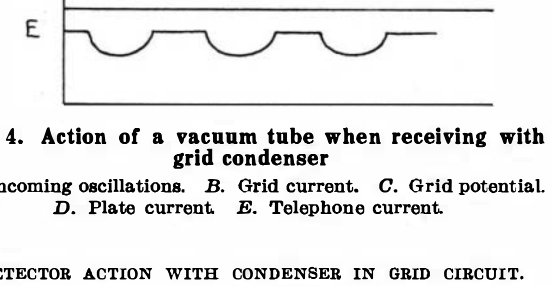

Fig. 4. Action of a vacuum tube when receiving with grid condenser

A. Incoming oscillations. *B.* Grid current. *C.* Grid potential. *D.* Plate current. *E.* Telephone current.

DETECTOR ACTION WITH CONDENSER IN GRID CIRCUIT.

If a grid condenser is used in accordance with Fig. 3, the action of the tube as a detector of incoming oscillations is quite different. The action now follows the exact form of the characteristic curve shown in instalment VII (SCIENTIFIC AMERICAN SUPPLEMENT No. 2285). When the voltage applied on the grid is of the same value as that of the filament and no grid oscillations are present, the grid current is zero; that is to say, no current or electrons are passing from the filament to the grid. Now if we suppose that a series of wave trains, as shown at *A* in Fig. 4, impinge on the antenna and the circuit *LC*, in Fig. 3, is tuned to them or is in resonance, then oscillations are set up in this circuit. If similar voltage oscillations are impressed on the grid through the grid condenser C_2—a condenser usually of 0.0002 microfarad capacity, each time the grid becomes positive, electrons will flow to it, but during the negative half of each oscillation no grid current will flow. This action is shown in Fig. 4 at *B*. The grid will continue to gain negative charges during each wave train, and then fall as shown in Fig. 4 at *C*.

As explained in a previous instalment, a negative charge on the grid always opposes the flow of electrons, causing the plate current to decrease. This charged condenser leaks off either through the condenser or by the use of a high resistance placed across what is called the grid leak resistance, and the plate current resumes its normal value as shown at *D* in Fig. 4. The telephone diaphragm cannot vibrate at radio frequencies but it manages to smooth out the plate current variations into a form shown graphically in Fig. 4 at *E*, causing a note to be heard of a frequency corresponding to the transmitter's note.

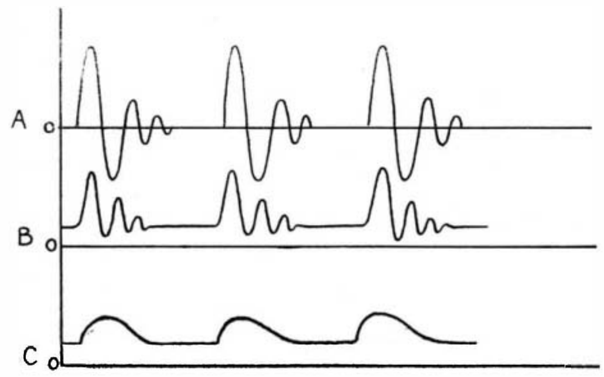

Fig. 2. Action of vacuum tube as a detector

A. Voltage oscillations impressed on the grid. *B.* Resulting plate current variation. *C.* Corresponding telephone current fluctuations.

AMPLIFYING ACTION OF VACUUM TUBE.

It has been pointed out that a vacuum tube rectifies because when an alternating voltage (incoming oscillation) is applied to the filament and grid, the current produced in the plate circuit is of oscillating nature but its oscillations are *positive* only. The plate oscillations have greater amplitude or vertical height, resulting in a louder response in the telephone. This is the reason why a vacuum tube is a more sensitive detector than the crystal type, which rectifies but does not amplify.

It is often desirable to amplify without rectifying an alternating current. This is done by keeping a voltage on the grid of such value that the symmetry of the oscillations in the plate circuit are not altered. Referring to Fig. 5, it will be noted that the input circuit is connected to the alternating voltage which is to be amplified, and that this is impressed between the grid and the filament, so that the grid potential will alternate in accordance with the alternations of the applied electromotive force. These grid variations produce changes in the plate current of corresponding characteristics. For instance, if the mean potential of the grid and the amplitude of the applied electromotive force are such that the current in the plate circuit is always in that portion of its characteristic curve where it is a straight line, then the variations of the grid potential will be exactly duplicated in the variations of the plate current, both being in exact phase.

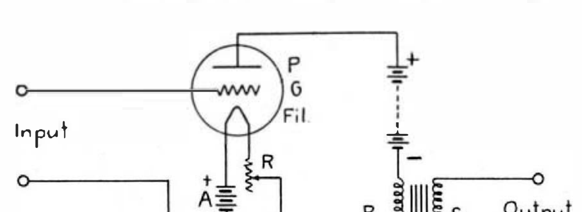

Fig. 5. Using vacuum tube as an amplifier—transformer coupled

Taking into consideration Fig. 6, the portion *A* represents the grid variations due to the applied alternating electromotive force, and portion *B* represents the fluctuations of the plate current. For a given amplitude *A* the resultant amplitude of the component current in *B* will depend on the steepness of the characteristic curve of the plate. The applied alternating voltage on the grid supplies only the very small grid filament current, and the power drawn is very small, but the resultant power is quite considerable, thus resulting in a large volume of amplification. This large volume of amplification can be utlized by connecting it to the output circuit, or it can be diverted to the grid and filament of a second vacuum tube, and with proper design of the associated circuits a further amplification can be obtained. This can be carried through a number of progressive stages of amplification, but a limit is finally reached where howling begins. In regular practice amplification is limited to three stages for the type of circuit just described. This method is termed the audio-frequency amplifier, because the current is audible to the human ear when passed through a telephone receiver.

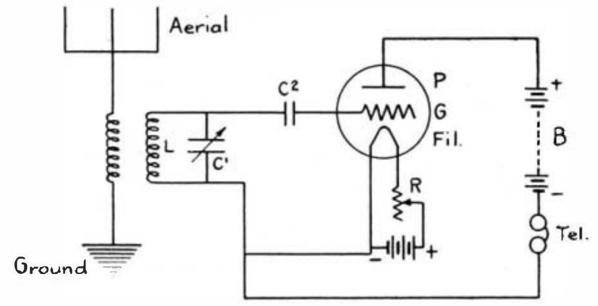

Fig. 3. Method of connecting three-electrode vacuum tube as a simple detector, with condenser in grid circuit

*This article is one of a series appearing in the SCIENTIFIC AMERICAN SUPPLEMENT for the past few months. The first instalment appeared in the issue dated July 5, 1919, No. 2270. Back numbers may be obtained as long as the supply lasts. (Copyrighted, Scientific American Publishing Company.)

The Salvage of Leclanché Cells

IN a paper read before the Inst. of Railway Signal Engineers, W. J. Thorrowgood describes a method of renovating the porous pots of Leclanché cells. Mere soaking and washing proved to be useles, but it was noticed that the contents of such pots had an alkaline reaction. They were therefore allowed to stand in a solution of commercial hydrochloric acid (one part of acid to five parts of water), the depth of the acid being such that it comes nearly to the black rim at the top of the pot. The pots are allowed to stand for 24 hours in the acid. They are then washed and soaked in clean water for 48 hours, the water being changed after 24 hours' immersion. The cells are then ready for use. Service tests in railway working have shown that cells so treated stand up well. The method has been put to considerable use on the London and South Western Railway. It is also found that the interiors of spent dry cells may be used as porous pots. To render the sack interiors of spent cells suitable for use in place of porous pots the zinc case is removed, the jelly is washed away (in the case of Dania cells), leaving the interior to dry. A little pitch is heated and placed on the top of the sack and around the carbon rod, or the top of the sack and carbon rod when dry are varnished with an insulating varnish or paraffin wax to prevent the salts from creeping. The sack is then ready for use in an ordinary Leclanché cell. If a spent interior after being washed does not give satisfactory results in testing, it is submitted to the hydrochloric acid process, similarly to a spent porous pot, but for a shorter period. Up to March 31, 1919, 4165 interiors of spent dry cells were thus treated. It is found that one quart of hydrochloric acid is sufficient to treat 36 porous pots, and the average cost of material and labor, including war wage, is 2d. per pot. Spent interiors of dry cells cost 2.5d. to render useful. When porous pots are treated in bulk, say, about 40 at a time, the cost works out at 1.5d. each. It is estimated that the value of a treated porous pot or of a treated interior of a spent dry cell is approximately 50 to 60 per cent of that of a new porous pot.—*Science Abstracts.*

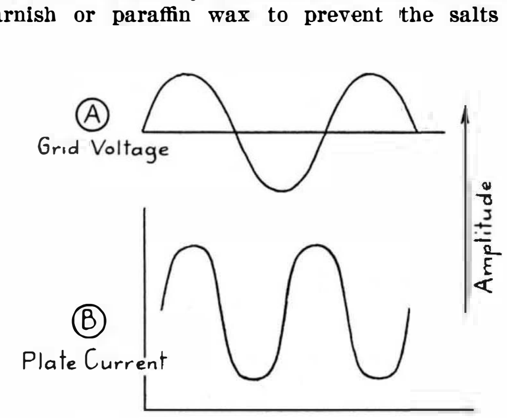

Fig. 6. Showing variation of plate current with grid voltage