A New Non-Oscillating Tube

A Novel Principle Governs the Operation of a Detector Designed to Eliminate Distortion and Capacity Effects and to Secure Maximum Response Without Regeneration

A NEW type of detector tube was described and demonstrated before the Institute of Radio Engineers late in December by Harold P. Donle, chief engineer of the Connecticut Telephone and Electric Company.

He explained that this new tube has no grid, and has no useful period of oscillation, but he claimed for it sensitiveness equal to a standard detector tube used in a circuit where increased signal strength is secured by means of regeneration, or semi-oscillation. In addition the new tube when in its most sensitive condition, does not seem to generate energy in an antenna to produce interference with other nearby receivers. The new tube also appeared to have another quality in that it is not sensitive to body capacity effects while being tuned or adjusted for maximum response. Maximum response to signals of a given wave length is accomplished by varying the neutralizing potential of the input circuit of the tube.

The construction of one form of this tube is illustrated diagrammatically in figure 1 where F is the filament, A is the anode, which may be of metallic sodium in the bottom of the tube, and H is the heater which is a short length of resistance wire cemented to the outside of the glass directly underneath the anode. This heater maintains the anode at proper operating temperature. C is the "collector" electrode of sheet metal bent into a "U" and positioned above the filament, with its open side toward the anode.

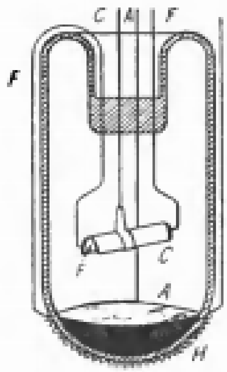

Figure 1—Diagram of the Donle tube

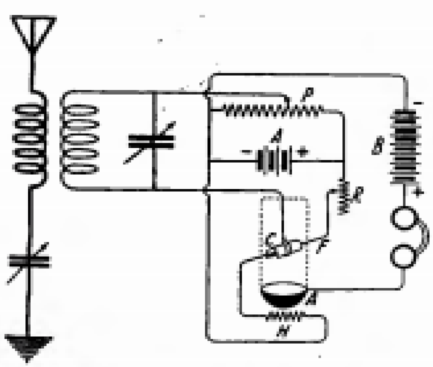

Figure 2—Circuit showing connections for the new tube

In operation the tube may be connected to the circuit, shown in figure 2, which is simply a two circuit tuner with one terminal of the secondary connected to the collector electrode of the tube and the other to a contact operating on resistance connected directly across the filament battery terminals. The remainder of the circuit is as used with any simple detector.

The adjustment of the collector potential is the only one necessary for efficient operation other than the usual variation of capacity and coupling of the tuning circuit. The potential of the "B" battery is not at all critical and usually may be varied between ten and thirty volts without much effect on response.

Mr. Donle secured a response with this tube in a plain circuit equal in magnitude to the response from a regenerator, using maximum non-oscillating regeneration. A regenerative circuit under this condition of critical adjustment gave very considerable distortion.

On the other hand, the new detector created no noticeable distortion, and, as it does not oscillate over its useful range, it cannot create any interference with other receivers.

The response of the tube is greatly improved by very weak coupling between the circuits. This is due to its very low input impedance, which also makes the proportion of capacity and inductance of the secondary circuit for maximum results quite different from those for other tubes. Although the new detector can be used successfully in an ordinary two-circuit tuner, results will fall short of the maximum unless means are available for selecting the best value of secondary inductance.

In this tube there is an electron flow from the filament to the collector, the magnitude of this current being due in part to the relatively large area of the collector and to its close proximity to the filament. It, therefore, receives an equivalent of large electron flow when it is at the same potential as the negative end of the filament. In order to reduce this flow an opposing potential —which may be taken from the "A" battery—is introduced into the circuit between the collector and filament. This potential is called the neutralizing potential and is used as abcissas of curves shown in figure 3, which show the variation in anode and collector currents Ia and Ic with variation of neutralizing potential En, and also the collector current when the anode circuit is open I'c. The curves labeled Ic-I'c is the difference between the collector current with the anode circuit completed and opened. This last curve is interesting in that it apparently takes into consideration various phenomena concerned in the operation, and its slope is practically a direct index of the functioning of the tube as a detector.

These curves show some of the fundamental characteristics of the tube.

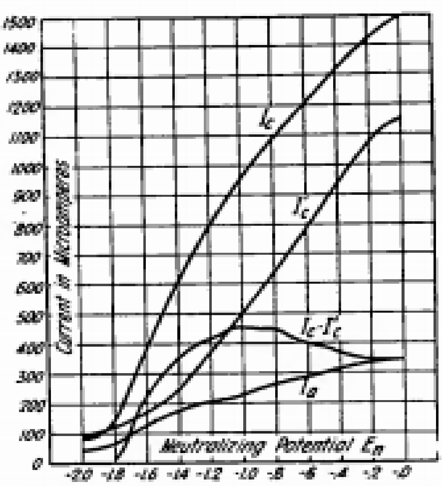

Figure 3—Characteristic curves of the gridless tube

The abrupt bend in the collector current at En=—1.8 is a point at which maximum detection would be expected to take place, according to the usual conception of detection as being due to rectification over a section of the characteristic slope where the rate of change is large. One would also gather from this curve that the effect of a signal impressed would be to increase the average value of the collector and anode currents. Although some detection takes place on this part of the curve, in magnitude it is incomparable to that secured over the sensitive portion of the slope. The point of maximum sensitivity for these curves is at En = —1.4 volts, which is at a relatively flat portion of the collector current curve and considerably above the lower bend. Furthermore, a signal impressed on the collector circuit always gives a decrease in collector current regardless of whether the characteristic curve at the sensitive point is concave or convex, many examples of both types having been observed. It should also be noted that this point of maximum sensitivity occurs somewhat above the center of the Ic-I'c curve. Another point of interest in connection with these curves is the values at operating potentials of collector and anode currents, the collector current usually being two to four times that of the anode.

Figure 4 shows the change in collector current of the sodium tube for impressed signals of different wave lengths. The ordinates of this curve show in micro-amperes the actual decrease in collector current caused by a signal of variable frequency, but of constant amplitude. This curve shows that the response for the particular tube on which this data was taken becomes small above the wave length of 1,000 meters, and that below this wave length detection increases rapidly. This might seem to indicate a limited wave length band of operation for this type of tube, but the entire shape and position of this curve depends upon the relative potentials of the tube electrodes and upon their proportions and relative positions. It is possible radically to change this curve by a simple variation of the neutralizing potential. It is also possible by a proper selection of values to secure a serrated form of this curve of which figure 5 is a typical example. The possibilities indicated by this curve in the elimination of interference are obvious.

Figure 6 shows the variation in collector current at various values of En due to an impressed signal of constant frequency on the collector circuit. Thus it represents the range of the neutralizing potential for a signal, and gives some idea of the ease of adjustment of this variable for maximum signal. This adjustment is obviously broad and allows a relatively wide variation of neutralizing potential for an audible signal, making it simple and easy to locate the point of maximum sensitivity.

Although the collector current pulsates at low frequencies, the tube is entirely ineffective as a heterodyne receiver due to the almost negligible detection at this frequency. As can be observed by an examination of figure 4, no appreciable detection takes place until the signal frequency is at least four or five times the fundamental pulsation frequency.

Since slow changes in the collector circuit current are reflected in the anode circuit, a decrease of the average value of the collector current will result in a like decrease in the anode current, but this occurs without any appreciable amplification. By experiment on a large number of tubes the ratio of change of power in collector circuit to resulting power change in anode circuit was found to be approximately unity.

The action of this tube depends upon ionization produced by electrons emitted from the filament. The use of an easily vaporized anode metal allows great possibilities in the way of controlling ionization, in part because it becomes possible to secure a very sharp density gradient of atoms available for ionization, and to supply these atoms continuously at the proper rate required for operation, thus leaving unrestricted the mean free path beyond the zones of ionization.

Sodium is a convenient metal of this type, but similar useful effects have already been secured from a variety of differently composed anode materials. In practice the heater is connected in series with the filament, and the two are thus controlled simultaneously.

At first thought it would seem necessary to allow a considerable time after lighting the tube filament before the anode would become sufficiently hot. That is, however, not the case, for on account of the following most interesting phenomenon:—When the filament is first lighted the anode receives a small amount of heat by direct radiation from the filament and there will be, even at this relatively low temperature, a considerable emission of particles from this anode. This emission will, however, decay with time, and in a period of possibly one hour it will have reached a small fraction of its initial value. However, with the external heater connected in series with the filament, as described above, when the filament is lighted the anode will commence to receive heat from this heater. Its effect in raising the anode temperature will be necessarily slow on account of the interposition of the glass wall of the tube, but the temperature of the anode will be increased by this heater at a rate approximately correct to compensate for the decay of the initial emission, and thus the emission of particles from the anode will become fairly constant within a few seconds after the filament of the tube is first lighted.

The result of this combination of affairs is that when the tube is lighted it is almost immediately in operative condition, although in some cases a slight re-adjustment of neutralizing potential is later necessary to maintain a maximum sensitivity.

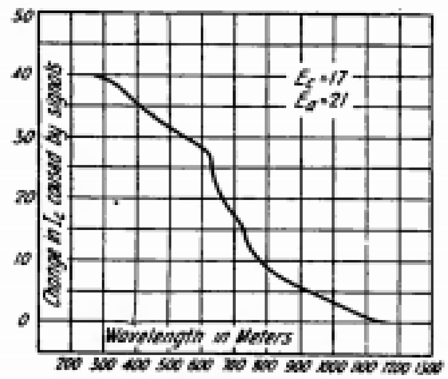

Figure 4

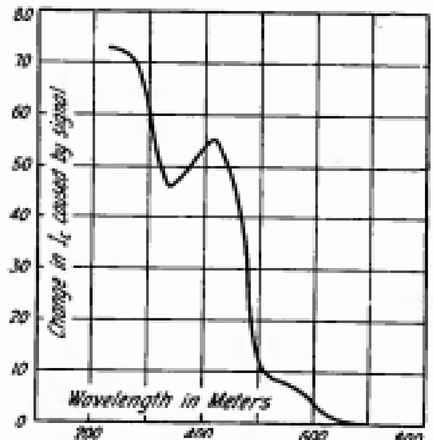

Figure 5

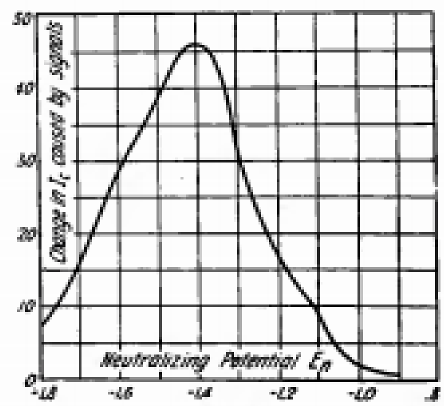

Figure 6

Characteristic curves of the Donle tube under various conditions of operation