High level plate circuit rectification

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DURING the past several years a rather complete theory of detection or rectification for small signals has been built up mathematically. The theory, however, is only satisfactory for practical purposes when the input voltage is small and the higher order terms of the series expressions derived in the mathematical theory are negligible and may be neglected, for as the input voltage is increased the higher order terms became increasingly important making computations too difficult for practical purposes.

The experimental procedure for attacking the problem of plate rectification with large input voltages is receiving considerable attention at present. The necessary experimentally determined curves may be obtained very easily so that anyone with measurable a.c. voltages and a fairly accurate d.c. milliammeter may plot his own rectification characteristics for a resistance load. The fundamental relation in the experimental procedure is the relation between the direct current and the a.c. voltage impressed on the grid of the tube with either a constant grid bias and a variable plate voltage or a constant plate voltage and a variable grid bias.

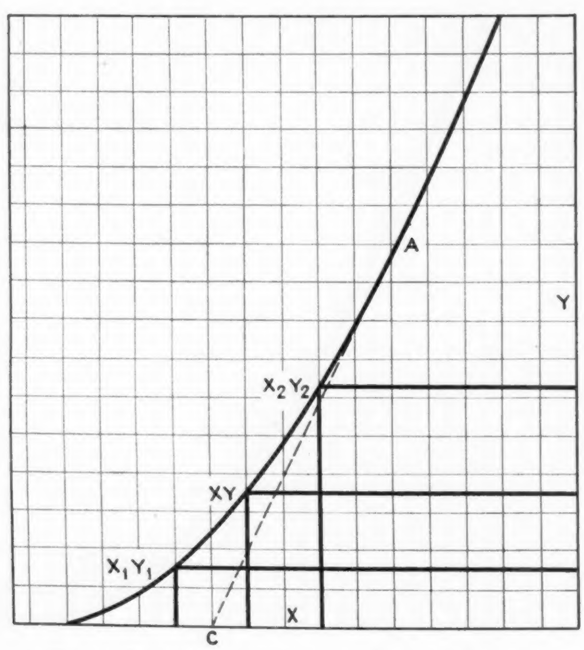

Fig. 1—Typical characteristic on which rectification takes place

The device having a linear relation between the current such as shown by the line AC in Fig. 1 would be an ideal rectifier for the usual signal provided that the operating point was located at C. The current for a voltage to the right of point A is $I = E/r$ where r is the resistance of the device and the current for a voltage to the left of the point A is zero.

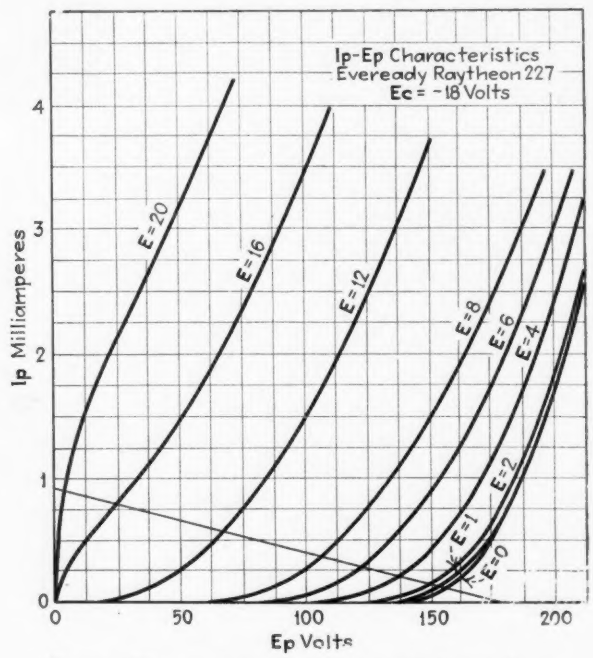

Fig. 2—Plate current as function of plate voltage and carrier input voltage

If a voltage $E \sin \omega t$ is applied to the ideal rectifier and if the operating point is located at the point C the average current would be

$$(1)\quad I = \frac{E}{\pi}\,\frac{1}{r}$$

If a resistor R is inserted in series with the device the current will be

$$(2)\quad I = \frac{E}{\pi(r+R)}$$

The rectified voltage will be RI or

$$(3)\quad V = \frac{E}{\pi}\,\frac{R}{r+R}$$

The sensitivity which will be defined as $\frac{dV}{dE}$ is

$$(4)\quad S \text{ or } \frac{dV}{dE} = \frac{1}{\pi}\,\frac{R}{r+R}$$

If the external resistor is by-passed for the carrier the sensitivity will be increased by the ratio $\frac{r+R}{r}$, hence the sensitivity is

$$(5)\quad S = \frac{1}{\pi}\,\frac{R}{r}$$

If a 100 per cent modulated input is applied as shown in Fig. 1, the plate current will vary between the values for zero and twice the input voltage. If the modulation percentage is any value, the audio frequency output voltage may still be found readily, for the output will vary between the values given by $E - ME$ and $E + ME$ where M is the percentage modulation.

The action of the tube rectifier will be considered next. The curve in Fig. 1 shows an experimentally determined characteristic curve of I_p plotted versus E_g with E_p constant. It is to be noted that the curve approximates the straight line characteristic of the ideal rectifier provided that the input voltage is made large enough and the operating point is located near the point C so that area under the curve to the left of the line AC is made small compared to the area to the right. It is to be noted that for small signal voltages the detector will act as the normal square-law detector and as the input voltage increases the working characteristic aproaches a straight line. The audio frequency output first varies as the square of the input voltage and then approaches linearity as the signal voltage increases.

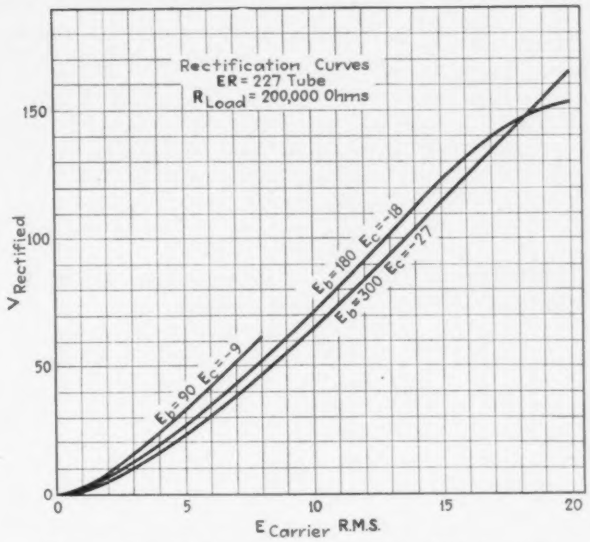

Fig. 3—Rectified output voltage of typical detector

The output voltage could be calculated by determining experimentally either the $I_p - E_p$ curves with E_g constant and various AC input voltage impressed on the grid or the $I_p - E_p$ characteristic with E_p constant and E_g variable with various a.c. voltages in the grid. The latter method is somewhat restricted as it is necessary to take the curves with some fixed external plate resistor so that in a general study many curves will have to be taken. The method of using the $I_p - E_p$ curves with a given C bias on the other hand allows a very general study to be made with comparatively few sets of readings so that the output may be calculated for any B voltage and any value of external resistance from one set of curves. A general study of any type of tube may be made from several groups of curves with different C bias voltages.

The rectified output voltage or the d.c. voltage across the external plate resistance is found from the $I_p - E_p$ curves for various a.c. input voltages. Figure 2 shows typical $I_p - E_p$ curves taken with an ER-227 tube with 18 volts C bias. A load line for a 200,000-ohm external resistor is shown plotted in from 180 volts. Any other resistor or battery voltage could be used just as well. In general though, it is not advisable to use over 200,000 ohms for the external resistor because the various capacities which shunt this resistor change the effective value of impedance if the resistor is made too high. The result is that the effective impedance decreases with increasing frequency, thus cutting off the higher audio frequencies.

The most useful information derived from this curve is the rectified output voltage curve. This curve is the change of voltage across the external load resistor and is a measure of the output voltage as will be noted below. In Fig. 2 the point where the load line crosses the curve for zero input voltage is taken as the reference voltage. The rectified voltage for any carrier voltage is then the difference between the two intersections. It is to be noted that the voltage should be greater than the voltage at which the curve for zero input voltage starts otherwise considerable distortion will result. For example, if the B-voltage is 125 volts there would be no rectified output voltage until a 2-volt carrier is impressed.

Figure 3 shows typical rectified curves for three different grid voltages obtained using an ER-227 tube. As was explained previously the rectified output voltage for any carrier will fall along the load line for $E - ME$ and $E + ME$. The output voltage for any carrier and percentage modulation may be found quite readily from these curves. For example, with E_b 300 volts and E_c — 27 volts assume a 12-volt carrier modulated 33 per cent. The total audio swing will then be between $12 - 4$ and $12 + 4$ or 8- and 16-volts carrier. For a 16-volt carrier the output is 124 volts and for an 8-volt carrier it is 47 volts so that the resultant peak audio frequency voltage is $\frac{124 - 47}{2} = \frac{77}{2}$ volts or 38.5 volts. Similarly, the peak audio frequency voltage may be found for any other carrier and percentage modulation.

Curves like those in Fig. 2 give complete detection data.

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