Amplification Factor Chart

A method of determining the amplification factor of a receiving tube from its geometrical construction by means of a graphical solution of the Vodges and Elder formula

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ONE of the most important parameters in the design of radio receiving tubes is the amplification factor and there are almost as many methods of calculating it as there are tube engineers. The reason for this multiplicity of solutions is that no formula has yet been found which is completely satisfactory.

The most widely used formula is probably that of Van der Bijl. It is very useful for quick computations and its accuracy is quite sufficient for practical purposes after its constant for the particular structure in question has been determined. The formulas of Miller and King are certainly more accurate, but the increase in accuracy is not sufficient to compensate for the large increase in complexity of computation. A more accurate version of the formulas, given by Vodges and Elder, is rather involved.

To enable the engineer to compute the amplification factor as accurately as possible with computations kept to a minimum, this formula was put in nomogram form. The chart presented gives the value of the amplification factor for both cylindrical and plane structures.

The Vodges and Elder formula for cylindrical triode electrodes is

$$\mu = \frac{2\,\pi\,N\,R_g \log_e R_p/R_g - \log_e \cosh \pi\,N\,W}{\log_e \coth \pi\,N\,W}$$

and for plane electrodes it is

$$\mu = \frac{2\,\pi\,N\,D - \log_e \cosh \pi\,N\,W}{\log_e \coth \pi\,N\,W}$$

in which μ = amplification factor
N = pitch of grid winding
W = diameter of grid wire
R_p = radius of plate (cylindrical structure)
R_g = radius of grid (cylindrical structure)
D = distance between grid and plate (plane structure)

In order that the chart will consist of straight line scales, two new variables have been introduced. The screening factor of the grid, given by the product NW, is used instead of the grid wire diameter W and the ratio of plate radius to grid radius, R_p/R_g, is used instead of the plate radius.

The amplification factor is determined in the following manner. On scale I a point is located which represents the actual grid pitch and on scale II a point is located which represents the screening factor of the grid or the product NW. A straight line connecting these two points is extended to intersect scale III at a reference point. At this point a discrimination must be made between plane and cylindrical structures. For a plane structure, a point corresponding to D is located on scale V and a straight line drawn connecting it and the reference point on scale III. This line intersects scale IV at the value of amplification factor for the structure in question.

COMPARISON BETWEEN CALCULATED AND MEASURED VALUES OF AMPLIFICATION FACTOR.

Tube type	Structure number	Form factor	Calculated values of μ_p	μ_c	μ	Measured μ
2A3	1	00	4.2	...	4.2	4.2
31	2	.11	4.0	2.2	3.9	3.8
45	2	.11	4.0	3.2	3.8	3.5
26	5	.44	8.5	5.8	7.3	8.3
76	6	.55	16	11	13.1	13.8
75	7	.66	148	69	95.8	100
6K5	8	.77	92	47	66.5	70
6B5	9	.88	5.6	4.1	4.24	4.20

For a cylindrical structure, points are located on scales VI and VII corresponding to R_p/R_g and R_g respectively and connected by a straight line extended to intersect scale V at a reference point. A line connecting the reference points on scales III and V intersect scale IV at the value of amplification factor for the structure in question.

The most serious discrepancies from theory result from the presence of grid supports and the fact that tube structures are generally a combination of shapes rather than plane or cylindrical. The general procedure is to determine the value of μ considering the structure to be both plane and cylindrical and to take an intermediate value. A fairly close evaluation of the effect of electrode shape can be made by the use of the following formula:

$$K = \frac{\mu_p - \mu}{\mu_p - \mu_c}$$

Where K = form factor
μ_p = amplification factor for plane structure
μ_c = amplification factor for cylindrical structure
μ = amplification factor for actual structure

The insert shows an attempt to evaluate the form factor for various practical constructions. The diameter of the grid supports is kept constant. A few typical results are tabulated below.

An exhaustive discussion of the discrepancies would be too long due to the complexity of the problem. However, a few cases might well be pointed out. For instance, the twelve per cent error shown for type 45 is due to the abnormal structure of this tube. The plate is very close to the grid and the grid has a relatively large diameter and a course pitch. Therefore, the values of μ_p and μ_c are close together and their approximation is poor because of the nonuniformity of the field at the surface of the plate.

In cylindrical structures the most common cause of error is that due to the variation in size and position of the grid supports. A change in diameter or in the center-to-center distance will change the form factor. The relative position and size of the supports has been omitted in the diagram so as not to complicate the problem any further. An average value which has proved to be quite accurate in practical cases has been taken.

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