VI. MICROWAVE ELECTRONICS*

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A. HIGH-PERVEANCE HOLLOW ELECTRON-BEAM STUDY

Preliminary results have been obtained in the dc tests of a magnetron injection gun. The gun consists of a cylindrical cathode (diameter, 14.2 mm) and a conical anode (half-angle, 15°). The transition to the drift tube (diameter, 19.1 mm) is formed by a bullet-shaped nose that is attached to the cathode. The gun is operated in a uniform magnetic field. The current intercepted by the anode, as well as the cathode and collector currents, can be measured. The beam cross section can be observed through a telescope on an incandescent screen in the drift tube.

The beam that was produced had a perveance in the range $16\text{-}20 \times 10^{-6}$ amp volt$^{-3/2}$ for 1-7 kv voltages. At 7 kv, the beam current was 12 amps, which corresponds to an electron density of 2.4×10^{10} cm^{-3} or a plasma frequency of 1400 mc. The magnetic flux density was approximately 1650 gauss. The beam was almost perfectly symmetrical and showed no breakup under maximum perveance conditions. Its outside diameter was approximately 16.5 mm and its thickness approximately 15 per cent.

These tests will be repeated for different anode positions. Radiofrequency interaction measurements will be made subsequently.

A. Poeltinger

B. APPROXIMATE TECHNIQUE FOR EVALUATION OF ELECTRONIC LOADING IN A KLYSTRON GAP IN THE PRESENCE OF A POTENTIAL DEPRESSION

We have previously developed formulas that are applicable to the calculation of parameters describing the interaction between the fields at klystron gaps and electron beams.[1] This formulation employs the kinematic assumption (the action of electric fields arising from electron bunching is neglected) and treats the situation in which the dc beam velocity is a function of distance. We wish to develop an approximate technique that may be used to evaluate certain of the parameters. This technique will be applicable to a system such as that shown in Fig. VI-1 in which a thin, hollow electron beam interacts with rf electric fields introduced through a slit in the drift-tube wall.

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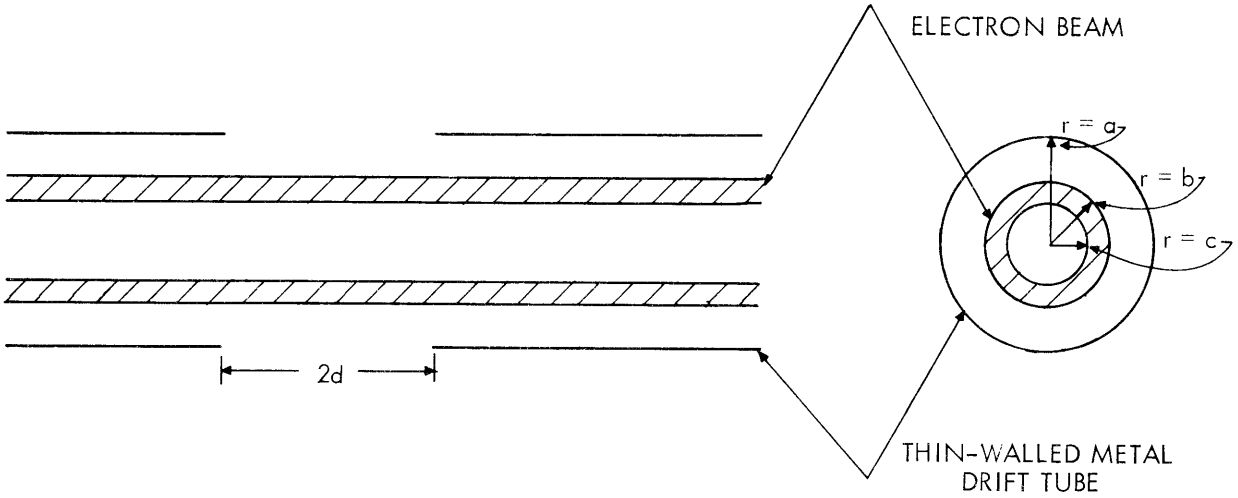

Fig. VI-1. Klystron gap region.

Let us outline a method that can be used to find the voltage coupling coefficient, current coupling coefficient, and electronic loading for the geometry of Fig. VI-1.

Step 1: We evaluate the parameters mentioned above under the assumption of space-independent dc beam velocity.

Step 2: We consider an electron beam that interacts with rf electric fields introduced by means of a gridded gap. We find a gap length that is such that the interaction parameters are the same in both problems.

Step 3: We make a piecewise linear approximation of the velocity as a function of transit time, as shown in Fig. VI-2.

Step 4: We evaluate the gap interaction parameters by means of the gridded gap of step 2 and the approximate velocity of step 3.

Beaver, Demmel, Meddaugh, and Taylor[2] have performed experiments with high-density electron beams and klystron gaps. We shall use some data obtained in one of their experiments.

A 114-amp hollow electron beam with an inner diameter of 1 inch and an outer diameter of 1.16 inches was passed through a drift tube that has an inner radius of 1.50 inches. The drift-tube potential was 45 kv. The beam had a perveance of 12×10^{-6} amp/volt$^{3/2}$. The mean beam potential away from the gap region was 39.7 kv. The gap in the wall of the drift tube was 0.875 inch long. The excitation frequency for the experiment was 1300 mc. The beam passed through a symmetric static potential depression caused by the presence of the gap opening. This potential depression was measured in an electrolytic tank simulation of the gap geometry and beam space charge. The measured electronic loading resistance was approximately 1900 ohms.

Let us first calculate the electronic loading under the following assumptions:

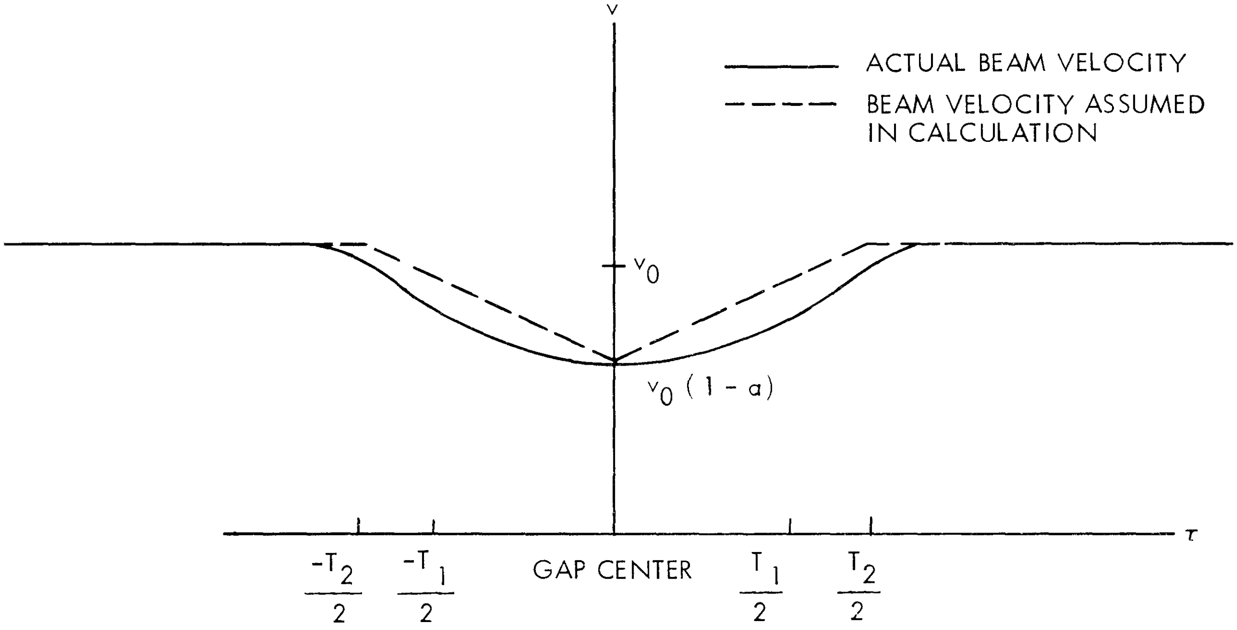

Fig. VI-2. DC beam velocity vs transit time in the gap region.

(a) We assume no potential depression; hence, we assume that the beam velocity is constant through the gap region and is equal to the beam velocity far away from the gap.

(b) We assume a constant velocity in the gap region which is the average of the actual velocity in the gap.

The relativistic, kinematic formula for electronic loading by a thin electron beam, as obtained from the relativistic space-charge theory of gap interaction[3] in the limit $(\omega_p/\omega) \to 0$, is

$$G_{e\ell} = \frac{G_o}{R(R+1)} \left[\frac{I_o(\gamma b)}{I_o(\gamma a)} J_o(\beta d)\right]^2 \left[\beta d \frac{J_1(\beta d)}{J_o(\beta d)} - R^2 \gamma b \frac{I_1(\gamma b)}{I_o(\gamma b)} + R^2 \gamma a \frac{I_1(\gamma a)}{I_o(\gamma a)}\right]$$

where

$$G_o = \frac{I_{beam}}{V_{beam}}$$

$$R = \frac{1}{\sqrt{1 - \frac{v_{beam}^2}{c^2}}} \; ; \; \frac{V_{beam}}{\left(\frac{m_o c^2}{e}\right)} = R - 1$$

$$\beta = \frac{\omega}{v_{beam}}$$

$\gamma = \frac{\beta}{R}$

b = beam radius

a = drift-tube radius

2d = gap length.

Results of the calculations are summarized below

	Case 1	Case 2
βd	0.815	0.843
γb	0.935	0.971
γa	1.298	1.349
R	1.08	1.07
G_o	2.871×10^{-3} mhos	3.089×10^{-3} mhos
$G_{e\ell}/G_o$	0.1600	0.2019
$G_{e\ell}$	4.59×10^{-4} mhos	6.24×10^{-4} mhos
$R_{e\ell}$	2180 ohms	1600 ohms

Now we shall employ the method described above in steps 1-4.

First, we find the voltage coupling coefficient and current coupling coefficient for our device to be

$M_o = 0.7503$

$N_o = 0.2132.$

Second, the appropriated gridded gap length is found to be

$d = 2.45 \times 10^{-2}$ meters.

Third, from the electrolytic tank data, we find an approximate velocity

$$
\begin{aligned}
v &= v_o && -\infty < \tau < -T_2/2 \\
&= v_o\left(1 - a - \frac{2a}{T_2}\tau\right) && -T_2/2 < \tau < 0 \\
&= v_o\left(1 - a + \frac{2a}{T_2}\tau\right) && 0 < \tau < T_2/2 \\
&= v_o && T_2/2 < \tau < \infty
\end{aligned}
$$

Here, $v_o = 1.113 \times 10^8$ meters per second; $a = 0.04$; and T_2 is a transit time corresponding to a distance, d_2, of 4.225×10^{-2} meters.

Fourth, using the values in the formula for electronic loading previously derived,[1] we find that $G_{e\ell}/G_o = 0.1846$. Hence $G_{e\ell} = 5.301 \times 10^{-4}$ mhos, and $R_{e\ell} = 1890$ ohms; this value of $R_{e\ell}$ compares very favorably with the measured value. It must be mentioned, however, that all three values of $R_{e\ell}$ presented above fall within the limits of experimental error.

Work on potential depression in klystron gaps has been completed and the results presented in a thesis, entitled "Effects of Potential Depression in Klystron Gaps," that has been submitted by the author to the Department of Electrical Engineering, M. I. T., in partial fulfillment of the requirements for the degree of Master of Science.

C. W. Rook, Jr.

References

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