VII. MICROWAVE ELECTRONICS*

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A. TWO-GAP KLYSTRON CAVITIES

1. Introduction

Klystron microwave amplifiers have, in the past, been considered as inherently narrow-bandwidth devices because resonant cavities have been used in these amplifiers for coupling electromagnetic power into and out of the electron beam. The use of multiple, stagger-tuned, intermediate cavities has resulted in such an increase in theoretical bandwidth that the output cavity, which was once considered to be broadband with respect to the rest of the system, is now the limiting factor on bandwidth (1).

The use of two-gap output cavities has been suggested (2) as a means of increasing bandwidth for the following reasons. The amount of rf power extracted from an electron beam is inversely proportional to the equivalent shunt conductance of the output cavity, and the Q of the cavity is inversely proportional to its shunt conductance, and thus the power extracted from the beam is directly proportional to the Q of the cavity. If two gaps with two coupled cavities are used, each gap need extract less power, and hence the Q of the cavities can be lower.

Two-gap, double-tuned cavities, which have been built by Litton Industries, Inc., San Carlos, California, and by Eitel-McCullough, Inc., San Bruno, California, show increased bandwidth for equivalent output. Saharian (2) has presented a detailed theoretical analysis of single-gap and two-gap coupled klystron output cavities.

2. Description of Cavity and Equivalent Circuit

A two-gap cavity has been constructed for the purpose of conducting tests in the absence of an electron beam. This cavity is shown in Fig. VII-1. Each half of the cavity is tunable at frequencies around 3000 mc. The gap widths are for electron transit angles of approximately 1 radian for a 100-kv beam. The transit angle between the centers of the two gaps is π radians.

The equivalent circuit for the cavity is shown in Fig. VII-2. The inductances L_s and L_c represent the inductances of the septum and of the connector from the center
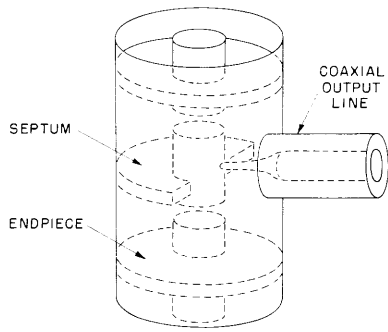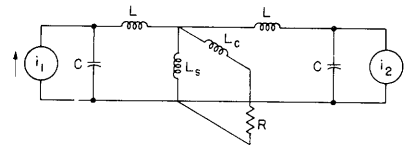
Fig. VII-1. Two-gap output cavity.

Fig. VII-2. Equivalent circuit for the cavity of Fig. VII-1.

conductor of the coaxial line to the center post of the cavity; the current generators i_1 and i_2 represent the currents induced in the gaps by the beam; and R is the load to which power is delivered.

3. Analysis of Operation

The type of circuit shown in Fig. VII-2 will have both a symmetric and an antisymmetric mode of operation. The current flow for each case is shown in Fig. VII-3.

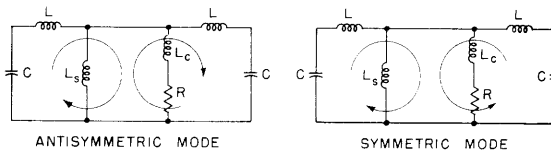ANTISYMMETRIC MODE   SYMMETRIC MODE

Fig. VII-3. Modes of operation for the circuit shown in Fig. VII-2.

This circuit can be operated in either or both of the two modes by adjusting the phase between i_1 and i_2. When only the antisymmetric mode exists, no output is seen because no net current traverses the center branch of the network. When only the symmetric mode exists, maximum output is seen across the load R.

4. Experimental Results

The cavity was excited with a probe at each gap, and power from the coaxial output was measured as a function of frequency. With both halves of the cavity tuned to the same frequency, maximum output power was observed for the symmetric excitation, and practically no output power was observed for the antisymmetric excitation. With one side of the cavity slightly detuned, the antisymmetric mode became visible. This

mode exhibited a higher Q than the symmetric mode, since only a small fraction of the total current flowed through the load R.

Experiments were made with septum angles of 270°, 240°, and 180°. The Q of the symmetric mode decreased as the septum angle was decreased because the resultant increase in L_s caused more current to flow through the load. With a septum angle of 180°, as shown in Fig. VII-1, the approximate value of the loaded Q was 10.

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References

1. L. D. Smullin and D. L. Morse, Broadband-buncher klystron, Quarterly Progress Report No. 56, Research Laboratory of Electronics, M.I.T., Jan. 15, 1960, p. 93.

2. A. Saharian, Broadbanding of a Klystron Output Cavity, E.E. Thesis, Department of Electrical Engineering, M.I.T., Jan. 4, 1960.