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Bandwidth Extension of an S-band, Fundamental-Mode Eight-Beam Klystron

Khanh T. Nguyen  
Beam-Wave Research, Inc.  
Bethesda, MD 20814

Dean E. Pershing  
ATK Mission Research  
Newington, VA 22122

David K. Abe and Baruch Levush  
U.S. Naval Research Laboratory, Code 6840  
Washington, DC 20375

Abstract: We present the design of a five-cavity, broadband, high-power multiple-beam klystron (MBK) operating in S-band. The MBK uses a 32 A, 45 kV eight-beam electron gun [1] whose design has been successfully tested in a previous narrowband MBK circuit [2, 3]. The circuit was optimized using the 3D particle-in-cell code MAGIC; the predicted performance includes a 3-dB bandwidth of 6.7%, peak power of ~600 kW and a gain of 33 dB. This circuit performance represents a three-fold increase in the bandwidth-power product relative to our previous circuit.

Keywords: Multiple-beam klystron; MBK; bandwidth extension; broadband cavity.

Design of a Broadband Multiple-Beam Circuit  
To achieve broad bandwidth operation, the circuit employs three two-gap cavities (the input cavity, second cavity, and output cavity) and two single-gap cavities (third cavity and penultimate cavity). The purpose of the two-gap cavities is to increase the $R/Q$ to enable broader bandwidth operation while maintaining the desired saturated power and gain within the constraints of a short overall interaction length. In the two-gap cavities, four rectangular slots couple two separate but dimensionally-identical cavities via their common endwalls. As expected for a system of two coupled individual cavities, there are two eigenmodes with distinct frequencies: the $m = 0$ (2π-mode) and the $m = 1$ (π-mode). The coupling slot dimensions control the mode frequency separation and also the coupling strength between the two gaps. For stability reasons and because of geometric constraints, the π-mode was selected as the operating mode for all of the two-gap cavities.

The first four cavities comprise the bunching circuit (Fig. 1a) which produces a highly bunched beam over the frequency band of interest at the axial location of the output cavity with reasonable gain. The evolution of the bunching currents for several frequencies as a function of axial position at 300 W of input power is shown in Fig. 1b. The magnitudes of these currents peak at an axial location approximately 18 cm downstream from the center of the first gap – the logical position to place the output cavity. In Fig. 2, the bunching current at this axial location is plotted as a function of frequency for different input drive power levels. Note that the beam modulation is relatively flat with frequency and linear with input power.

The predicted MBK output power as a function of frequency is shown in Fig. 3 (using a broadband, two-gap output cavity and a constant 300 W RF input drive). As seen in the figure, the circuit generates >550 kW across the band with a peak power of more than 600 kW at ~3.27 GHz. The 1-dB bandwidth is 5.2% (3-dB bandwidth of 6.7%) with a maximum gain of 33 dB and corresponding efficiency of 42%. This performance has been achieved with an overall circuit length of ~22 cm. Table I summarizes the operating characteristics of the five individual cavities (the 2π-mode frequencies of the three two-gap cavities have been tuned well outside the operating band).

Acknowledgement  
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References  
**Figure 1.** (a) MAGIC-3D solid model of the bunching circuit; (b) the computed fundamental bunching current as a function of axial position for a variety of driving frequencies (constant 300 W RF input drive).

**Table 1:** Individual characteristics of the five cavities comprising the broadband MBK circuit.

<table>
<thead>
<tr>
<th>Cavity</th>
<th># of Gaps</th>
<th>( f_0 ) (GHz)</th>
<th>( Q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>2 (( \pi )-mode)</td>
<td>3.160</td>
<td>54</td>
</tr>
<tr>
<td>Idler 1</td>
<td>2 (( \pi )-mode)</td>
<td>3.328</td>
<td>65</td>
</tr>
<tr>
<td>Idler 2</td>
<td>1</td>
<td>3.384</td>
<td>63</td>
</tr>
<tr>
<td>Idler 3</td>
<td>1</td>
<td>3.456</td>
<td>–</td>
</tr>
<tr>
<td>Output</td>
<td>2 (( \pi )-mode)</td>
<td>3.213</td>
<td>19</td>
</tr>
</tbody>
</table>

**Figure 2.** Computed (MAGIC-3D) fundamental bunching current as a function of frequency at an axial location of ~18 cm downstream from the center of the first gap for a variety of input drive power levels.

**Figure 3.** Computed (MAGIC-3D) frequency response of the eight-beam, five-cavity MBK circuit for a constant drive power of 300 W.