Cathode Follower RF System with Frequency Modulation

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abstract

A model RF system with a cathode follower was tested under frequency modulation in the 1-3.5 MHz range. The repetition rate was 40 Hz. The oscillation was stable, and the output impedance was measured to be around 20 ohm.

I. INTRODUCTION

The cathode follower RF system was first implemented as a beam buncher in the Proton Storage Ring at the Los Alamos National Laboratory [1]. For further applications to synchrotrons, it is necessary to study the feasibility under frequency modulation. A model RF system with a cathode follower [2] is being tested for this purpose. This report describes the results of the preliminary tests.

II. RF SYSTEM

Figure 1 shows the system setup. Two cavities are connected by a single-turn bias winding, either of which is directly coupled to the cathode of the final amplifier. Five ferrite rings (TDK SY-5, 440 mm o.d., 240 mm i.d. and 25 mm thick per ring) with cooling plates are stacked in each cavity. A 30-ohm resistor is installed at the grid input of the cathode follower to prevent the likelihood of vigorous oscillations, which could be expected from a negative resistance seen looking into the grid circuit [3]. In the driver stage high power tetrode (max. plate dissipation 90 kw) was used to drive a 500-ohm resistor across the grid input.

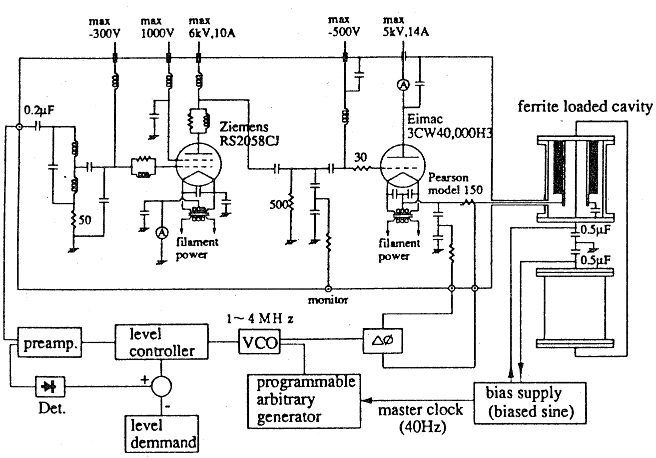

Figure 1. System setup

The bias power supply for cavity ferrites comprises a dc plus a resonant power source, which was originally purchased to study a ring magnet power supply at a high repetition rate. The output current has a shape of the dc-biased sinusoidal wave at a 40 Hz repetition. The power supply is provided with a self-trigger system to maintain the oscillation at resonance. Since the ac amplitude was limited to 250 A, the bias current was divided into three groups (200-700 A, 700-1200 A and 1200-1700 A) to cover the entire range of the RF frequency of interest.

A Tektronix programmable arbitrary/function generator produces a predetermined reference voltage for a voltage-controlled oscillator (VCO) at a constant clock rate. The waveform is generated with 12-bit resolution and the full scale of memory is 8192 points. The start of the generator cycle is synchronized with the repetition of the bias power supply. The phase difference between the grid voltage and the cathode current, the sensor of which is a Pearson model 150 current transformer, is also fed into the VCO. The level control loop is incorporated only to keep the preamplifier output constant.

III. OUTPUT IMPEDANCE AND HIGH POWER RESULTS

A Hewlett Packard 4195A network analyser was used to measure the output impedance; the probe was connected to the 'cold' gap where no quiescent current flows. Figure 2 shows a typical result compared with calculations using an electronic circuit simulation program, Spice. In the calculation, parameters were taken from the characteristics data sheet on the valve such that the amplification factor of the cathode follower is 18, the plate resistance 370 ohm, and cathode-grid capacitance 70 pF. Any stray capacitances across the grid input were estimated to be 83 pF. The bias current for ferrites was

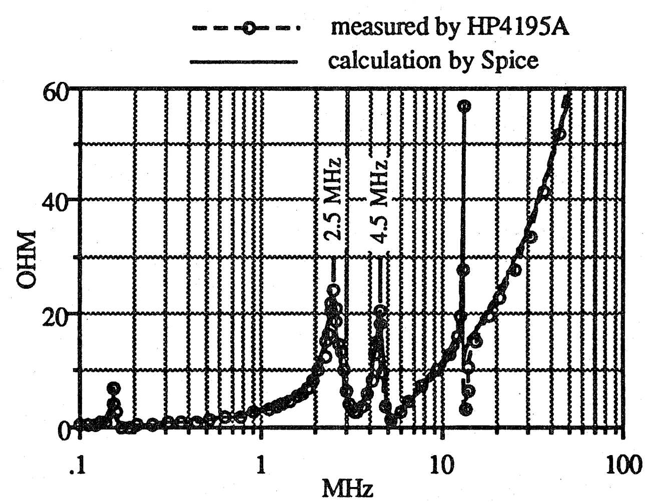

Figure 2. Typical result of an output impedance measurement. The cavity is tuned at 2.5 MHz.

adjusted to the resonance at 2.5 MHz. The peak at 4.5 MHz showed a parasitic resonance through the inductance (0.3 μH) of the bias winding loop, where the gap voltages of the two cavities swung 180° out-of-phase with nearly the same amplitudes. The calculation also fits the other spikes and the steep slope at higher frequencies, where contributions are from the lead inductance of the measuring probe and the cavity capacitors, as well as the bypass capacitor at the feeding point of the cavity bias current. Good agreement was obtained in phase data as well. The output impedance seen by the beam is summarised in Figure 3. A slight increase of the impedance with frequency is due to the fact that less voltage is developed between the grid and the cathode as the frequency becomes higher. Figure 4 displays RF wave forms over the range of 1.0-2.2 MHz. The voltages are lower by half or less than expected from the low-level measurements of the cavity shunt impedance [2]. 1.2 kV per two gaps was attained so far at 1.1 MHz. The oscillation was stable and no liability to buildup oscillations has been observed.

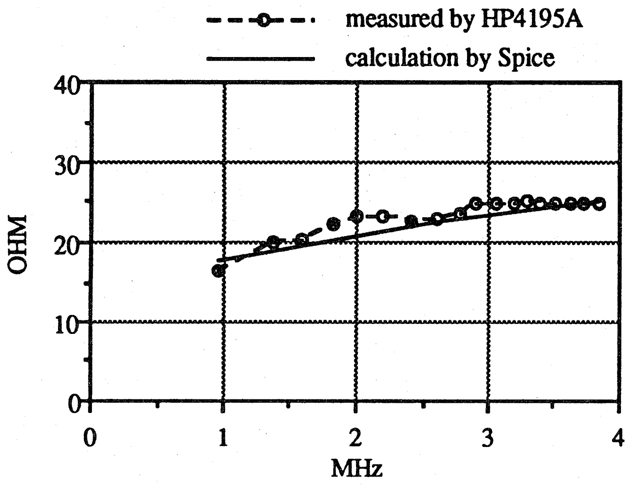

Figure 3. Output impedance seen by the beam vs frequency.

IV. DISCUSSION

A cathode follower RF system with a few-ohm output impedance may be feasible for synchrotrons, depending upon the choice of the valve. However, since the voltage gain of the cathode follower is less than unity, the power consumption at the driver stage will be a problem. At higher frequencies, the reactance due to the total capacitance between the grid and ground becomes a dominant term (Figure 5), and a much higher current will be required than that of the final stage amplifier.

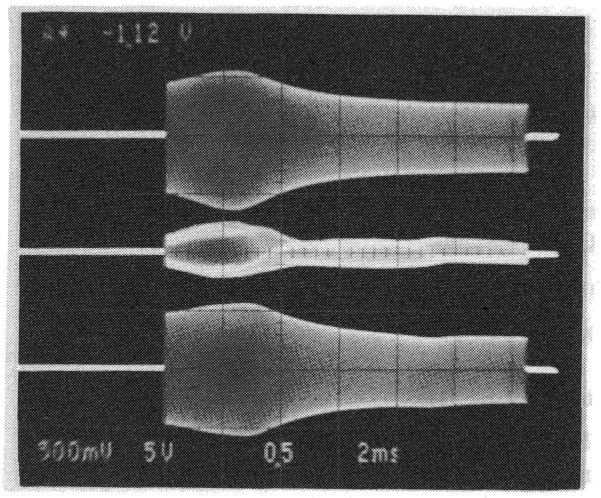

Figure 4. From the upper to the lower traces: the grid input voltage (500 V/div), the cavity input current (10 A/div), and the cathode voltage (500 V/div) over the range of 1.0-2.2 MHz.

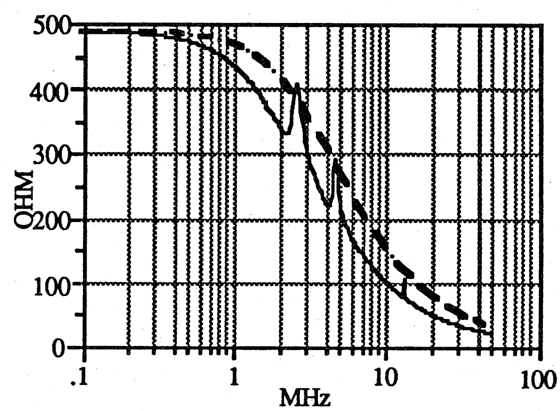

Figure 5. Grid input impedance (dotted line) provided that the cavity is always tuned at any given frequencies. For comparison, the case is shown when the cavity is tuned at 2.5 MHz (solid line).

V. REFERENCES

[1] T. Hardek, "A low-impedance, 2.8-MHz, pulsed bunching system for the Los Alamos Proton Storage Ring," Preprint LA-UR-84-1935.

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[3] F. Clapp, "Some aspects of cathode-follower design at radio frequencies," Proc. I.R.E., 37, pp.932-937, August 1949.