PHASE LOCKED MAGNETRONS AS ACCELERATOR RF SOURCES

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ABSTRACT

The problems associated with operating magnetrons into accelerator cavities is well known. However, as the magnetron is a simple inexpensive device, compared with most other rf power tubes, it is an attractive candidate for future accelerator rf systems. A test stand has been constructed at GA and has operated a Varian VMP 1702 425 MHz magnetron at a peak power level of 2 MW and a nominal pulse length of 100 μs. Included in the test stand is a tetrode cavity amplifier, also at 425 MHz, with a maximum peak power capability of 250 kW. The amplifier is driven by a solid state oscillator. The intent of the program is to use the tetrode amplifier output to phase lock the magnetron to produce an rf pulse having characteristics suitable for accelerator applications. Later it is intended to extend the experiment to address the problems of marrying the magnetron directly to an accelerator cavity.

INTRODUCTION

Recent interest in rf systems for space based accelerators has created a need for small lightweight rugged high power rf sources. The magnetron meets all of these requirements but does not possess the necessary phase stability. Recent work by Varian has shown that magnetron phase coherence can be obtained by locking the magnetron to a stable rf source. A test stand has been constructed and tested at GA to operate a Varian VMP 1702 magnetron. GA and Varian are now preparing to conduct a test program to demonstrate phase-locked operation of the magnetron into a high Q resonant cavity load.

EXPERIMENTAL ARRANGEMENT

A schematic diagram of the test stand is shown in (Fig. 1). The Varian VMP 1702 magnetron is rated for an output of 2 MW peak power, 100 μs pulse length and a frequency of 425 MHz. The 55 kV 98A pulse is provided by a 60 section lumped constant Blumlein pulse forming network charged from a 100 kV 10 kW DC power supply. The pulse forming network is switched by means of a triggered vacuum spark gap. Each inductor in the pulse forming network is tuned by means of an aluminum slug to give a 100 μs pulse flat to $\pm 1\%$. The equipment general arrangement is shown in the photograph (Fig. 2). The front end of each half of the PFN has several fast sections to improve the pulse risetime. These initial PFN sections are unequally allocated between the two halves in such a manner to shift the ripples out of phase and further enhance the pulse flatness.

The magnetron phase locking signal is provided by a tetrode cavity amplifier driven by a solid state oscillator/amplifier chain. The tetrode is pulsed from a hard tube modulator and is capable of delivering a peak power of 250 kW for pulse lengths of several milliseconds at a frequency of 425 MHz.

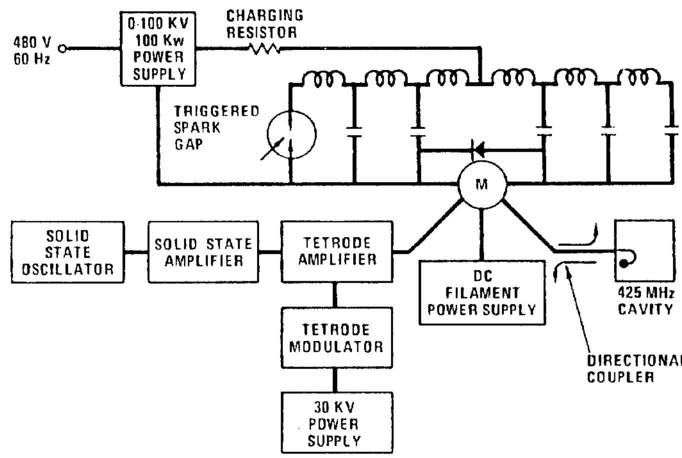

Fig. 1. Test stand schematic diagram

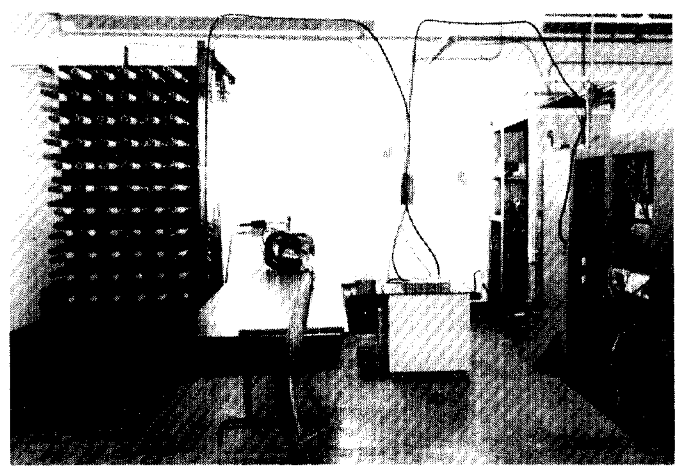

Fig. 2. Equipment general arrangement

The resonant cavity to be used for the experimental program will operate in the TE_{011} mode and has a Q of approximately 50,000. The cavity and the magnetron are each tunable over the range of 400 – 450 MHz. The rf input to the cavity is by means of $3\frac{1}{8}''$ rigid coax and coupling is by means of a loop and ceramic window.

EXPERIMENTAL STATUS

During the past three years, Varian Beverly Microwave Division has been conducting a program to study the injection locking of magnetrons for various applications. Results from

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this program have demonstrated phase errors of less than 1% at K_u, X and S bands at power levels from 200 W to 1 MW. However, these tests have been conducted using circulators to isolate the magnetron from the load and to provide means to inject the phase locking signal. The test stand at GA has been constructed to demonstrate that these results can also be achieved at power levels, frequency and pulse lengths of immediate interest and with the magnetron coupled directly to a high Q cavity. In order to make the demonstration Varian is modifying a second magnetron with a phase locking rf input port coupled to the magnetron cathode. Cathode coupling is expected to enhance the phase locking interaction while providing space charge shielding from the anode structure.

EXPERIMENTAL PROGRAM

The objective of the experimental program is to show, through a series of tests, that a phase locked magnetron can be operated directly into a high Q cavity, with the necessary phase stability and control, to fill the cavity and withstand the effects of simulated electron beam loading with the precision necessary for accelerator application. The general equipment for the experimental phase measurement arrangement is shown in (Fig. 3). The experiment consists of three tests as described below.

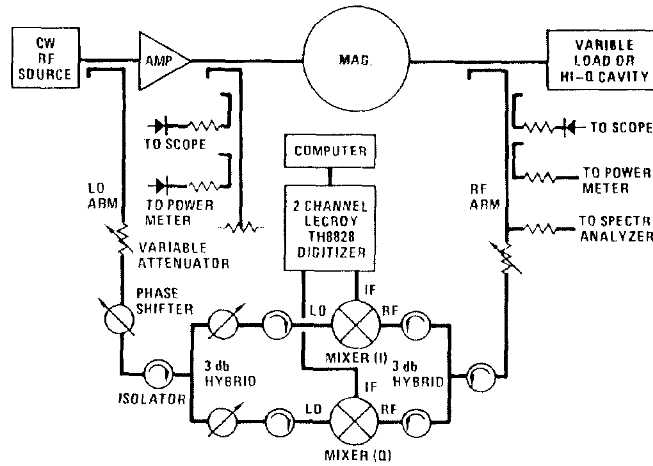

Fig. 3. Phase measurement arrangement

1. **Pulse Phase Control Test.** In order to show that we can adjust the phase during the pulse on a microsecond time scale, the magnetron shall first be operated into a matched dummy load with no isolating element between the load and the magnetron output. Initially, the phase stability, as a function of drive power, will be measured to obtain baseline performance parameters. The phase of the magnetron output rf will then be changed, during the pulse, by changing the phase of the rf drive signal. The rf drive power necessary to change the phase of the magnetron output rf, at various rates in accordance with accelerator requirements, will be measured.

2. **Cavity Fill Time Phase Control Test.** For this test, a single cell cavity with a "Q" in the range of 50,000 to 100,000 shall be substituted for the matched dummy load. The rf pulse used shall be of sufficient length to fill the cavity to the point where the input VSWR has changed over the range encountered in the accelerator application. This test will demonstrate that the injected phase locking pulse will influence the magnetron to fill the cavity while maintaining all the characteristics necessary to fully meet the accelerator application requirements.

3. **Beam Transient Phase Control.** The purpose of this test is to investigate phase control with large instantaneous changes in the Q of the cavity such as is experienced upon injection of a LINAC beam. We anticipate that the simulation will be accomplished by providing an external loading to the high Q cavity which can be rapidly switched in to give large phase transients.