RF DRIVERS FOR THE BEVALAC INJECTOR FINAL STAGE RF AMPLIFIERS

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ABSTRACT

A 200Mhz intermediate power amplifier system, comprised of four separate chassis or cavity amplifiers is being developed as a driver stage for the Bevalac injector final RF amplifiers. These amplifiers are intended to upgrade and replace the present systems with an expected increase in the available RF output power and the system reliability while reducing the associated operating costs. The system construction, design, and initial high power test results will be presented.

INTRODUCTION

The 200 Mhz intermediate power amplifier cart is designed as a self contained, turn-key system to provide amplification from the 10 milliwatt to the 300Kw level in four stages.

The initial stage is a 200 Watt, solid state, RF amplifier with 44 db of gain. The two succeeding stages are cavity amplifiers that incorporate vacuum tubes manufactured by Varian, Power Grid Division. The first of the tube type amplifiers is driven by the 200 W amplifier and contains a 3CPX800A7 triode calculated to output a maximum of 5 Kw. The next stage, driven by the 5 Kw amplifier, contains a 4CW25000B tetrode and is designed to drive the final amplifier. While the 4CW25K stage is calculated to provide a maximum output power of 50 Kw, the drive requirements of the final stage are quite modest by comparison. This feature should provide for conservative operation.

The final stage is designed to operate with either a Varian 4CW100000e or a TH535 manufactured by Thomson-CSF. The final stage gain, using the 4CW100Ke, is calculated to be 13 db at approximately 300 Kw output. Using the Thomson tube, the stage gain is calculated to be slightly greater, however the maximum achievable RF output power is approximately 300 Kw.

All the amplifiers, with their associated electronic supplies, cooling systems, interlocks, and status indicator panels, are installed in a single 6 foot roll-around rack. The rack is constructed of two standard 19 inch double sided racks mounted back to back.

5 KW AMPLIFIER

The 5 Kw amplifier is intended to replace an RCA 7651 amplifier stage. The benefits of this change are simplified cavity construction, reduced bias system requirements, ease of maintenance, and tube replacement cost savings of ~ $800 per tube.

The 3CPX800A7, chosen as the 7651 replacement tube, is an oxide coated cathode, high - mu triode provided by Varian, EIMAC. The initial calculations using 3CPX800A7 tube curves predict 14db gain with 5 Kw of RF output power.

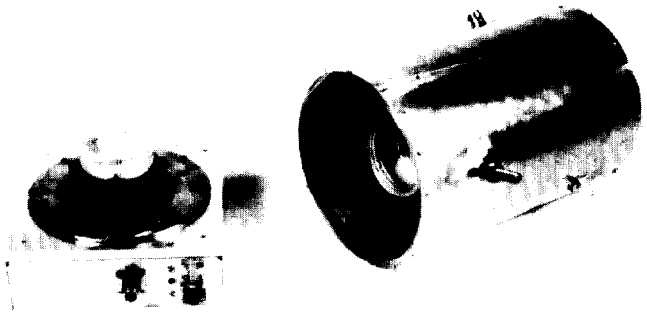

Fig. 1

The 3CPX800A7, the grid circuit enclosure, and the anode circuit resonator are shown in Figure 1. Attached to the coaxial resonator are the anode frequency tuner and the RF output and monitor connectors.

The amplifier is designed to run class B, RF grounded grid and DC grounded cathode. RF grounding of the grid is accomplished by sandwiching the insulated grid plate between ground planes. The grid-cathode RF input circuit is designed to provide adjustment free, wideband operation from 195 Mhz to 205 Mhz, with an input SWR of less than 2:1. The input circuits are "factory tuned" for minimum SWR at 200 Mhz by use of novel tuning devices[1] located within the grid-cathode enclosure. With the exception of the anode connections, all signal, control and power supply voltages are interfaced to or from the amplifier via plugs mounted on the enclosure.

At the design frequency, the tuning devices present positive to negative continuously adjustable input reactances. Each device is shunted by a choke to redistribute the reactance

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tuning range and to provide a path for anode return currnet. In circuit, the devices perform as double stub tuners.

HIGH POWER TESTS

The anode cavity resonance was adjusted at each of the operating frequencies listed. The amplifier input impedance was adjusted during full power operation at 198.965 Mhz. No other adjustments were made during the tests.

Frequency	198.9 Mhz	195 Mhz	205 Mhz
Plate Volts	4 Kv	4 Kv	4 Kv
Grid Volts	-27 V	-27 V	-27 V
Plate current	1.7 A	1.8 A	1.2 A
Grid current	28 ma	60 ma	3 ma
Power, DC input	6.8 Kw	7.0 Kw	4.6 Kw
Power, RF input	232 W	257 W	119 W
Power, RF output	4.8 Kw	5.2 Kw	3.0 Kw
Input SWR	1.5:1	1.4:1	1.8:1
Efficiency	70.6 %	73 %	65.5 %
Gain	13.2 db	13.1 db	14.5 db

50KW AMPLIFIER

The 50 Kw amplifier is intended to replace a second RCA 7651 amplifier stage. In addition to most of the previously described benefits, this replacement significantly increases the available RF drive power to the 300 Kw amplifier.

As the Bevalac has many 4CW25000Bs in service, it was chosen as the 7651 replacement tube. This tetrode, employing a thoriated tungsten filament/cathode, has recorded filament life times in excess of 40000 hours. In addition to the the long filament life times, the 4CW25K is a commonly rebuilt tube. These features should dramatically reduce the operating costs of this stage. The initial calculations using 4CW25K tube curves supplied by Varian predict 10db gain with 50 Kw of RF output power.

The 50 Kw amplifier is mounted in the roll around rack on slides to provide easy access for the maintenance or tuning of the components mounted on the amplifier support plate. These components include the 5 Kw amplifier, a 50 ohm dummy load, the 4CW25K plate supply voltage divider, the filament voltage Variacs for the 4CW25K and 3CPX800, and the input impedance tuners for the 50 Kw amplifier. With the exception of the 50 Kw and final stage outputs, all the amplifier input and output connections and the dummy load connection are brought to the front panel, where each stage may be tested, loaded, or configured for normal operation.

The 50 Kw amplifier mechanical layout shown in Figure 2 is not to scale but does approximate the adjustable 3/4 wave resonant anode and half wave resonant grid circuits, the RF output assembly, the anode RF bypassing and the fixed frequency screen-control grid resonator. The resonant frequency of this circuit directly affects the anode to grid circuit isolation. The isolation, measured at -2 db with the grid grounded at the socket, was increased to -47db by terminating the grid as described. The capacity, G1 to G2, is shunted by the reflected impedance of the shorted resonator, which in this case is a line >1/4 <1/2 wave lengths. Refering to the article[2] by Robert Sutherland and William Barkley it can be seen that this is an alternative method to obtain self-neutralization.

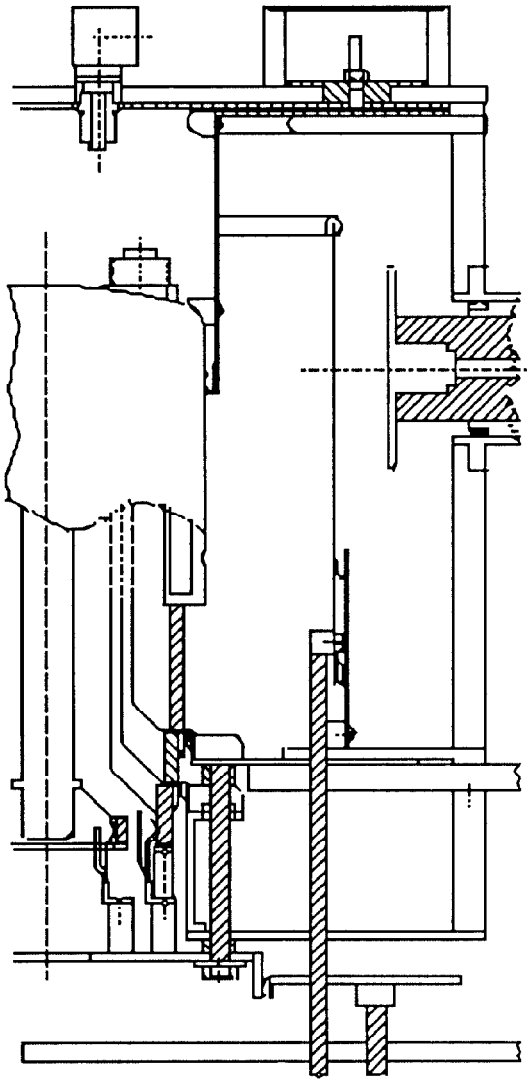

Fig. 2
(Not to scale)

50 KW HIGH POWER TESTS

Frequency	198.9 Mhz	195 Mhz
Plate volts	10 Kv	10 Kv
Screen volts	750 V	750 V
Grid volts	-400 V	-400 V
Plate current	7.4	6.4 A
Screen current	600 ma	480 ma
Grid current	180 ma	Not measured
Power, DC input	74 Kw	64 Kw
Power, RF input	5.0 Kw	4.6 Kw
Power, RF output	53 Kw	44 Kw
Input SWR	1.1:1	1.5:1
Gain	10.2 db	9.8 db
Efficiency	71.5 %	68.8 %

300 KW AMPLIFIER

The final amplifier stage is intended to replace the original RCA 4616 with either a 4CW100Ke or a TH535. Both replacement tubes have thoriated tungsten filament/cathodes and were cheaper than the 4616. The two tubes of different origin were chosen as a hedge against future manufacturing cost increases or lack of availability. The confidence to proceed was given by the success of our European colleagues in testing tubes of different manufacture[3] in the same basic structure.

The 4CW100Ke mechanical layout shown in Figure 3 is not to scale but does approximate the 3/4 wave resonant anode and the adjustable half wave resonant grid circuit and the anode frequency tuning slugs.

To date only the 4CW100Ke has been operated at high power. Future operations with the TH535 will require a new flange to interface the tube anode to the bottom plate, removal of the tube socket adapter plate which is installed when using the 4CW100Ke and replacement of two adapters in the grid-cathode circuit.

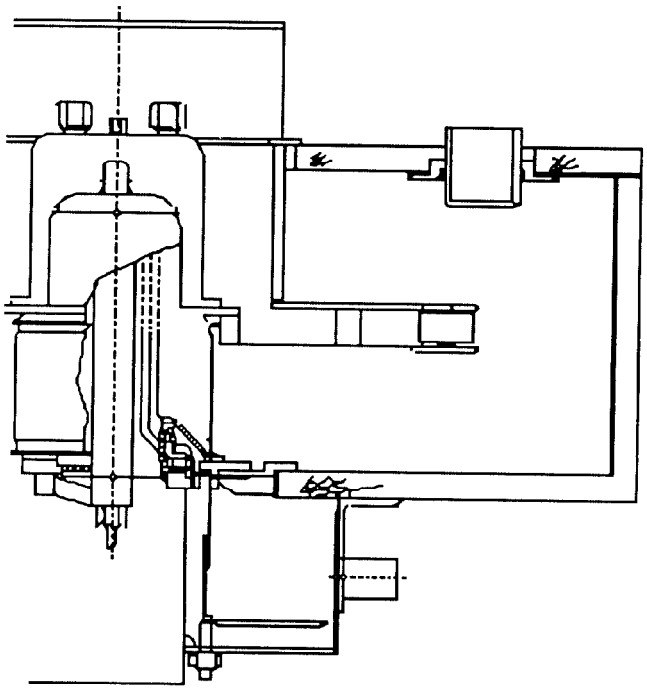

Fig. 3
(Not to scale)

HIGH POWER TESTS

An alternative method of radial line construction for the anode resonator was tried with limited success. A double sided printed circuit board was fabricated as an integral replacement for the capacitively end loaded radial plates shown in Figure 3. The computer generated circuit board layout was sent off-site by modem where the data was transformed to the etched product. Seen as a potentially inexpensive option, the board was successfully operated to 280 Kw output, however the operating pulse width was reduced to less than 1/5 that required. RF generated tracking could be observed between the layers of fiber glass at the outer edge. A new and as yet untested board has been constructed of a solid dielectric in hopes of relieving this problem before incurring the costs of a copper deposited, Teflon board.

The most meaningful high power test was performed when we successfully operated the LINAC RF system with the highest power requirements, using the 300 Kw amplifier with the 4CW100Ke installed. The high power test data documented below were taken with the amplifier loaded by a 50 ohm water load. The data does not reflect any output power limitation associated with the 300 Kw amplifier but rather the drive limitations of the 7651 amplifier. The poor efficiency is caused by the pulsed grid bias system. The addition of the 50 Kw amplifier should eliminate the need for the pulsed bias system and increase the output RF power. As reported[4], higher output power from the 300 Kw amplifier may simplify operation of the final amplifier associated with Tank 2 of the LINAC RF system. It is hoped that operation of the 300 Kw amplifier with the higher powered 50 Kw drive system will soon confirm this thought.

Plate volts	18.4 Kv
Screen volts	2.2 Kv
Pulsed grid volts	-340 V
Plate current	29 A
Screen current	1.8 A
Grid current	No reading
Power, DC input	534 Kw
Power, RF input	12.2 Kw
Power, RF output	280 Kw
Input SWR	2.4:1
Gain	13.6 db
Efficiency	52.4 %

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2. Electronic Design, May 10, 1967
3. Personal Communication with Gerald Hutter , GSI
4. D. Howard et al, "Bevalac Injector Final Stage RF Amplifier Upgrades", this conference.