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125 KW - 52.88 MHz TETRODE AMPLIFIER FOR THE NATIONAL SYNCHROTRON LIGHT SOURCE

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INTRODUCTION

The Power Devices group of Electro Optics and Devices, RCA, Lancaster, Pennsylvania, has developed a 125Kw, 52.88 MHz amplifier for use in the National Synchrotron Light Source accelerator at Brookhaven National Laboratory, Upton, Long Island, New York. Four of these amplifiers will be combined, by Brookhaven, to provide a CW output power of 500 Kw. Each amplifier utilizes one RCA A3016 tetrode in a single-tuned, cathode-driven, coaxial cavity circuit. The A3016 is a water cooled version of the RCA 8984 that is used in commercial television transmitters at frequencies up to 216 MHz and output power levels of 55 Kw. Except for its higher plate dissipation and plate voltage ratings, the electrical characteristics of the A3016 are identical to that of the 8984. The cavity, designated Y1386D, features a high efficiency, one-quarter wavelength, single-tuned output circuit. The cathode-driven input circuit utilizes a combination of coaxial line and lumped circuit elements. For operating convenience, all tuning and loading controls for both the input and output circuits are located on the front panel of the amplifier. The Y1386D features standard 24 inch rack mounting and includes self-contained filament transformer and step-start circuitry.

AMPLIFIER SPECIFICATIONS

For this application the amplifiers were required to deliver rated output power of 125Kw continuously into a matched load; be capable of providing rated forward power into a VSWR of 2; and capable of providing 40% of rated forward power into a load with a VSWR of 3. These conditions were to be met without any changes in the cavity tuning or loading controls. In addition, the amplifier was required to provide a power gain of more than 10 db with a DC to RF power conversion efficiency of 60% or more from 50% to 100% of rated power output.

The over-all stage gain was not permitted to vary more than $\pm$ 2 db from 10% to 100% of rated output power. Spurious signals and parasitic oscillations were to be more than 40 db below rated fundamental power for any drive power from zero to that required for full power. The cavity was to be capable of tuning more than $\pm$ 3 MHz around a center frequency of 52.88 MHz with an instantaneous bandwidth at the 3 db points of greater than 1 MHz. All of these requirements were met or exceeded by the Y1386D/A3016 amplifier.

RCA A3016 LINEAR BEAM POWER TUBE

The RCA A3016 linear beam power tube, Figure 1, was designed for 125 Kw useful power output at 70% efficiency and 16 db gain. To accomplish this objective, special attention was given to the filament, grid and screen designs. In order to have the tube withstand high mismatches, the anode was conservatively designed for 100 Kw dissipation and the screen assembly can withstand 100 joules of fault energy and dissipations up to twice the typical operating values.

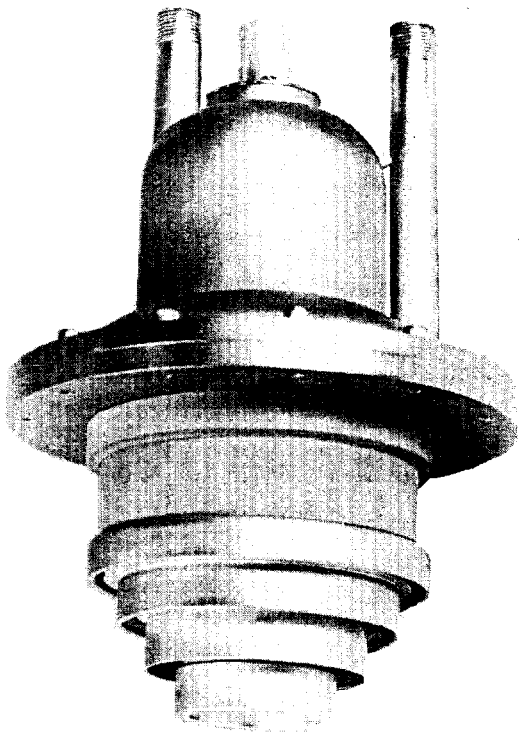

Figure 1

A carburized thoriated tungsten wire mesh type filament was chosen because of its long life characteristics, high emission capability and resistance to poisoning and arcing. At the typical operating temperature of 2000° K this filament structure will conservatively deliver a current of 60 amperes. In operation at 125 Kw the required peak filament emission is less than 45 amperes and thus a minimum reserve of 33% is available. Filament emission life of greater than 30,000 hours has been demonstrated with similar structures used in broadcast applications.

The grid and screen structures are each made of one piece molybdenum cups that are fastened to their mounting rings just inside the tube envelope, thus avoiding the thermal stresses in joints made near the active region. Grid to filament and grid to screen spacings were designed to give a transconductance of .25 mho at zero grid voltage with an average mu of 15. This configuration produces a relatively sharp

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cutoff transfer characteristic which improves linearity and gain.

The grid and screen wires are kept in perfect alignment by fastening the assemblies to their mounting rings and electrical discharge machining slots in both cups simultaneously.

Cooling of the anode is accomplished with high velocity water that flows between copper flutes. Dissipations up to 100 Kw can be handled with only 40 GPM water flow at less than 60 PSI.

The anode separator is an accessory and will fit any A3016 tube. Only one separator is required per socket and is easily removed for inspection and cleaning of the tube cooling course. Additional data on the separator and other tube characteristics are detailed in the A3016 tube data sheet.

Y1386D CAVITY

The RCA Y1386D cavity utilizes a cost effective concept of square design with many parts made from flat sheet metal instead of the more conventional machined tubing.

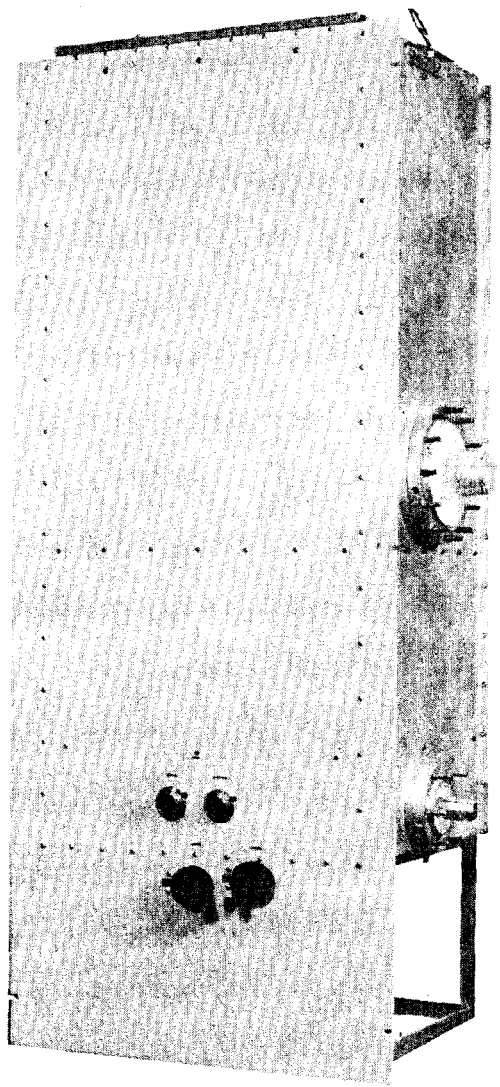

Figure 2

The cavity, as shown in Figure 2, was designed to be mounted in a standard 24" rack. Knob and counter type controls are all located on the front panel for ease of operation.

The filament transformer and filament step-start circuit are provided in a steel support compartment at the bottom of the cavity. An access opening for cavity and tube seal cooling air is also provided in this compartment and is easily accessible from the rear of the cavity.

The output circuit consists of a one-quarter wavelength resonant cavity, foreshortened by the screen-to-plate capacitance of the A3016 tube and tuned by means of a moveable shorting plunger. The center conductor of the cavity is made from standard 6-1/8 inch diameter transmission line and the 19 inch square outer conductor consists of 1/8 inch thick aluminum panels.

The output circuit resonant frequency is adjustable from 49 to 56 MHz by means of a control on the front panel of the amplifier. Power is coupled from the side of the output cavity through a standard EIA, 6-1/8 inch, 50 ohm, gas stop connector. A front panel control is provided to match the output cavity to the impedance of the load system.

The cathode-driven input circuit consists of a combination of coaxial and lumped elements. Tuning of the one-half wavelength coaxial circuit is accomplished by means of an adjustable capacitor. A second adjustable capacitor serves to match the circuit to provide a 50 ohm input impedance. A standard EIA 3-1/8 inch, 50 ohm input connector is provided on the side of the amplifier. Both the tuning and matching capacitors are adjusted from the front panel.

Air cooling is required for the filament and input seals of the A3016 tube as well as for cavity cooling. A six inch diameter flange is provided as the air inlet at the bottom of the cavity. The air flow required for proper cooling is 200 CFM at 4" H_2O. The entire air supply is channeled into the output cavity for circuit cooling, and then routed past the tube seals and exhausted from the bottom of the cavity.

Water cooling is required for the A3016 tube anode. 20 GPM at 15 PSI is sufficient for 50 Kw of anode dissipation. Flow must be increased to 40 GPM at 60 PSI for 100 Kw of anode dissipation. Two 1/2" threaded pipes are provided on the tube for connection to the water system.

TEST RESULTS

Typical operation - Class C RF power Amplifier Service at 53 MHz into a matched load.

Anode Voltage	16,000 v
D.C. Grid-No. 2 Voltage	1,500 v
D.C. Grid-No. 1 Voltage	-250 v
D.C. Anode Current	10.5 A
D.C. Grid-No. 2 Current (Approx.)	.24 A
D.C. Grid-No. 1 Current (Approx.)	.65 A
RF Drive Power	2,700 W
RF Power Output	125,000 W

Power Gain	16.5 db
Power Efficiency	74%

Typical operation - Class C RF power amplifier service at 53 MHz into a 2:1 mismatched load (specified phase).

Anode Voltage	16,000 v
D.C. Grid-No. 2 Voltage	1,500 v
D.C. Grid-No. 1 Voltage	-250 v
D.C. Anode Current	10.4 A
D.C. Grid-No. 2 Current (Approx.)	.28 A
D.C. Grid-No. 1 Current (Approx.)	.8 A
RF Drive Power	2,850 W
RF Power Output (Load)	112,500 W
Power Gain	16.0 db
Power Efficiency	67%

Typical operation - Class C RF power amplifier service at 53 MHz into a 3:1 mismatched load (specified phase).

Anode Voltage	13,700 v
D.C. Grid-No. 2 Voltage	1,500 v
D.C. Grid-No. 1 Voltage	-220 v
D.C. Anode Current	5.7 A
D.C. Grid-No. 2 Current (Approx.)	.07 A
D.C. Grid-No. 1 Current (Approx.)	.120 A
RF Drive Power	1,200 W
RF Power Output (Load)	40,600 W
Power Gain	15.3 db
Power Efficiency	52%

CONCLUSION

The RCA Y1386D/A3016 amplifier successfully met the requirements of the 125Kw 52.88 MHz National Synchrotron Light Source specification. The technique of combining several amplifiers to achieve a given power level offers several advantages over the single amplifier approach. Prototype development and reproductive costs can often be reduced by utilizing a modification of an existing commercial amplifier design. Design and fabrication cost savings can also be realized since cavities such as the Y1386D do not require pressurization or complicated cavity cooling techniques which are often required for the single amplifier approach. As power level is increased, physical tube size must be increased with resultant decrease in maximum operating frequency capability. Therefore, higher frequency operation can be achieved using multiple tubes for a given power level.

The Y1386D/A3016 amplifier design concept is readily adapted for operation at other frequencies. The A3016 tetrode is rated for full input to 300 MHz.