AN 805-MC 1-1/4-MW AMPLIFIER FOR ACCELERATOR SERVICE*

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Summary

An 805-Mc 1-1/4-Mw amplifier has been constructed for test and evaluation as a power source for accelerator service. The amplifier has been designed for 6% duty factor and a maximum pulse length of 2 milliseconds. The amplifier is described and preliminary test results are presented.

Introduction

A major engineering problem in the design and construction of a proton linear accelerator is the RF system used to provide power for the accelerator. This system must supply a substantial amount of RF power which is well regulated in phase and amplitude. For the proton linac which is under consideration by the Los Alamos Scientific Laboratory approximately 45 megawatts of RF power is required at a frequency of 805 Mc and a duty factor of 6%. The phase and amplitude control requirements are of order 1° and 1% respectively. The loss of any section of the RF system precludes acceleration of protons beyond the lost section so the reliability requirement is stringent. A convenient size for the amplifiers is one megawatt peak power output.

This paper reports on a portion of the experimental work being done at the Los Alamos Scientific Laboratory on high power amplifiers operating at 805 Mc; it reports some of the results through February of 1965. Our object in this work is to test those components of the RF system which we consider most subject to failure or to unsatisfactory performance.

The choice of system components is difficult since there are many conceivable ways in which one could build an RF amplifier of the desired type. We have chosen for our initial test work a triode and tetrode amplifier chain which amplifies from the one watt level to the one megawatt level. In addition to the gridded tube system a klystron amplifier has been constructed with a gain of 50 db and an output power of 100 kilowatts.[1] The initial tests on the klystron amplifier are encouraging but further study is needed; the klystron work is not further discussed in this paper.

Description of the Amplifier

We have minimized the cost of this testing program by using government surplus wherever feasible in the system. This resulted in a system which is physically much larger than would be needed for a prototype. The present system occupies a floor space of some 1600 sq. feet.

a. The Intermediate Power Amplifier

We define the intermediate power amplifier (IPA) as that portion of the system which amplifies from 1-watt level to the 100-kilowatt level. The first stage in the IPA is a commercial cavity amplifier -- the Eitel-McCullough X456A; this is used as a buffer stage between the frequency source and the other stages of the IPA. The tube lineup then is 6816, 6816, 7650, 7213, and 6806. The first 6816 is used to modulate the drive to the rest of the chain. These tubes are tetrodes in which the screen is externally bypassed in all stages but the 6806 stage; in that stage internal bypassing is provided as part of the tube structure. The only modulation used in the chain is in the drive. All of the stages are operated as grounded grid amplifiers.

This particular tube lineup is not unique but is representative of several possible combinations. By a somewhat different selection of tubes and by working the stages harder it should be possible to reduce the number of stages.

Most of the RF circuits for the IPA are in the form of coaxial resonators in which the resonant frequency is determined by the position of an adjustable short. For the smaller tubes (through the 7213) the grid, screen, and plate circuits are concentric; the grid and plate circuits either 1/4 or 3/4 wave and the screen circuit is 1/2 wave in length. The dc blocking capacitors are of teflon and are constructed as a portion of the tube mount. The 6806 is a double ended tube so the plate cavity is on one side of the tube and the grid cavity on the other. The 6806 grid cavity is a modified commercial cavity which was originally designed for TV use; we removed some of the broadband features and improved the high voltage insulation. The 6806 plate cavity is a radial cavity in which the tuning is accomplished by varying the shunt capacity of the cavity with a coaxial tuning plunger; dc blocking is provided by 1/4-wave chokes in the plate connection.

b. The Modulator

The modulator for the power amplifier uses an experimental Machlett tube which is called an LPT 14. This tube has high power gain and is driven by a 4CX5000. The capacitor bank has a maximum capacity of 98 mfd and the power supply is 40 kilovolts. A detailed description of this modulator is given in "A 40-Kilovolt, 125-Ampere Hard Tube Modulator for Accelerator Service," by R. M. Freyman, proceedings of this conference.

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c. The Power Amplifier

The power amplifier from the 100-kw level to the 1-megawatt level is an RCA Coaxitron (the A15191). This tube is a triode in which the RF circuitry is an integral portion of the tube's vacuum envelope. It is a fixed frequency device whose bandwidth is a few megacycles; its design center frequency is 805 Mc. The cavities are designed so the tube operates as a zero bias grounded grid amplifier. The power and water requirements are:

Filament current	3400-3500 amperes dc
Filament voltage	2.5 volts
Plate voltage	25-35 kilovolts
Plate current	80-95 amperes
Drive power	85 kw
Water requirement	70 gpm at 60 psi

The output window matches into WR 975 waveguide and the input is in 1-5/8" coaxial line. The peak output is 1-1/4 megawatts with a power gain of 11 to 12 db.

At present we are operating this tube into a resistive load in the form of a water filled glass finger inserted into the output waveguide. The VSWR of this load at 805 Mc is approximately 1.1.

d. The Water System

The deionized water system is of conventional design and is largely constructed of surplus components. It is capable of providing 200 gpm at 100 psi. Typical conductivity values are 3 to 5 megohm-cm.

Amplifier Operation

The IPA has been in operation since the summer of 1964. Relatively little difficulty has been encountered with the RF circuitry; the present cavities would be simplified in mechanical design for a prototype. The IPA has been operated into a variety of loads both to test the operation of the IPA and to test components at the 100-kw level. It has been quite useful in driving short sections of accelerator structures for sparking tests.[2]

The complete amplifier has been in operation since the last week of January 1965. Much of our time has been spent in the usual shaking down process; however, some useful data has been obtained. This data is discussed below and should be regarded as preliminary in nature.

The results of our measurements of power output and efficiency of the Coaxitron are shown in Figs. 1 and 2. Figure 1 shows the power output as a function of anode voltage for three values of grid drive. The output power apparently decreases when the drive is increased above the 85-kw level. The output power is linearly related to the anode voltage because the anode current largely depends on the drive and is nearly independent of the anode voltage. The efficiency of the Coaxitron is shown in Fig. 2; it is defined as the ratio of the output power to the sum of the drive power and plate input power. Again, it is apparent that the tube is overdriven with 100 kw of drive since the efficiency is reduced; the efficiency is approximately the same for both 70 kw of drive and 85 kw of drive.

We have tried operating the tube at slightly different frequencies from 805-Mc design frequency. No striking changes in performance are noted between 801 Mc and 806.5 Mc; further tests are needed to measure the bandwidth of the Coaxitron.

The highest output power at which we have operated the Coaxitron in this laboratory has been slightly in excess of 1 megawatt for pulse lengths of 200 microseconds. At 1-millisecond pulses we have operated the tube at 690-kw output power (3% duty factor). The tube did not display any serious outgassing problems at any time nor an excessive missing pulse rate (a Vac-ion pump is used to continuously monitor the tube pressure).

The plate lead chokes on the first Coaxitron were oil-filled and these have caused some breakdown problems; these chokes are presently being redesigned with solid insulation. This does not seem to be a serious problem.

As soon as some modulator difficulties are resolved we shall begin extensive testing of this amplifier at 2 milliseconds and 6% duty factor. The amplifier will be operated into a resonant load as well as into the present resistive load, and its control characteristics will be measured.

Acknowledgments

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References

1. T. F. Turner, Los Alamos Scientific Laboratory, (private communication).

2. J. R. Parker, J. D. Doss, R. W. Freyman, E. A. Knapp, and W. J. Shlaer, Paper BB-13 this conference.

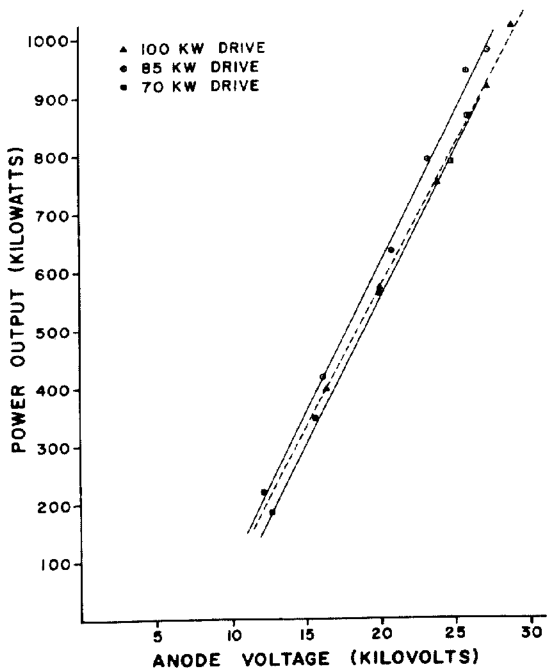

Fig. 1. Output power as a function of anode voltage for three values of drive power. The output power was measured calorimetrically. The filament current was 3460 amperes.

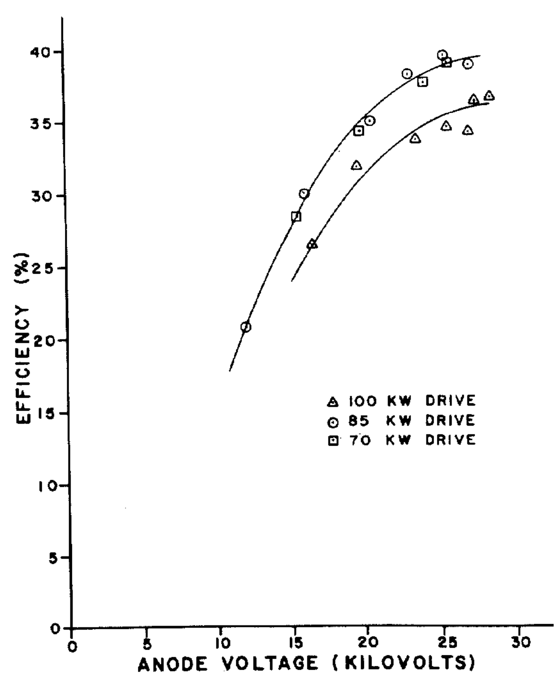

Fig. 2. Efficiency of the Coaxitron as a function of anode voltage for various drive powers. The efficiency is the ratio of output power to the sum of the drive power and the anode input power.