HIGH DUTY FACTOR MODULATOR FOR LOS ALAMOS MESON PHYSICS FACILITY*

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Summary

The Los Alamos Meson Physics Facility (LAMPF) requires 3 MW of peak rf power from each of three 200-MHz sources.[1] Each source requires a series anode modulator which has three principal functions, viz, programming the amplifier pulse length and rate, varying the amplifier plate voltage during the pulse so as to provide an rf power output controllable over a dynamic range of 30% to a tolerance of ±3%, and switching the amplifier off quickly in the event of a load fault. The modulator must be capable of operation initially at 8.4% DF (700 μsec, 120 Hz) with a design capability of 14.4% DF (1200 μsec, 120 Hz).

A modulator utilizing either two Machlett 7482-PV triodes or two ITT 7560 triodes has been constructed and tested in this application.

System Description

A simplified schematic of the modulator system is shown in Figure 1. Two high power triodes are connected in parallel to obtain a peak output current of 200 A. The triodes are driven by an Eimac 4CW100,000D tetrode. Grid drive for the 4CW100,000D is obtained from a video driver with an Eimac 5CX3000 pentode in the output stage. The 100-Ω resistor from grid to cathode of the triodes is used to minimize the effects of negative grid current.

7482-PV Modulator

Initially two Machlett 7482-PV triodes were employed and the modulator operated into a 300-Ω video load. Parasitic oscillations were observed during saturated operation. These oscillations necessitated the use of considerable shunt RC damping from grid to cathode and series LR damping in the anode leads. Subsequent unsaturated operation required the addition of series LR damping in the grid lead.

After stable operation of the 7482-PV triodes was obtained with a video load, the modulator was used to drive the 7835 rf power amplifier. Initial operation was restricted to 3% DF (250 μsec, 120 Hz). During this period a problem of frequent failure of the 7482-PV grid bias power supply was encountered. Investigation of this phenomena showed it to be caused by internal modulator tube arcs from anode to grid. These appeared to be a function of the average dissipation.

It was also shown that during a load fault the 7482-PV's were forced into a region where grid emission occurred. This grid emission caused the triodes to latch up at approximately 400 A of cathode current per tube. Under such conditions it was observed that the probability of experiencing an internal modulator arc was greatly enhanced.

A clamp circuit, utilizing a Krytron, was connected from modulator grid to bias supply.[2] In the event of a load fault, the Krytron is fired, thus shorting out the grid resistor and returning the grid directly to the supply. This technique worked very well in pulling the modulator tube out of the grid emission region, but was ineffectual when an internal modulator tube arc was encountered. Such an arc placed the energy storage bank across the clamp.

The 7482-PV modulator was operated for extended periods of time at 8.4% DF. The rise time and fall time for the system were 6 μsec and 4 μsec, respectively. The switch-off time was sufficiently short to permit load fault clearing by removal of modulator drive. The modulator satisfied the requirements for both dynamic range and tolerance. Tube arcs, however, were of sufficient frequency so as to raise the system crowbar firing to an intolerable level.

7560 Modulator

In view of the above experience, two ITT 7560 triodes with a specially treated non-emitting grid were placed in the same modulator circuit. Stable operation of these tubes in both the saturated and unsaturated mode was achieved with minimal parasitic suppression required. Extensive testing showed no grid emission and the swamping and clamping circuits were found to be superfluous.

The tubes were operated for about 40 hours into a 300-Ω video load at 3% DF. While several tube arcs were noted during this period, their frequency was well below that experienced with the 7482-PV's. The 7560's were then operated at 8.4% DF with no apparent increase in the frequency of arcing with the resultant increase in dissipation.

Measured rise and fall time for the current pulse were both approximately 2 μsec. This improvement was due to the removal of parasitic suppression from the modulator. The system bandwidth was found to be somewhat in excess of 200 kHz. Load fault clearing by removal of modulator drive proved feasible except when accompanied by a modulator tube arc.

This modulator, using two 7560 triodes, has subsequently been placed on the 7835 at duty factors up to 3% with very satisfactory results. Rise and fall times for the current pulse were again both approximately 2 μsec. Requirements for both dynamic range and tolerance were both satisfactorily met. In the near future, it will run at 8.4% DF at which time a more extensive evaluation will be possible.

An alternate modulator for this application using two Eimac 4CW250,000 tetrodes is now being

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fabricated. Due to previous experience with the 4CW100,000D in modulator service it is felt that this approach may prove fruitful. This system offers the potential advantage of simplified circuitry due to a reduced drive requirement when compared to the above-mentioned triodes.

Conclusion

The work described above demonstrated the feasibility of using a triode modulator for the high duty factor requirements of the Los Alamos Meson Physics Facility. It would appear that elimination of modulator tube grid emission is of prime concern in obtaining reliable operation. Further work in investigating the causes and methods of eliminating tube arcs is, however, necessary.

References

1. Jr. R. Faulkner and T. J. Boyd, Jr., "LAMPF 200-MHz Power Sources", Proceedings this conference, P.87.

2. J. D. Doss, "Fault Protection Circuitry for the LASL 201.25-MHz Power Amplifier," Proceedings this conference, P.101.

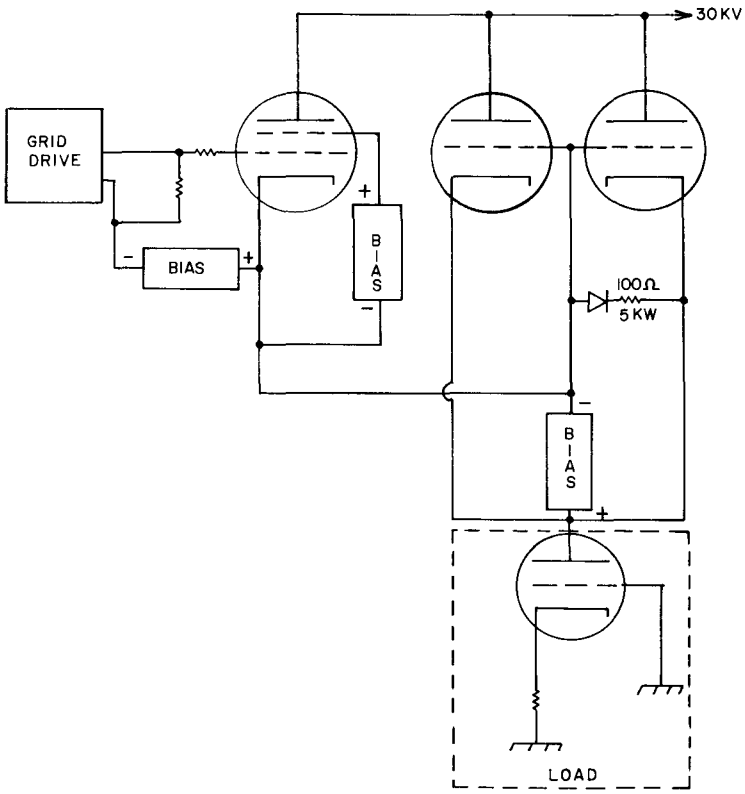

Figure 1 — Simplified Schematic Diagram of Triode Modulator.