IMPROVEMENTS TO THE RF SEPARATOR IN THE M9 MUON CHANNEL AT TRIUMF

G. C. Blaker, A. K. Mitra, R. L. Poirier
TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C. V6T 2A3

ABSTRACT

The M9A secondary beamline at TRIUMF incorporates an RF cavity driven at the cyclotron frequency to separate pions and electrons from the muons required at the experiment target. The RF system has undergone a major upgrade in the last 3 years in order to improve its operating reliability and ease of operation. The 23 MHz cavity was completely overhauled, and a new 150 kW amplifier system was built at TRIUMF. In order to locate the amplifier away from the radioactive experimental area, the amplifier is connected to the cavity via a 20 meter rigid six inch coaxial transmission line. When powering a high Q resonant cavity at the end of a long line, the line's electrical length is critical. Measurements made to determine the proper length in order to avoid exciting transmission line resonances are presented. The major features of the RF system are described and operational experience reported.

1. INTRODUCTION

The RF Separator[1)] is a device incorporated in the M9A beamline which is used to select either pions or muons, produced near the T2 production target, by deflecting unwanted particles whose time of flight causes them to be out of phase with respect to the RF frequency. The system consists of a pair of electrodes mounted parallel to the beam and connected to quarter wave resonant cavity structures, which are driven by a 150 kW RF amplifier at the cyclotron frequency of 23 MHz. The RF power is coupled to the cavity via a 50 ohm coupling loop mounted in the upper resonator. The phase of the separator RF is varied with respect to the beam phase in order to deflect the unwanted particles, while allowing the desired particles through to the experimental target and detectors.

2. AMPLIFIER RELOCATION

The first Separator amplifier was the original TRIUMF cyclotron center region model amplifier manufactured by Continental Electronics[2)]. It was located next to the RF cavity, and was connected to the cavity by a length of transmission line and two capacitors in shunt. This arrangement presented problems in servicing the amplifier due to the high radiation fields in the experimental area, and the vacuum capacitors used to tune the transmission line were unreliable and difficult to replace. The new amplifier was relocated to the mezzanine above the experimental area, and was connected to the cavity via a 20 meter length of six inch transmission line, with no tuning capacitors. In order to eliminate the tuned line, the coupling loop was redesigned to be 50 ohms, and was moved from the bottom resonator to the top.

3. POWER AMPLIFIER DESIGN

The power amplifier was designed and built at TRIUMF, and uses an Eimac 4CW150000 power tetrode operating in grounded grid configuration. With 1.5 kW of drive power, the amplifier delivers 100 kW to the cavity. The schematic for the amplifier is shown in Fig. 1.
The anode tank circuit is a quarter wave resonant cavity, with an adjustable loading

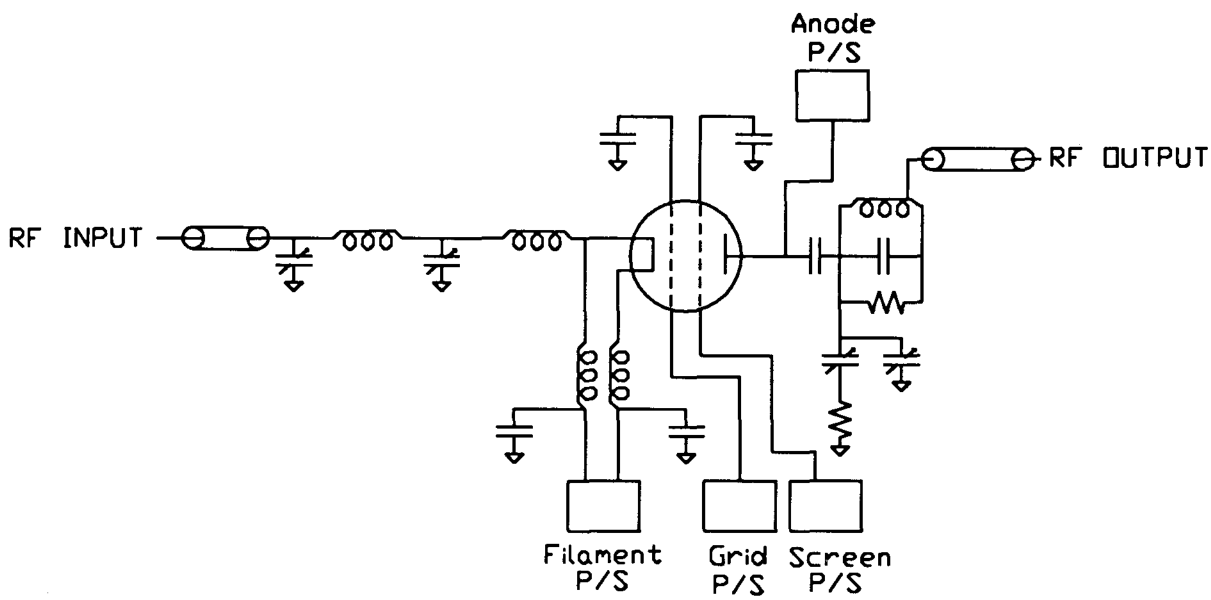

Figure 1. Power Amplifier Simplified Schematic

capacitor and adjustable galvanic coupling to the 50 ohm output transmission line. The tube output impedance is tuned to approximately 1000 ohms.

The input circuit is a pi network consisting of Jennings variable vacuum capacitors and a copper inductor. This circuit matches the 50 ohm source impedance of the driver amplifier to the 22 ohm impedance of the grid-cathode circuit.

The tube is biased to operate class A-B, with a plate idle current of 6 amps and a plate voltage of 18 kV. There is an air cooled damping resistor capacitively coupled to the anode to suppress parasitic modes caused by the long transmission line. The damping resistor dissipates about 1kW of RF power at 100 kW output.

4. SOLID STATE DRIVER AMPLIFIER

Figure 2 shows the schematic for a driver amplifier module. The driver is also a TRIUMF designed and built unit. It is a 2 kW solid state amplifier, with a gain of 67 dB. This amplifier consists of a preamp whose 20 watt output is split 8 ways to drive 8 250 watt amplifier modules. These outputs are then recombined to give 2000 watts using a TRIUMF designed 8 input water cooled combiner. The amplifier modules use Motorola MRF151G TMOS FET devices and conventional ferrite RF transformers. The circuit boards are designed with built-in stripline reflectometers to provide signals for the amplifier protection circuits.

Each amplifier module is mounted on a water cooled copper heatsink, and incorporates overvoltage, over current, over temperature and VSWR protection.

The driver amplifier is capable of operating with one module tripped, delivering 1600 watts, which is sufficient to drive the separator to full power. Two or more tripped modules shut off the separator through an interlock to the main control circuits.

The amplifier has been constructed in a modular fashion, so that replacement of failed amplifier modules is quick and simple, and so that similar modules can be used in other applications at TRIUMF.

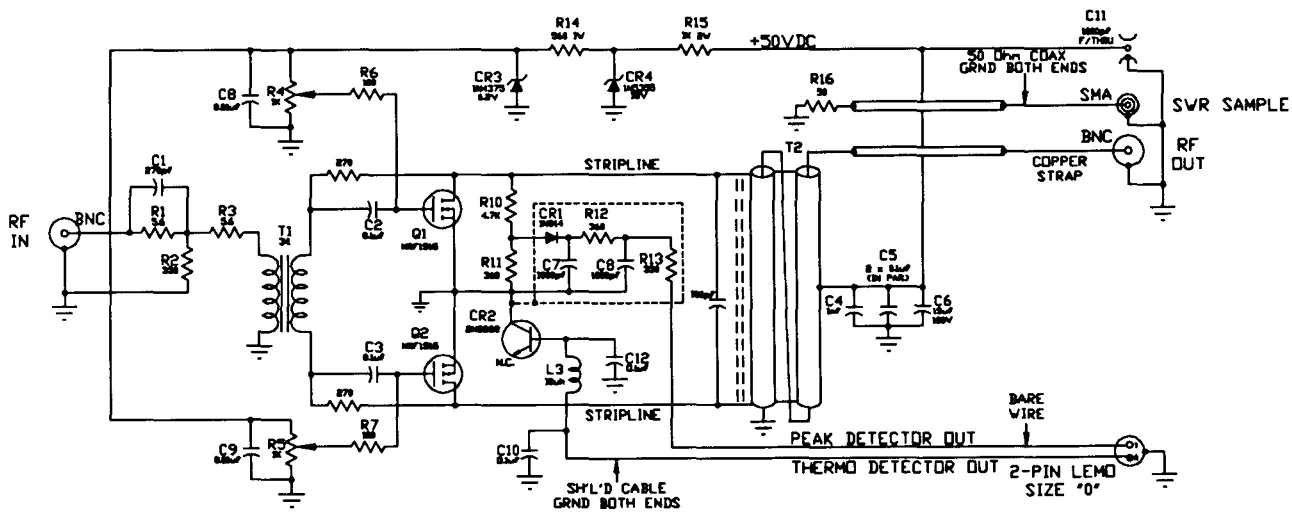

Figure 2. Driver Amplifier Module

5. TRANSMISSION LINE

The power amplifier is connected to the cavity via a 20 meter length of 6 inch copper 50 ohm transmission line. The line was initially installed with the shortest length possible, but after operating for a short time, it was clear that amplifier stability was not satisfactory. The screen current was higher than expected from the tube characteristic curves, and was very unstable, causing many screen power supply trips. This problem was traced to the length of transmission line, which was an arbitrary length, and was transforming the cavity impedance back to the amplifier such that the amplifier was seeing a sharp impedance variation with frequency. This caused the load impedance of the tube to change significantly with small frequency changes. The proper length of line was calculated using a computer circuit analysis code NODE[3], and was verified with low level network analyzer measurements of the system, as shown in Fig. 3. The extra length of line was installed, and immediately improved the stability of the system. No further problems with the transmission line have been encountered.

6. METERING & CONTROLS

The separator amplifier controls are based on conventional relay ladder logic, and incorporate latching interlocks for the various cooling water and air circuits, voltage proves for all amplifier power supplies, cavity vacuum, cavity magnet, and driver amplifier status. Metering is provided for all amplifier power supplies, as well as driver and power amplifier forward and reflected power signals. The separator cavity frequency and cyclotron RF frequency are also displayed.

The RF low level controls for the separator consist of an STD based supervisory and control computer linked to analog circuitry for the amplitude and phase regulating loops and the cavity tuning loop[4) 5)].

7. PERFORMANCE

The separator has been operating extremely well since the upgrade program was undertaken. There have been many weeks of data taking in the M9 muon channel with very little lost time due to separator problems. The system is largely operated by experimentalists with little training on the system, but because of its

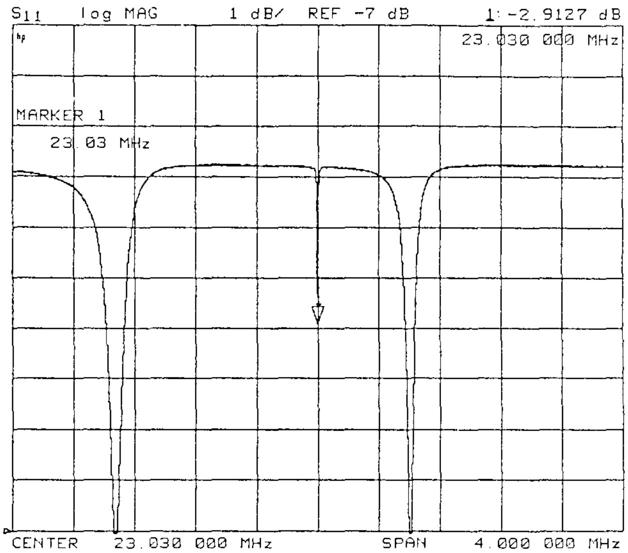

Figure 3. Cavity & transmission line modes.

simplicity, has been of little problem for the users. Initial problems with the original commercial driver amplifier have been solved with the new driver, which has performed very well.

8. CONCLUSIONS

The upgrading of the RF separator has been a great success. The system is now easier for the experimenters to use, requires no tuning by the users and is much more reliable than the original system. The expertise gained in developing the driver and power amplifiers in-house has proven extremely worthwhile, and this knowledge has been applied to other applications at TRIUMF.

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10. REFERENCES

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