RF POWER AMPLIFIER WITH DEDICATED INTERLOCK AND FEEDBACK CONTROLLER

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ABSTRACT

A 100 MHz 1 MW pulsed rf amplifier chain with its local control system capable of fulfilling all necessary remote functions as well as phase and amplitude feedback is described here. The high power rf amplifier as a self-contained unit incorporating power supplies, cooling, modulation units and dedicated processors has been used to power up an accelerating structure namely RFQ.

A Siemens Microprocessor System (SMP) with Mitsubishi PC backup is employed for setting up the dc operating point of the amplifier and monitoring the status of the same. Amplifier diagnostic and test routines are also installed through software packages. Finally, to achieve maximum personal and machine safety several interlocks and control levels are defined and discussed.

INTRODUCTION

The purpose of the 100 MHz rf power amplifier system is to provide excess of 800 KW pulsed power to RFQ[1] for the proposed SNQ project[2]. The required pulse width is 250 µs with a repetition rate of 100 Hz. For operation of the RFQ certain requirements concerning the phase and the amplitude stability of the applied rf voltage must be fulfilled. Calculations pointed out that phase stability of 1° and amplitude stability of 0.1 % during beam should be maintained. The described 100 MHz system has been successfully tested up to 1 MW output power with a pulse width of 500 µs and 100 Hz repetition rate against a high power dummy load of 50 ohms impedance. The same system was later on connected to a 1 m prototype RFQ along with amplitude and phase feedback and micro-processor control units.

Radio Frequency System

The 100 MHz rf amplifier system in principle consists of four stages of amplifiers: a solid state amplifier of 300 W CW, pre-driver and driver stages up to 120 KW pulsed output and a final power amplifier capable of producing 1.2 MW output at the specified pulse width and duty cycle. The complete chain can be driven from any suitable source. Pin diode modulator, directional couplers, rf pick ups and level detectors along with ignitron crowbars in the anode circuits protect the amplifiers against arcing, excessive reflected power and any other faulty operation. Complete personal safety is ensured against high voltage and high rf radiation hazards.

The power amplifiers which were procured from outside were operational[3] at 108 MHz hence they were modified to 100 MHz for powering the RFQ and all subsystems namely water and air cooling, high voltage dc power supplies and local interfaces were installed. Typical operating characteristics of the driver and the final power amplifier for an output of 990 KW are listed in Table 1. The amplifiers operated very successfully without any inherent tube oscillations although a low frequency ringing in the anode current of the final power amplifier was noticable which was due to the power supply choke, storage capacitor and other low frequency components in the dc anode line. Attempts are being made to damp such a ringing.

The local microprocessor interface and control system are installed to operate the complete power amplifier chain from a remote station or a local terminal.

System Description

The complete system consists of rf reference line, rf switch operated from timing bus, amplitude and phase modulators, power amplifier chain, RFQ, feedback controller and local control system connected to the overall computer link, emergency line and feedback control. This is shown in figure 1. Signals proportional to the amplitude and the phase of the voltage in the RFQ are picked up by loops and fed to the feedback controller. The rf pulsing using a pin diode switch which is triggered by TTL logic simulates the timing bus.

The interlock for the complete system is divided into three categories. The basic safety interlocks concerning main power circuit braker, high voltage area protecting fences, excessive temperature limit switches and water-air sensors are all hardwired. The next level uses digital and analog circuits so as to protect against system malfunction such as high reflected power or crow-bar due to high anode current and also acts in case of external emergency signal. The third level of interlock will be served by software modules fulfilling all the requirements concerning system measurements as well as other subsystem status signals.

Local Control - SMP System

The Siemens SMP system employing CPU NSC800 and 128 Kbyte RAM memory is used to interface with all analog and digital signals of the rf system and to control several system states and interlock levels. This serves as the local control and is often referred as local terminal in this paper. A Mitsubishi PC BFM186 acts as a remote controller which will be replaced by a overall computer link. Figure 2 shows the system configuration with SMP.

Four system states are defined and can be received via command message from the remote control station or activated by the local terminal. The defined system states are:

OFF STANDBY READY OPERATIONAL

In the OFF state the local system is switched off and no energy resides in the system. In the STANDBY state the local system is switched on along with cooling circuits, filament power for the tubes and all power supplies except high voltage on the final amplifier. The high voltage is switched on in the READY state and finally in the OPERATIONAL state rf power is available under software control and timing. The logic sequence and controlled change from one state to the next higher or low level will be performed by software routines residing in the local control system. A message status will be sent to the operator to confirm the newly reached state. All control tasks are running under CP/M3 operating system.

Specifications	Driver		Final Amplifier	
DC Anode Voltage	11.5	kV	20	kV
DC Anode Current (pulsed)	18	A	100	A
DC Screen Voltage	1420	V	1550	V
DC Screen Current (pulsed)	0.1	A	0.5	A
DC Bias Voltage	-250	V	-620	V
Input DC Power (pulsed)	207	kW	2000	kW
RF output power (pulsed)	100	kW	992	kW
RF drive power (to pre-driver)	250	W	100	kW
Gain (pre-driver and driver)	26	dB	10	dB
Efficiency	48	%	49.6	%
Tube type: Tetrode	Siemens RS 1084 CJ		Siemens RS 2074 SK	

Table 1: Operating characteristics of driver and final power amplifier

The hardware of the SMP system is divided into two parts as shown in figure 3. The modules shown in the upper region are needed by the SMP system itself, controlled by the CP/M3 operating system and its device drivers. The modules in the lower region are interrupt control, analog inputs, analog outputs, digital inputs, digital outputs and power outputs. All analog inputs like anode current, rf power output, cooling water temperature etc. can be monitored and used as interlock input parameters. Analog output signals are used to control rf amplifier working conditions (anode voltage, anode current etc.) and to give certain set points (rf amplitude and phase) to slow feedback system. Digital input modules read status of the complete amplifier system where as new status can be derived by the digital output control signals. Power output modules of the SMP system enable to switch ON/OFF a device directly, bypassing the manual switch. The interrupt control mode is used to interrupt a running control task by an action initiated by rf control or interlock. The interrupt control starts an emergency routine to shut down all normal controls and put out a message on CRT/Printer or to the overall control system.

Amplitude and phase Feedback

The amplitude and the phase modulators use commercial components which operate at 10 mW signal level. The signals needed for the feedback are coupled out of the RFQ through pickup loops, -40 dB coupler and a power divider. One of the outputs of the power divider is detected and fed to the amplitude modulator via feedback controller where as the other output mixed with the reference phase provides the signal for the phase modulator. With close loop feedback the rf amplitude is settled approximately in 50 µs and variations are kept within 1 percent. The result is shown in figure 4 where the upper trace shows the actual rf signal in the RFQ and the lower trace is the control signal of attenuator modulator. With the existing phase feedback loop further improvements are needed to achieve the required stabilisation.

Conclusion

The 100 MHz power amplifier system which produced 1 MW pulsed power proved to be very reliable since the performance could be repeated over a period of a few months without any major interruption. All possible faults were simulated and tested with the computer interface. The amplitude and phase feedback via SMP system controlled through software was also operational. The feedback system was tested without beam in the RFQ.

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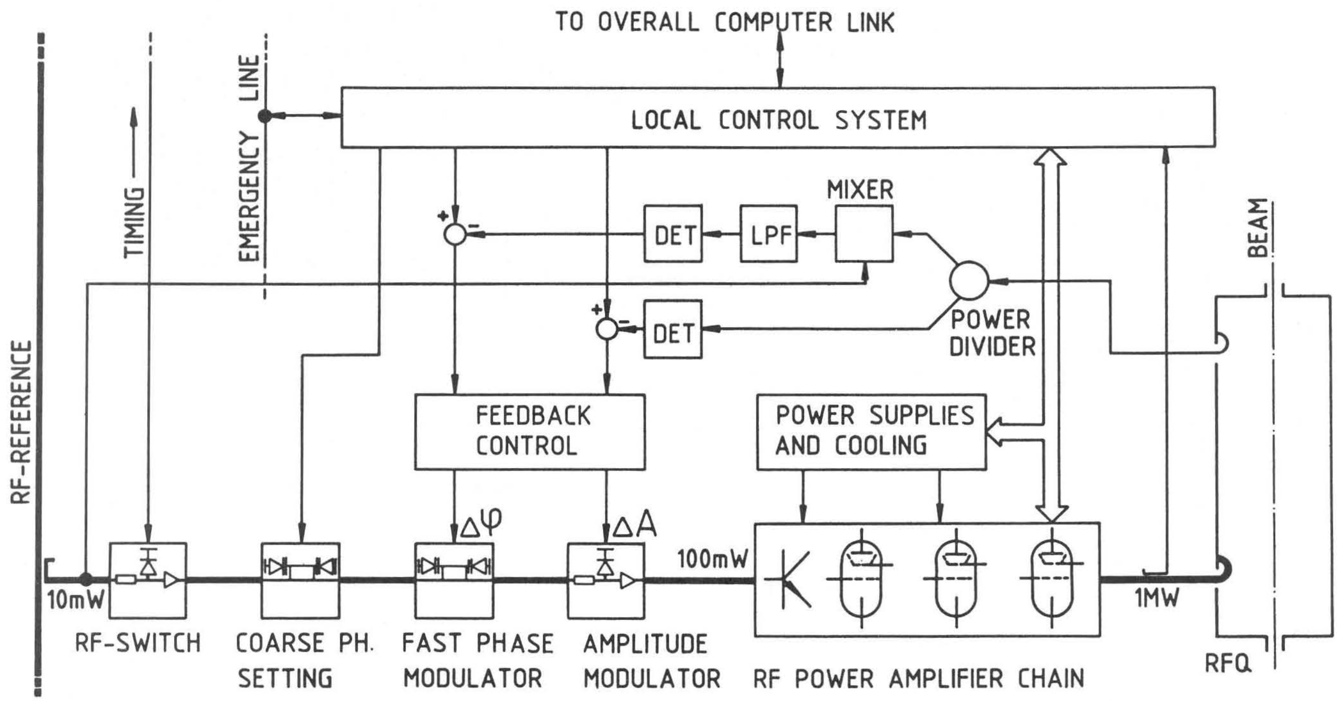

Fig. 1 Complete RF System

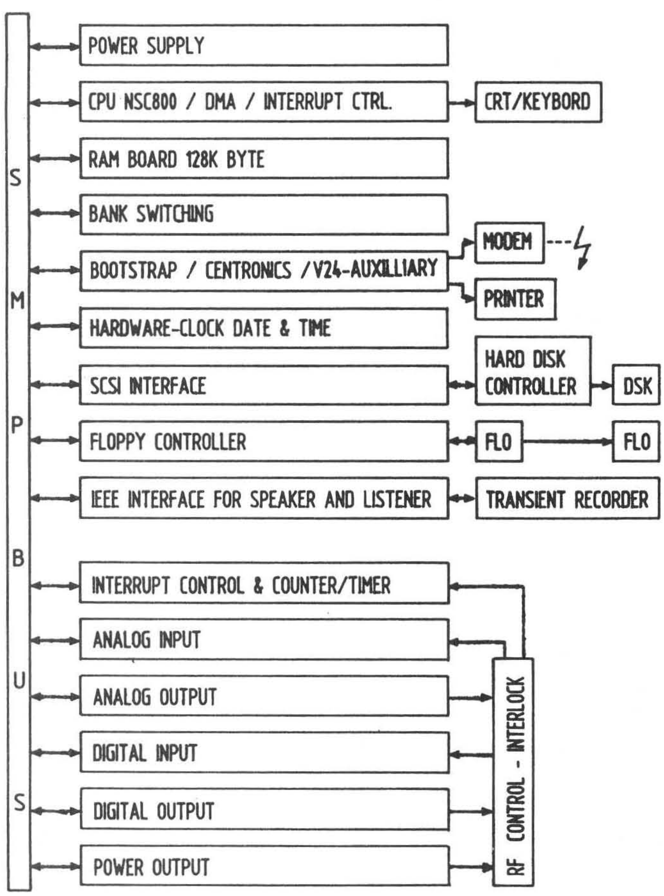

Fig. 3 Internal Structure of the SMP-System

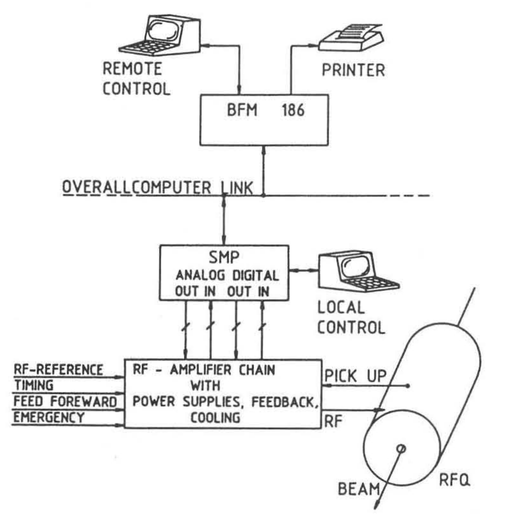

Fig. 2 Control System Configuration

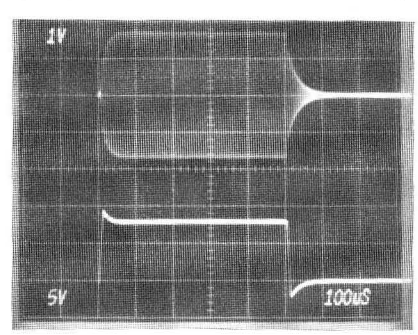

Fig. 4 RF output pulse and its control signal