# SSC LINAC RFQ RF SYSTEM

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## Abstract

The SSC RFQ accelerates a 25 mA, 7 to 35 µs, 10 Hz $H^-$ beam from 30 keV to 2.5 MeV. The RFQ requires 280 kW of RF power at 427.617 MHz to establish the RFQ accelerating field, plus an additional 63 kW for beam loading. The requirements [1] on phase and amplitude control are 0.5° and 0.5% during the beam pulse. A description of the RFQ RF system is given, and the results of operation into a test cavity with simulated beam loading are presented.

## Introduction

The SSC RFQ is required to accelerate a 30 keV $H^-$ beam to 2.5 MeV. The beam, at the exit of the RFQ, has a 25 mA, 7- 35 µs-long macropulse, with a repetition rate of 10 Hz. The RFQ uses a 100 µs-long RF pulse to establish its accelerating fields. The 100 µs RF pulse length allows ample time for cavity filling and field settling, so that the very stringent RF field control requirements of 0.5% of amplitude and 0.5° of phase can be maintained. The RF system consists of a 600 kW high power RF amplifier at 427.617 MHz, a Low Level RF control system (LLRF), and a supervisory control system.

## 600 kW RF Amplifier

The 600 kW RFQ amplifier was built as a joint development effort with Los Alamos National Laboratory (LANL) AT Division, and is based upon an earlier LANL design for a 300 kW amplifier. The amplifier output, 600 kW for 100 µs at 427.617 MHz with a repetition rate of 10 Hz, was specified to provide sufficient power output to establish the RFQ accelerating field (280 kW), enough beam power for up to 50 mA (125 kW), and to provide for distribution losses, control range, and a safety margin.

The RFQ amplifier consists of three stages: The first stage is a solid state amplifier with 48 dB of gain. This is followed by an intermediate or driver stage, which uses a triode (Eimac 8938), and has 15 dB of gain. The output stage of the amplifier uses a tetrode (Burle 4616), and has 14 dB of gain. The overall bandwidth of the amplifier is 300 kHz. The controls for the amplifier use a Programmable Logic Controller (PLC) that is connected to the RF supervisory control system via a serial link. The amplifier has been tested to full power, and performs to specification.

## LLRF and Supervisory Control System

The LLRF and Supervisory Control systems were built on a collaborative effort with LANL - AT Division, and are based upon the system developed for the GTA [2,3]. The LLRF system is VXI based, and uses an I & Q detection system. The cavity sample signal is downconverted to 20 MHz, where a vector demodulator performs I & Q detection. The I & Q signals are each input into a PID controller, where a comparison with the I & Q set points are made. Vector modulators are used to produce 20 MHz feedback signals from the output of the PID controllers. An upconverter returns the signal to 427.617 MHz for the RFQ amplifier input. The Supervisory Control system for both the LLRF and the RFQ amplifier is based on the EPICS control system. The control system uses a two tier client-server architecture. The system uses a UNIX platform for the user interface, and a VME/VXI-based real time kernel for data acquisition and control.

## Experimental Configuration

In order to test the RFQ RF system an RF cavity with a Q of 4000 was used. This Q is similar to the expected loaded Q of the SSC RFQ. The RF test cavity cannot handle high power, so the RF amplifier output is attenuated by 60 dB to produce a nominal 29 dBm power level input for the test cavity. Beam loading corresponding to a 25 mA beam (22.5 %) is provided by using a separate low power amplifier phased 180° from the RFQ amplifier. The beam pulse simulated in these tests was a square pulse, 40 µs long. The tests consisted of measuring the maximum variation of the cavity phase and amplitude during the beam pulse. This includes the beam loading transition response of the cavity and RF system. A feedforward signal was used to produce the minimum amplitude and phase variations. The test set up is shown in Figure 1.

## Results

The cavity phase and amplitudes are shown in Figures 2-4, for the following conditions. Figure 2 illustrates the cavity field without simulated beam loading. Phase and amplitude control, after cavity filling and settling, is 0.1° and 0.1 %, respectively. Figure 3 illustrates the cavity field with simulated beam loading, with feedback control from the LLRF system only. The maximum cavity amplitude variation is 2.8 %, and is outside the 0.5 % performance specification for 4 µs. The cavity phase remains within the 0.5° performance specification. Figure 4 illustrates the cavity field with simulated beam loading, with both LLRF feedback control and feedforward consisting of a square pulse input to the PID controllers 0.2 μs before the simulated beam pulse. This produced a maximum cavity amplitude variation of 0.4% and maximum phase variation of 0.2°. These tests show that the SSC RFQ RF system can meet its phase and amplitude performance specifications with a combination feedback and feedforward LLRF control system.

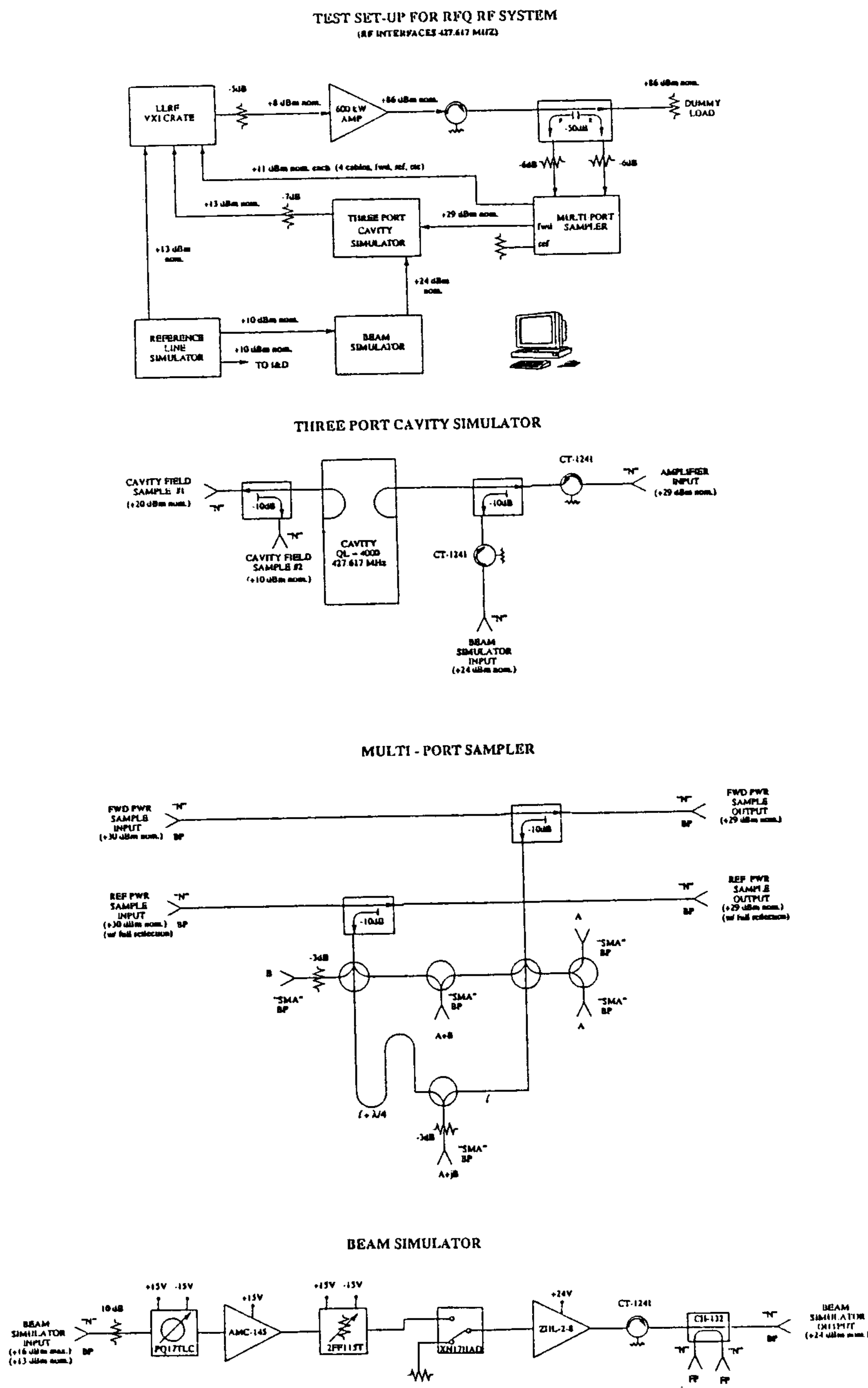


Figure 1. Experimental test set up for RFQ RF system.

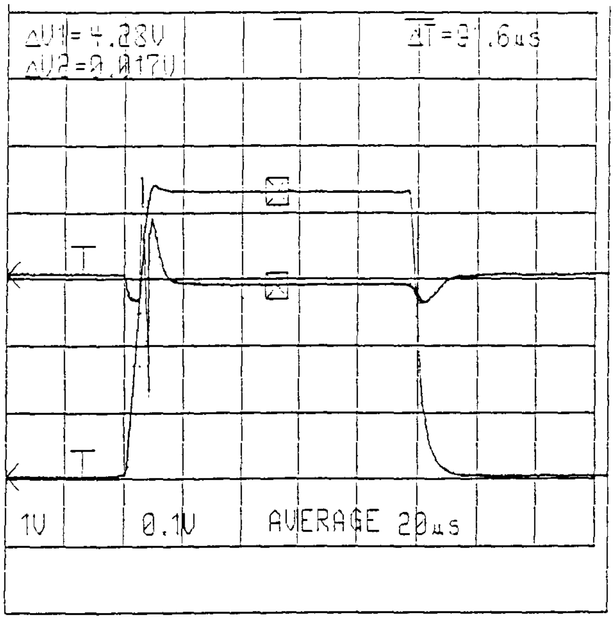


Figure 2. Cavity Phase (lower trace) and Amplitude (upper trace) of test cavity without beam loading simulation. Phase 1° per division.

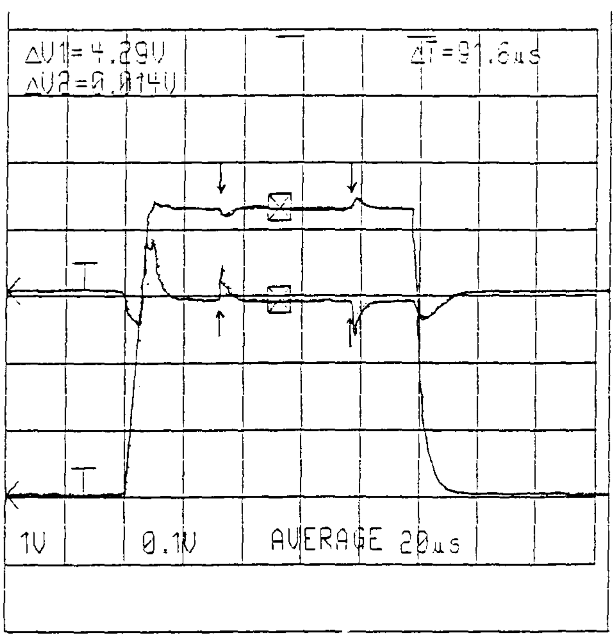


Figure 3. Cavity Phase (lower trace) and Amplitude (upper trace) of test cavity with beam loading simulation. Arrows denote beam loading simulation limits. Feedback only. Phase 1° per division.

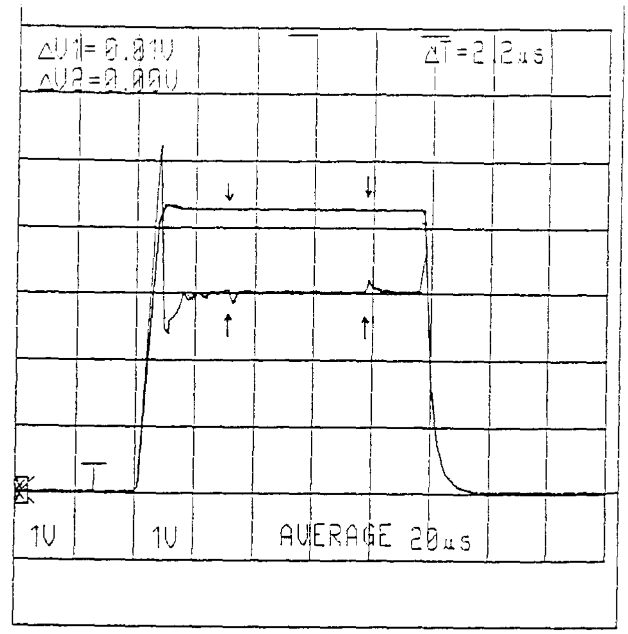


Figure 4. Cavity Phase (lower trace) and Amplitude (upper trace) of test cavity with beam loading simulation. Arrows denote beam loading simulation limits. Feedback and feedforward. Phase 1° per division.

## References

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[2] S.P. Jachim, "Some New Methods of RF Control", Proc. of the 1990 Linear Accelerator Conference,Albuquerque, NM, 1990. LANL publication LA-12004-C. p. 573.

[3] S.I. Kurokawa, "The EPICS Control System Architecture", ICALEPCS '91, Tsukuba, Japan, To be published.

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