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RF CONTROL AND DAQ SYSTEMS FOR THE UPGRADED VERTICAL TEST FACILITY AT FNAL *

Y. Pischalnikov#, R. Carcagno, F. Lewis, R. Nehring, R. Pilipenko, W.Schappert
FNAL, Batavia, IL 60510, USA

Abstract

The Fermilab Vertical Cavity Test Facility (VCTF) [1] is a used to test production cavities prior to their installation in cryomodules and to characterize the performance of research cavities as part of the extensive SRF cavity R&D program at FNAL. The performance of a variety of SRF cavities (325MHz, 650MHz, 1300MHz; bare and dressed) can be measured at VCTF. Recently FNAL upgraded the facility by adding two additional test stands (VTS2&3) in preparation for production of cavities for two new linear accelerators (LCLS II and PIP II). This paper provides an overview of the design features, technical parameters and experience with first operation of the upgraded RF control and DAQ systems.

INTRODUCTION

The VCTF was designed and built in 2007 as part of Fermilab's involvement the ILC Project by the Technical Division Test & Instrumentation Department (TD/I&C) in collaboration with Thomas Jefferson National Laboratory (JLab). The design of the RF Control and DAQ systems closely followed that of the JLab cavity test VTS [2,3]. Initial the RF system could only test 1.3GHz elliptical cavities. Recently, in anticipation of the of PIP II at Fermilab and LCLS II at SLAC, the ability to test other varieties of cavities was added and the number of dewars was increased from one to three.

RF CONTROL AND DAQ

The cryogenic system can simultaneously cool-down two of the three stands but only one stand can be powered at a time. A single Low Level Radio Frequency (LLRF) system capable of operating at multiple frequencies is multiplexed between the three stands and a single radiation shielding block is moved from stand to stand to protect personnel from the ionizing radiation that can be generated by field emission in a powered cavity.

A block diagram of the upgraded VCTF RF Control and DAQ system is shown in Figure 1. The system consists of the following subsystems:

- Interlock Subsystem
- Cavity Instrumentation
- RF Control Subsystem
- Frequency Multiplexing Subsystem
- Dewar Multiplexing Subsystem
- RF Power Subsystem
- DAQ Subsystem

Each of these subsystems will be described in more detail below. Operators can monitor and control each of these subsystems from the DAQ and Control Subsystem user interface (Figure 2).

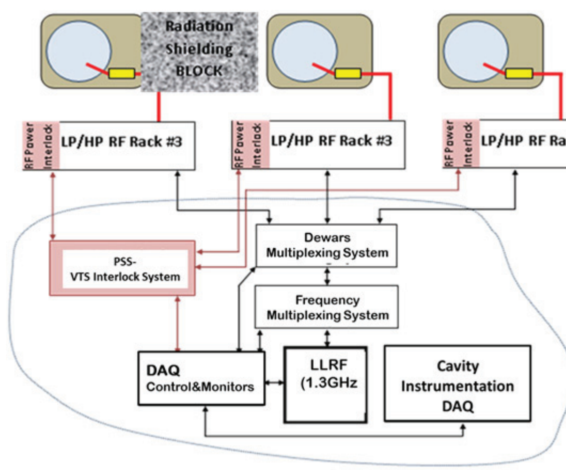

Figure 1: VCTF Control and DAQ System.

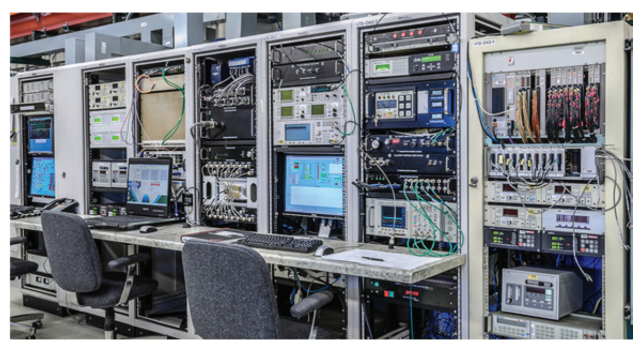

Figure 2: The VCTF Control Room.

Interlock Subsystem

Safety of personnel continues to be the highest priority of the VCTF. Personnel are protected by a Personnel Protection System (PSS or VTS Interlock system). The system issues permits to power the cavity only when all interlocks, (radiation monitors, shielding block position switches, RF leak detectors, etc.) are actively signalling safe conditions. If any of the PSS interlock signals drop, RF power will be automatically shut off. The VTS user interface described below allows users to monitor the status of the PSS.

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#pischaln@fnal.gov

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Cavity Instrumentation

Cavities under test are powered via ½ inch heliax cable. The cavity field probe signal is monitored by a power meter directly while the forward and reflected power signals are monitored by meters connected to a wideband 20 dB coupling/20dB directivity directional coupler inserted in the power cable [4]. Splitters allow a portion of each of these three signals to also be fed to the RF control subsystem.
Additional sensors monitor cavity temperature, pressure, radiation levels. Second sound sensors aid the localization of cavity sites.

A wideband directional coupler was chosen to accommodate the wide range of resonant frequencies encountered but the limited directivity of the coupler can lead to large systematic effects if the cavity is not close to optimally coupled. As an example, measurements of systematic uncertainty in Q_0 for a 1.3GHz cavity as a function of the coupling factor $\beta_1=Q_0/Q_1$ is shown in Figure 3. A variable power coupler installed on the cavity allowed the coupling ratio to be varied [5]. As the coupling factor was varied between 1.2 and 3.5 the measured value of Q_0 changed by ~25%. Commercially available wideband directional couplers with higher directivity could not be found.

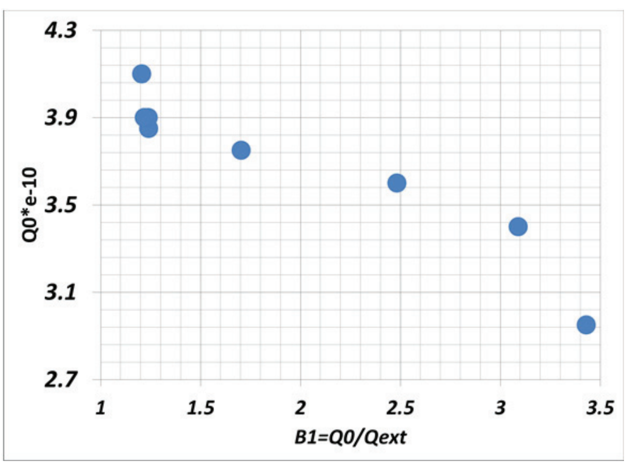

Figure 3: Changes in the Measured Value of Q_0 as the Coupling Factor, β_1, of the Cavity is Varied.

RF Control System

The RF control system employs an analog phase-lock-loop (PLL) to track the resonant frequency of the cavity under test. Signals from the cavity field probe and the directional coupler are mixed to baseband and the phase difference between the forward and probe is fed to the PLL. The output of the loop is connected to the FM input of the signal generator. As the resonant frequency of the cavity changes due to variations in the pressure of the helium bath, the frequency of the generator will follow.

Frequency Multiplexing System

The VTS RF control system operates at 1300MHz but 325MHz and 650MHz cavities can be tested a system of using frequency converters and multiplexers. A Frequency Multiplexing System (FMS) based on NI PXI-2546 RF multiplexers connects the RF control system under software control to the frequency converter needed for the cavity under test. The converters shift the frequency of the drive signal from 1.3GHz to the cavity resonant frequency (650MHz or 325MHz) and shift the frequencies of the forward and reflected signals from the cavity back to 1.3 GHz [6].

Dewar Multiplexing System

A multiplexing system based on Dowkey multi-pole RF switches [7] connects the RF signals following conversion to the stand that contains the cavity under test.

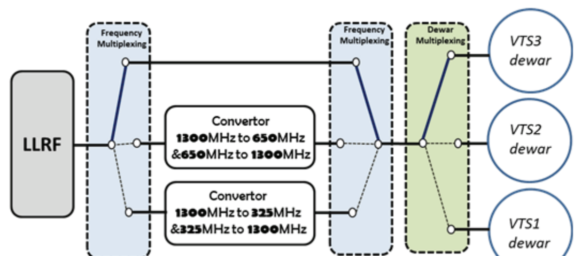

Figure 4: Dewar and Frequency Multiplexing Subsystems.

RF Power Subsystem

The RF drive signal from the control system must be amplified before it is sent to the cavity. Each stand is equipped with dedicated low power and high power amplifiers for each frequency. Low Power (LP) 1W wideband (10MHz-4.2GHz) amplifiers [8] are used for setup, calibration and measurements at low gradients. Narrowband high power (HP) 500W solid state amplifiers are used for high gradient measurements [9]. Each stand is equipped with three HP amplifiers (325MHz, 650 MHz and 1.3 GHz) interlocked for safety. A multiplexer again based on Dowkey multi-pole RF switches connects the appropriate amplifier to the cavity under either software manual control.

DAQ Subsystem

The DAQ subsystem continuously monitors signals from cavity instrumentation and allows users control the operation and measure the performance of the cavity under test. The DAQ subsystem allows operators to select the dewar, select the cavity operating frequency, control the cavity gradient and to monitor the power levels in the cavity forward, reflected and probe signals during operation via a graphical user interface. The interface also performs the calculations required to determine the cavity quality factor, Q_0, from the measured power levels and graphically displays the results. A screen shot of the user interface is shown in Figure 5 and Figure 6.

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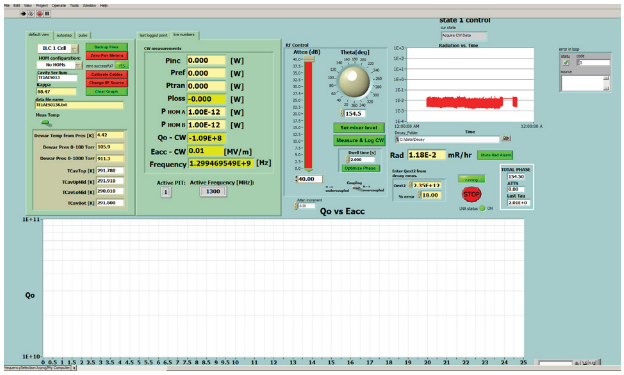

Figure 5: Front Panel of main VTS Program.

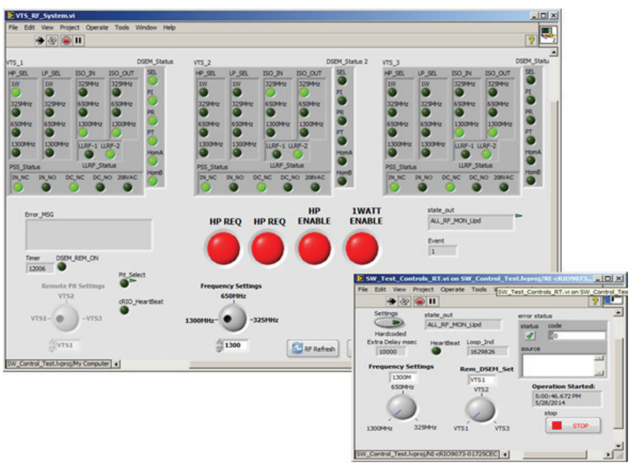

Figure 6: Front Panel of RF Switching Software.

A high level block diagram of the DAQ subsystem is shown in Figure 7. A user interface coded in LabView running under Windows provides high level control and monitoring. A real time embedded controller from NI cRIO-9073 [10] interfaces directly with the hardware components such as multiplexers.

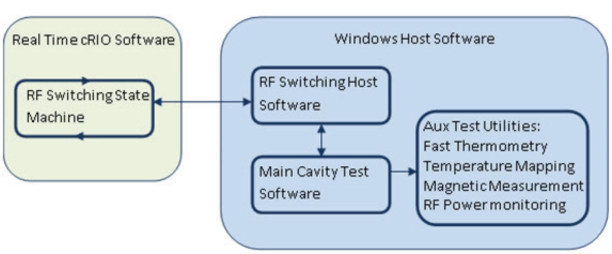

Figure 7: VCTF Facility RF Control and DAQ.

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