LLRF AND DATA ACQUISITION SYSTEMS FOR SPOKE012 CAVITY VERTICAL TEST AT IHEP*

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Abstract

Development of two Spoke012 cavities and their vertical tests have been completed successfully at IHEP (Institute of High Energy Physics) with a LLRF system and DAQ (data acquisition) system specially designed. The LLRF system is developed on the basis of the proven analog system used for the test of the BEPCII 500 MHz spare cavity. The Labview2009-based DAQ system is in charge of the communications of the measuring instruments, the local machine and the remote one. It realizes the real-time display of Q_0~E_{acc} and radiation dose curve for the first time at IHEP. The data connection between Labview and EPICS is implemented. The vertical test result shows that the LLRF and the DAQ system perform stably and reliably as expected. This paper introduces these two systems and the general information of Spoke012 cavity vertical test.

INTRODUCTION

Two 325 MHz spoke cavities whose β is 0.12 (Spoke012) have been fabricated successfully at IHEP. In order to get the relationship between the unloaded quality factor Q_0 and the accelerating gradient E_{acc} and evaluate the performance of the cavity, a vertical test should be implemented.

In the vertical test, due to the cavity's narrow bandwidth on the order of 1 Hz with superconducting state, the LLRF system must track the cavity frequency strictly to keep the resonance. Moreover, a large amount of data including RF powers, temperatures, vacuum and liquid helium levels need to be analyzed. All of these data should be acquired, transmitted, processed and stored synchronously and in real time [1]. According to these requirements, a stable, reliable and efficient DAQ and signal processing system is necessary.

LLRF SYSTEM HARDWARE

The layout of cabinet for vertical test is illustrated in Fig. 1. In general, the LLRF system mainly consists of a PLL (Phase Locked Loop) and parameter measurement system.

PLL

Because of the narrow bandwidth of a superconducting cavity, a PLL is required to keep the RF source operating at the cavity's resonant frequency. A schematic diagram of the RF equipment attached to the spoke cavity is shown in Fig. 2 [2].

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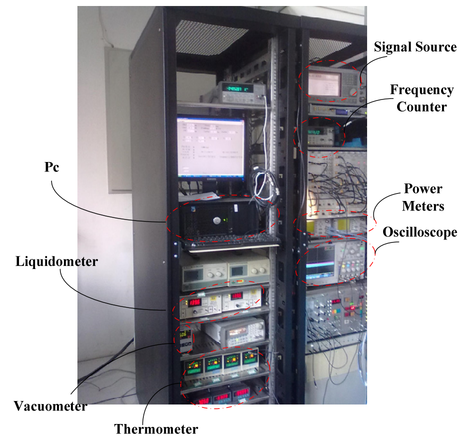

Figure 1: Cabinet of vertical test.

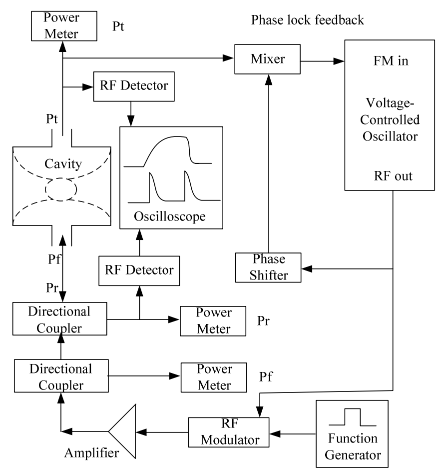

Figure 2: Schematic of the test equipment for RF measurements on spoke cavity.

The LLRF system uses the combination of down converter, phase detector and loop amplifier to obtain the phase difference between incident and transmitted signals. After filtered and amplified, the phase difference is fed back to the signal source's external frequency modulation (FM) control to adjust the RF source frequency and lock onto the frequency of the cavity. However, when the frequency is out of lock, a function generator is indispensable to provide a saw-tooth waveform of varying amplitude which is used to sweep the cavity's resonant frequency. A simplified block diagram of the LLRF system for Spoke012 cavity vertical test is shown in Fig. 3 [3]. From Fig. 3, it is clear to see the main LLRF loops and the measuring approaches.

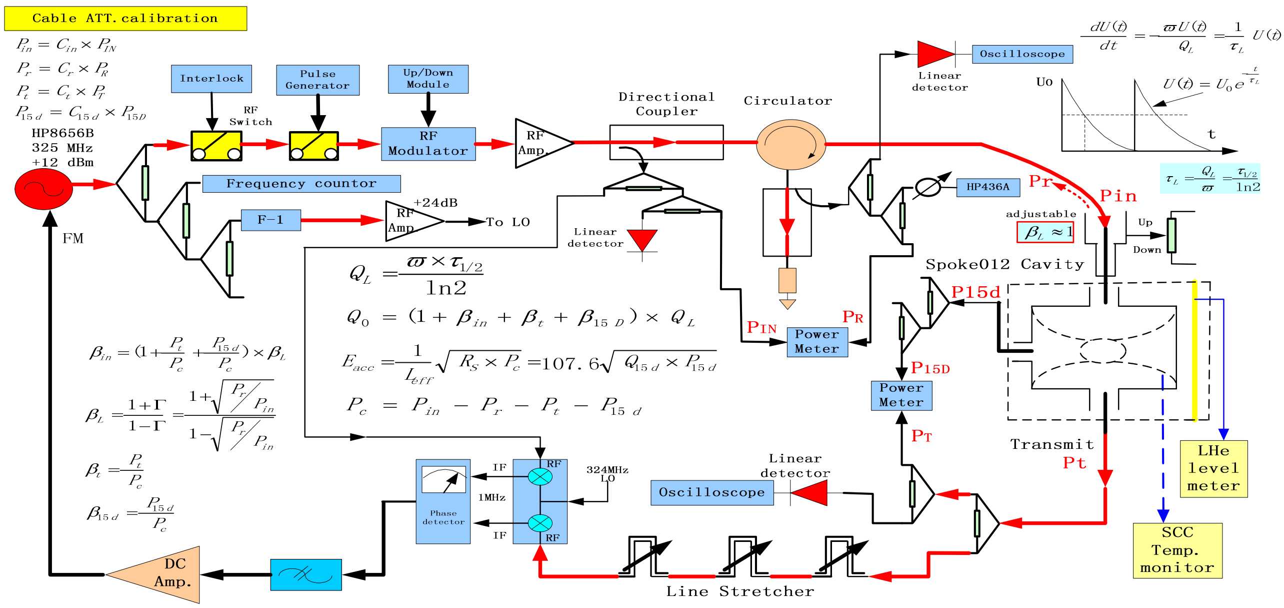

Figure 3: Block diagram of the LLRF system for Spoke012 cavity vertical test.

Parameter Measurement System

To measure Q_0 as a function of E_{acc}, the first step is to adjust the input coupler penetration and the phase shifter so that the reflected power is zero, the cavity is matched (β=1). Then, the decay constant τ is obtained by measuring the exponential fall of the stored energy immediately after the input power is switched off. Next, Q_0 and E_{acc} can be calculated by the incident, reflected, transmitted power signals and the decay constant τ [4].

DAQ SYSTEM SOFTWARE

The data acquisition system chooses different transmission interfaces according to the differences of bandwidths and precisions of the measured data as shown in Table 1. Fig. 4 shows the structure of the DAQ system.

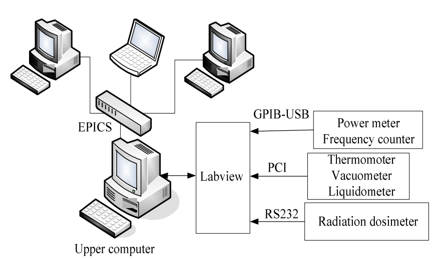

Figure 4: Structure block diagram of DAQ system.

Fast Signals Collection

Agilent high precision instruments are used directly to measure the power and frequency signals that vary quickly. To measure four-channel powers and one-channel frequency, two power meters and one frequency counter are connected in series. The three instruments' addresses are allocated in advance, and then a Labview program is run in the PC to operate these instruments.

Firstly, the VISA write module of Instrument I/O in Labview2009 gives a Fetch instruction to these instruments. Then the VISA read module will read the power or frequency out. Finally, a string to number conversion is very essential. The fastest transmission rate of GPIB is 1.8Mb/s, so the speed can meet the demand of fast signals completely.

Slow Signals Collection

For signals that vary very slowly, convert the instruments backboards' analog 4-20 mA current output to voltage signals and send them to a DAQ card. Finally, all data are transmitted to PC via PCI interface.

It should be noted that since the DAQ card involves the current/voltage signal transmission and ADC conversion, errors will be introduced into the system inevitably and they can cause a large data jitter. A digital filter is inserted into the Labview program to solve this problem.

Table 1: Instruments and Interfaces of Different Measured Parameters

Parameter	Way	Requirement	Instrument	Interface
Power	4	High accuracy, fast speed	Agilent E4417A,E4419B	GPIB-USB
Frequency	1	High accuracy, fast speed	Agilent 3132A	GPIB-USB
LHe level	1	Low accuracy, slow speed	DAQ card	PCI
Cavity vacuum	1	Low accuracy, slow speed	DAQ card	PCI
Tuner position	1	Low accuracy, slow speed	DAQ card	PCI
Radiation	1	Low accuracy, fast speed	XH3201	RS232

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Radiation Dose Collection

The radiation dosimeter communicates with the upper computer by serial port RS232. Fig. 5 illustrates how to use NI-VISA to implement serial communication in a simplified flow chart.

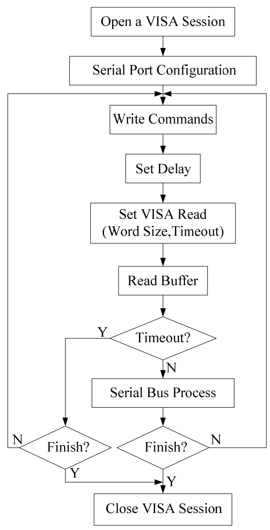

Figure 5: The flow chart of serial communication.

NI-VISA makes serial instrument programming fast and easy. After reading the bytes out by VISA Read, these bytes should be separated and combined again to get the value and the unit of the radiation dose according to the specifications.

The Features of the DAQ System

Fig. 6 shows the Labview interface of Spoke012 cavity vertical test. From the figure, all parameters and the test result are displayed clearly.

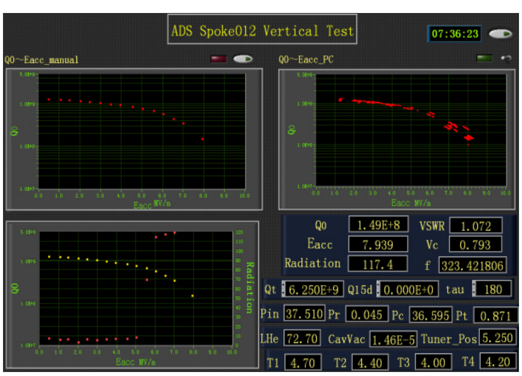

Figure 6: The Labview interface of Spoke012 cavity vertical test.

The features of the DAQ system are as follows.

a) All measured data are saved for Excel files in PC by Labview. The names of the Excel files can be changed automatically as the system time every other hour, which avoids Labview program errors because of a file's large capacity.

b) Since the cavity parameters must be measured at or near critical coupling, the system is designed to select effective data automatically when VSWR is between 1 and 1.1. At the same time, it draws a curve of Q_0 and E_{acc} (Q_0~E_{acc}_PC curve in Fig. 7) in real time.

c) Along with the increase of the incident power, there must be a point when VSWR is nearly close to 1 at each certain power level. These ideal parameters and the final Q_0~E_{acc} curve (Q_0~E_{acc}_manual curve in Fig. 7) can be presented on PC and saved in PC by clicking a button. It is timesaving to obtain real -time result without off-line analysis.

d) All data that Labview2009 acquires are connected with EPICS, which is easy to plot the curves of parameters. The data display interface is more beautiful as illustrated in Fig. 7. What's more, the interface can be displayed on several upper computers synchronously.

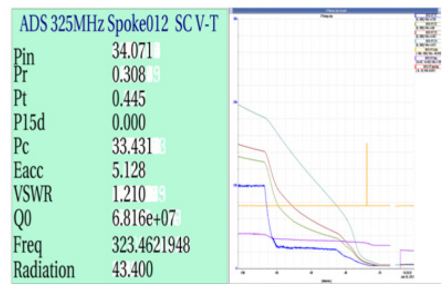

Figure 7: The EPICS interface.

CONCLUSION

The LLRF system has been locked onto the cavity and it tracked the cavity frequency well. The DAQ system has also been proven to be of reliable operation and easy maintenance after Spoke012-1#&2# cavities were tested successfully at IHEP. It can collect data and get real-time test results online for the first time in China. It also has implemented network distributed data acquisition with EPICS. The systems are portable for other vertical testing systems by making small changes easily.

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