

RF MONITOR SYSTEM FOR SuperKEKB INJECTOR LINAC

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Abstract

A new radio frequency (RF) monitor system for the SuperKEKB project has been developed at the KEK injector linac. The RF monitor unit, which consists of an analog I/Q demodulator, ADC/DAC board, and FPGA board achieved 50-Hz data acquisition and beam mode identification. On the RF monitor, the amplitude and phase measurement precision has achieved 0.1% rms and 0.1° rms, respectively. Sixty RF monitor units have been installed in the linac.

The present status of the RF monitor system will be reported.

INTRODUCTION

An RF monitor system has been renewed as one of the upgrades of the injector linac for the SuperKEKB project in KEK [1]. In simultaneous injections at the linac [2], the phase and timing of the RF pulse are controlled at 50 Hz. The data acquisition and recognition of the beam mode at 50 Hz were required for the RF monitor system.

The previous RF monitor system consisted of a VXI-base DAQ, a phase detector, and a peak power meter [3]. The data acquisition rate was at most 25 Hz. To improve the effective resolution of the phase measurement by an 8-bit ADC, the phase detection range was restricted to approximately 40° . Therefore, when the phase change exceeds the detection area, measurement is impossible. Moreover, the addition of hardware to recognize a beam mode was also difficult.

We decided to replace an RF monitor system because almost all the requirements could not be achieved by the previous system. Figure 1 shows a block diagram of the renewed RF monitor system. An RF monitor unit has been newly installed to measure the amplitude and phase of each high-powered RF source. The RF input channels were increased, such that all monitor signals can be measured constantly. A comparison of the function and performance with the old system is shown in Table 1.

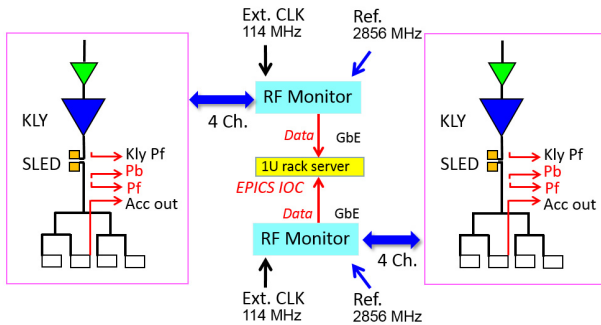


Figure 1: Block diagram of RF monitor system.

Table 1: Comparison to the Previous Monitor System

	PREVIOUS SYSTEM	NEW SYSTEM
Specification of ADC	8 bit, Max 2 GHz	14 bit, 100/114 MHz
Phase measurement range	$< 40^\circ$	360°
Number of RF input channels	8 (selective)	5 (simultaneous sampling)
50 Hz data acquisition	NG (25 Hz)	OK
Identification of the beam modes	NG	OK
Amplitude/Phase precision	0.15% rms, 0.2° rms	0.1% rms, 0.1° rms

RF MONITOR UNIT

The RF monitor unit has been developed based on the LLRF control unit, which consists of an analog I/Q modulator, analog I/Q demodulator, ADC/DAC board, and FPGA board [4]. To increase the RF measurement channels, an IQ demodulator was omitted, and five IQ demodulators were equipped. The Xilinx ML605 evaluation kit was adopted to reduce the development time and the cost of the FPGA board. To cancel the sampling jitter, an ADC is driven by the external clock that is synchronized with the LLRF control unit. Figure 2 shows a block diagram of the RF monitor unit.

The recognition of a beam mode was achieved by the event receiver included in the FPGA. A gigabit Ethernet interface was also installed in the FPGA for the 50-Hz data acquisition. The acquired data is processed by EPICS-IOC on the Linux server. An embedded CPU module and an LCD with a touch panel are equipped as the user interface, which can be used as a simple oscilloscope (Fig. 3).

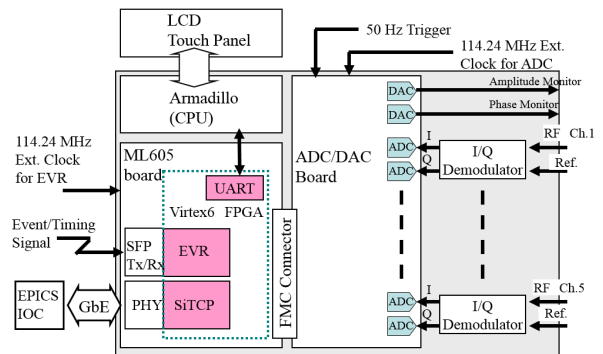


Figure 2: Block diagram of RF monitor unit.

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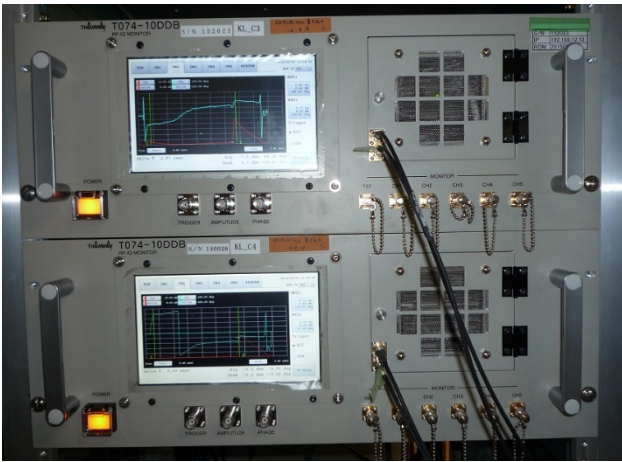


Figure 3: Front panel of RF monitor unit.

Event Receiver (EVR)

The beam mode and timing signals are controlled by an event-timing system, which consists of an event generator (EVG) and event receiver (EVR) in the linac. It is necessary to receive an event code delivered by the event-timing system to recognize a beam mode. An EVR, which is an 8b/10b high-speed serial interface designed by the Virtex6 GTX transceiver, has been installed on an FPGA to receive an event cord.

The EVR frequently malfunctioned during the test run of the RF monitor. This is because the phase noise of a reference clock for the GTX transceiver exceeded the restriction value. Originally, the 114.24-MHz reference clock was supplied from an event-timing system. To improve the phase noise, the clock source and the distribution system have been changed. Figure 4 shows the improved phase noise and a restriction value of the GTX.

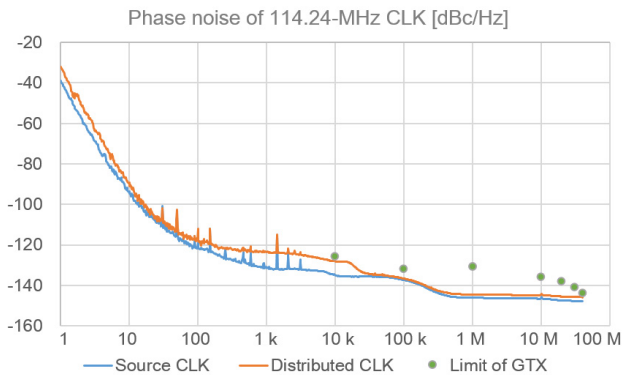


Figure 4: Phase noise of improved 114.24-MHz clock.

Data Transfer by SiTCP

SiTCP is the FPGA logic to connect a measuring instrument for physics experiments to the Ethernet [5]. Ethernet communication by hardware is possible without mounting the CPU on the FPGA. Ethernet is used as a data bus between the RF monitor unit and the EPICS-IOC in this system. The data acquired by the ADC is transferred to the SiTCP through FIFO. The capacity of the FIFO is 16-bit \times 2048 word per ADC. The network transfer rate is sufficient

for 50 Hz data acquisition. The event code, which is received by the EVR, is previously attached to the transmit data. Therefore, even if network latency occurs, the correspondences of the acquired data and beam mode are secured.

APPLICATION SOFTWARE

Originally, the data acquired by the RF monitor unit are the I/Q components of a monitor signal. EPICS-IOC provides the data converted to amplitude and phase. Moreover, the amplitude and phase are sorted for every beam mode. An amplitude waveform and a phase waveform are monitored constantly; when an abnormality occurs, the data is archived.

Waveform Viewer

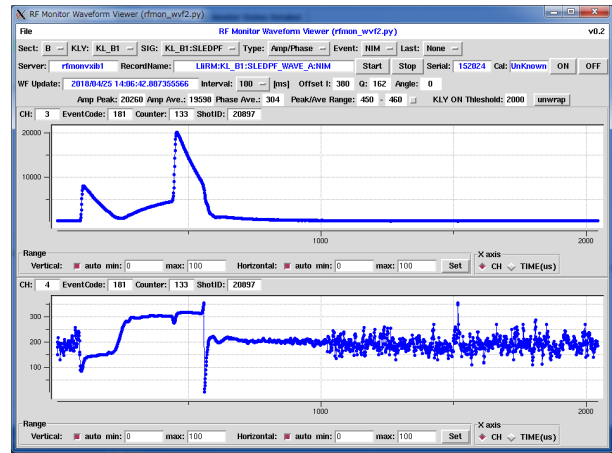


Figure 5: Waveform viewer.

The waveform viewer displays the amplitude and phase of the monitor system acquired in real time. Figure 5 is a sample that shows an SLED output signal. The upper waveform is the amplitude and the lower waveform is the phase. The user can choose the monitor signal and the beam mode by a pull-down menu.

CSS Archiver

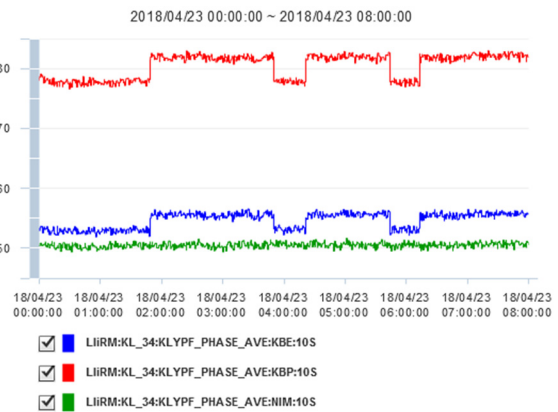


Figure 6: CSS archiver.

The EPICS-IOC samples' typical values of amplitude and phase are from the waveform data. The sampled data are stored in an EPICS archiver. A CSS-Archiver is a general-purpose software to display archived data. Figure 6 shows the archived phase data of the klystron output. The chosen beam modes are KEKB e- (KBE) and KEKB e+ (KBE) and no-injection (NIM).

Last Waveform Archiver

This is the program operating on the server computer that accumulates the waveform data to the ring memory. When a high-powered RF source is stopped by a safety interlock, the waveform data on the ring memory is archived. Fig. 7 is the data immediately before a high-powered RF source suspends because of VSWR. An increase in the backward power of the SLED (SLEDPB) occurred at the last pulse.

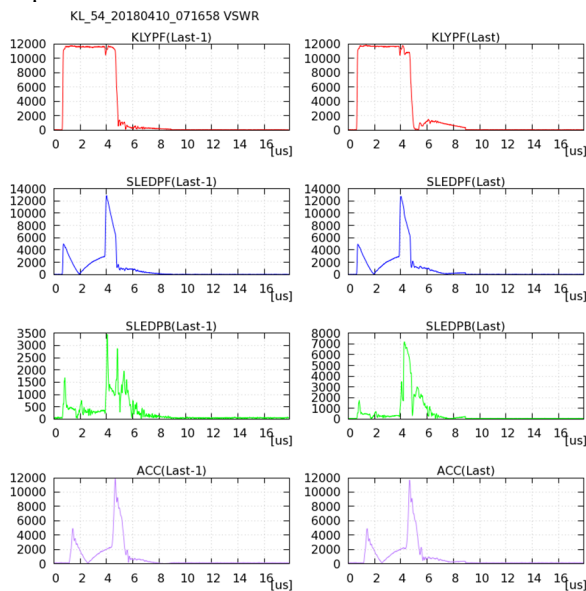


Figure 7: Archived last waveform.

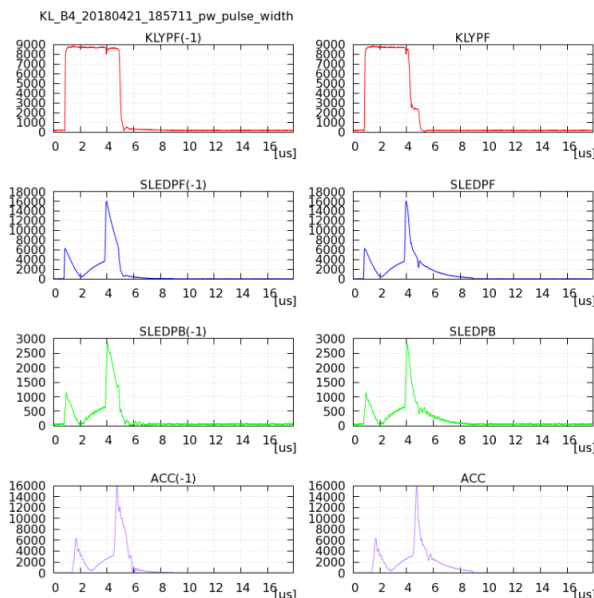


Figure 8: Archived pulse-shortening waveform.

Pulse-Shortening Detector

When pulse shortening occurs, the klystron output pulse width becomes shorter. The high-powered RF source is not always suspended. The pulse-shortening detector is a program that detects a pulse width that is shorter than usual and archives the waveform data. Figure 8 shows the waveform data acquired by this program. The peak of the reflection power (SLEDPB) did not change and only the pulse width of the klystron output (KLYPF) became shorter.

SUMMARY

The installation of the primary components of the RF monitor system has been completed. We are considering the measurement of the beam-induced wave [6] for beam commissioning. To detect the beam-induced wave by the RF monitor unit, additional component have been installed experimentally.

To improve the phase noise of the 114.24-MHz clock, the replacement of clock distribution modules is scheduled. The RF monitor unit has a function that corrects the detection error of the I/Q demodulator. The calibration depends on the temperature and LO power level of the demodulator. Therefore, the calibration of the demodulator in an actual environment is planned. An application software will be upgraded according to the user request.

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