INSTALLATION OF THE SPring-8 LINAC BPM SYSTEM

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Abstract

We installed a beam position monitoring system to the SPring-8 linac. Electric centers and sensitivities of BPMs were precisely measured. Band pass filter (BPF) units and detector units of BPM signal processors were matched to minimize a drift of the apparent position center. Output data of the processors are corrected by a process running on VME to compensate nonlinearity of the processors. The data acquisition system using an optically linked I/O system developed for fast data acquisition was installed. The BPM system is successfully working and application programs are under development.

1 INTRODUCTION

A BPM system has been developed several years for the SPring-8 linac. A logarithmic detector (AD8313, ANALOG DEVICES) is used for a signal processor. An AD8313 was chosen by considerations of S-band RF detection, wide dynamic range, simplicity, low power consumption and stability. A specification of signal processor was fixed in 2000, then thirty signal processors were manufactured and examined in 2001. A data acquisition system that was feasible to acquire all BPM data at 60-pps operation of the linac was planned in 2000. An optically linked remote I/O system was newly developed for fast data acquisition, and was installed in March 2002. At present BPM data are acquired using the SPring-8 standard software framework [1].

The signal processor consists of two nuclear instrumentation modules; the BPF module and the detector module as shown in Fig. 1. The principal processes are a logarithmic detection, an analog-to-digital conversion and a parallel output to VME. The signal processor has four equivalent process channels, and each channel must be matched with the others. Therefore, rearrangements of process units and an output correction of signal processors were performed as described in the section three and four. The section five and six describe about a data acquisition system and a measurement of beam positions.

2 BPM

Twenty-eight BPMs designed for non-dispersive section were manufactured in 2000. All of them were examined on a test bench. The test bench had a 1.2-m long rod which could introduce a single pulse (175 ps) simulating a beam pulse into a BPM. The rod was mounted on a linear motor
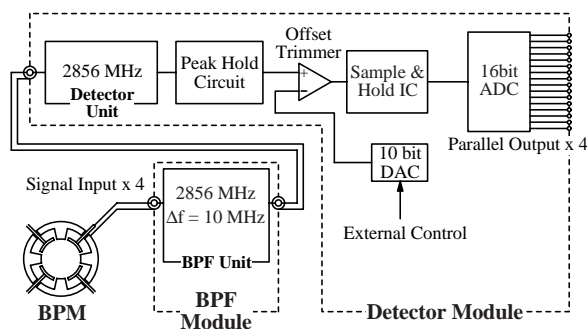
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Figure 1: Block diagram of the signal processor.

stage whose transverse moving range was ±2 mm. A transverse voltage map was obtained by changing the transverse position of the rod.

In order to measure precise transverse electric centers referring to the octagonal alignment base center [2], the mapping was performed twice per one BPM. The BPM was rotated by 180 ° around the base center. Thus electric centers and sensitivities of all BPMs were obtained as shown in Table 1. Here, the sensitivity $K_{H,V}$ is a proportional coefficient of logarithm as followings;

$$
\begin{aligned}
P_H &= K_H \log_e\left(\frac{A \cdot D}{B \cdot C}\right), \\
P_V &= K_V \log_e\left(\frac{A \cdot B}{C \cdot D}\right).
\end{aligned}
$$

$P_{H,V}$: Horizontal or vertical beam position

A, B, C, D : Output voltage of each electrode

The electric centers were measured within ±60 μm ($\approx 3\sigma$). We think this value mainly comes from deviation of four attenuation coefficients where the RF signal on electrode is passing through a coaxial feedthrough of a BPM.

Table 1: Performances of BPMs

	Mean	6σ
Electric Center H [μm]	+6.0	118
Electric Center V [μm]	+0.1	125
Sensitivity H [mm]	2.752	0.092
Sensitivity V [mm]	2.750	0.073

3 BPF MODULE

One hundred twenty BPF units were tuned under the condition of 33 ±0.1 °C. Table 2 shows performances of

BPF units. The center frequencies of BPF units were tuned precisely, while the deviation of band width became large. In the case of a short macropulse RF signal input, e.g. a 1-ns pulse, the output pulse amplitude is inversely proportional to the band width. While in the case of a long macropulse RF signal input, e.g. a 1-μs pulse, the output pulse amplitude does not depend on the band width. This causes a drift of apparent position center depending on the input pulse width. In order to minimize this position drift, four BPF units which had similar band widths were selected and mounted in the same BPM module. In consequence, the maximum deference of four band widths in the BPF module became 0.17 MHz. This value corresponds to the apparent center drift of $\sim$30 μm.

Table 2: Performances of BPF units

	Mean	6σ
Center Frequency [MHz]	2855.9999	0.029
Band Width @ -0.01 dB [MHz]	0.85	0.24
Band Width @ -6 dB [MHz]	13.75	1.71
Insertion Loss [dB]	1.83	0.31
VSWR	1.17	0.24

4 DETECTOR MODULE

4.1 Temperature Dependence

Output amplitude of the detector unit has large temperature dependence, and its deviation is also large. Therefore detector units are also needed to be rearranged like the BPF units. The measurement was done by changing temperature of the detector module and input power. The temperature range was 29 $\sim$ 37 °C by 2-°C step. The input power range was -45 $\sim$ -5 dBm by 1-dBm step. Because temperature coefficient varies with input power as shown in Fig. 2, we define that the average of these temperature coefficients represents the temperature coefficient of a detector unit.

The average temperature coefficient of one hundred twenty detector units was measured as -13.0 mV/°C, and its 6σ was 11.3 mV/°C. The maximum deference of the temperature coefficient in the same detector module became 3.1 mV/°C after the rearrangement. This value corresponds to the apparent center drift of $\sim$5 μm/°C.

4.2 Nonlinearity of Output

The AD8313 has nine detector cells and then the output voltage has a small nonlinearity to the input power in a unit of dBm. The maximum order of nonlinearity is expected as ninth-order of polynomial. Because the detector cells do not have the identical characteristics, apparent position center drifts depending on input power, i.e. beam current. Therefore, all the outputs of signal processors should be measured and corrected by an appropriate order polynomial. Figure 3 shows an example of the apparent horizontal position center calculated with or without third-order polynomial correction. In this case the correction works very
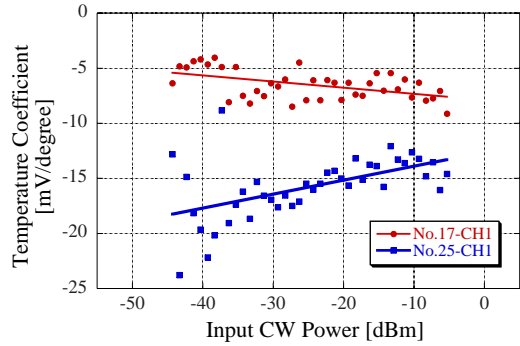

Figure 2: Temperature coefficient. One has the smallest temperature coefficient, the other has the largest temperature coefficient among one hundred twenty detector units.

well, and the maximum drift of the position center is reduced from 240 μm to 40 μm. In this way, the outputs of twenty-eight signal processors were measured.

All maximum drifts of the apparent position centers were reduced as shown in Fig. 4 (horizontally). In the figure almost all modules were corrected well, but a small number of modules were not corrected enough. The averages of maximum drifts were reduced from 200 μm (190 μm) to 110 μm (130 μm) horizontally (vertically) respectively. We are going to make all maximum drifts within 100 μm, because $6\sigma = 100$ μm is a target resolution of the BPM system. Therefore another correction scheme is now studied.
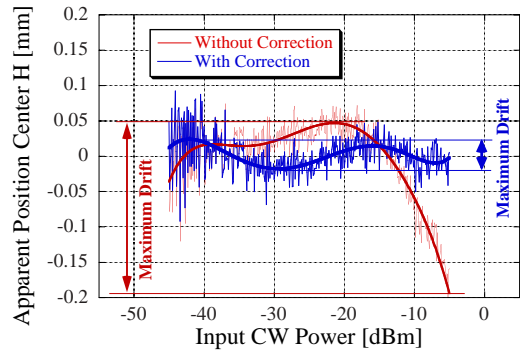

Figure 3: Drift of apparent position center due to change of input power.

5 DATA ACQUISITION SYSTEM

A data acquisition system for BPMs is built by using the SPring-8 standard software framework [1]. At present, a graphical user interface (GUI) running on an operator console directly collects a data set of the beam positions. The GUI sends control messages via a network to an equipment manager (EM) which is an application program on VME. Then the EM acquires the data set and sends it back to the GUI via the network. This data acquisition scheme is inadequate for single shot beam position measurement because
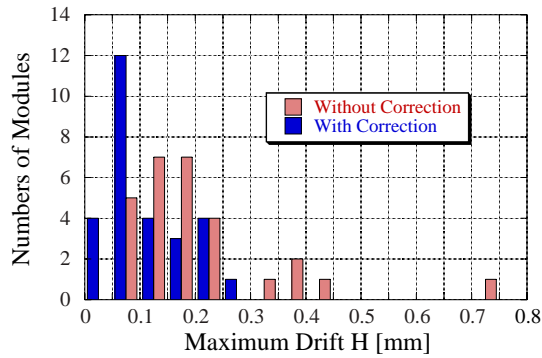
Figure 4: Histogram of the maximum drift.

a beam identification of all data sets can not be always guaranteed. Therefore a new software framework with a shared memory network will be introduced as shown in Fig. 5. In the new scheme, the data set of the beam positions for the identical beam shot will be taken synchronously and stored into a database. We are planning to achieve 60-Hz data acquisition cycle to meet the 60-pps operation [3].

For the fast data acquisition, an optically linked remote I/O system was newly developed. It consists of VME-based master boards and remote boards with four 16-bits digital inputs and four strobe signal inputs. The remote board transfers the register information to the master board every 20 μs via optical fiber. This cycle is fast enough to watch the strobe signal of 600-μs pulse width from the signal processor. The optically linked remote I/O system was installed in March 2002, and the system now works successfully.
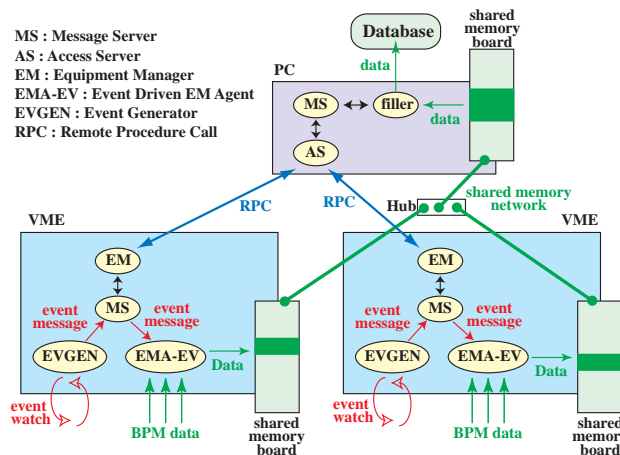

Figure 5: Diagram of a new software framework with a shared memory network.

6 MEASUREMENT OF BEAM POSITIONS

We have started various measurements of beam positions since the installation of the optically linked remote I/O sys-

tem. A shot-by-shot resolution was measured as a function of beam charge using a pulsed beam with a width of less than 1 ns. In consequence, the 6σ resolution was measured as 1 mm (130 μm) for the beam charge of 0.005 nC (>0.05 nC). The expected resolution that is calculated from the noise level of AD8313 is 1 mm (100 μm) for the beam charge of 0.005 nC (>0.05 nC) [4]. We think the difference of 30 μm for the charge of >0.05 nC comes from beam position fluctuation.

Figure 6 is the first developed GUI to measure the beam orbits. At present other application programs, e.g. the beam orbit correction program, beam energy stabilization program and so on, are under development.
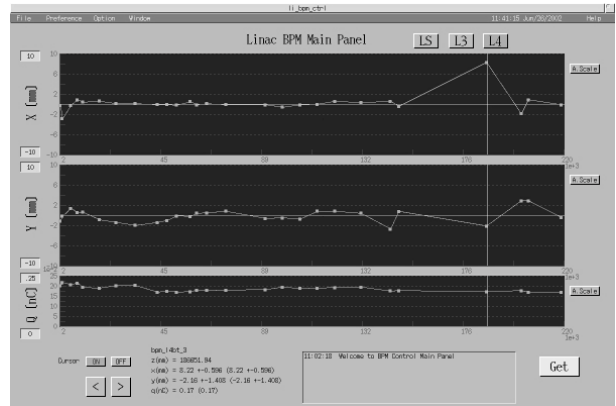

Figure 6: The first developed GUI for measurement of beam orbit.

7 CONCLUSION

In the SPring-8 linac, BPMs, signal processors and the data acquisition system were successfully installed. They are now used in duty operation without any serious problem. The maximum drifts of apparent position centers were reduced to $\sim$100 μm after the rearrangements of process units and output correction of signal processors. The minimum shot-by-shot 6σ resolution is $\sim$100 μm.

The remaining tasks are an additional installation of BPMs in the dispersive section, the shared memory network, the 60-Hz data acquisition and development of application programs.

8 REFERENCES

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