A BPM SYSTEM FOR THE SPring-8 LINAC

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Abstract

The beam position monitor (BPM) system for the SPring-8 linac is composed of BPMs, signal processors, VME computers for data acquisition, an external trigger system, and their connections. The BPM is a four-channel electrostatic stripline monitor whose stripline length is 27 mm. The BPM outputs a pure 2.856 GHz sinusoidal wave. For a single bunch beam, a band pass filter whose bandwidth is 10 MHz is inserted between the BPM and the signal processor. A logarithmic detector is used to detect RF amplitude. The post-processes of the detection are a peak hold, a sample hold, an offset subtraction, and an AD conversion. The signal is finally sent to the VME computer as a 16-bit digital signal. The total resolution measured under machine operating conditions was 23.4 μm (6σ).

1 INTRODUCTION

Beam operation of the SPring-8 linac began in 1996, but a BPM system was not in operation. Development of a BPM system started in 1990 and the conceptual design of the BPM system has been modified several times through testing or examining various methods for the BPM system. However, the conceptual design of the BPM system has now been fixed for several years. This paper describes the most suitable BPM system for the SPring-8 linac which consists of a BPM, a signal processor, and a data acquisition system.

The guidelines for designing the BPM system were as follows.

- Bunch separation as short as 350 ps (2.856 GHz).
- A wide dynamic range of macropulse width; i.e., from a 1 ns (including a single bunch) beam to a 1 μs beam.
- A wide dynamic range of beam power; i.e., from a 1 ns - 10 mA (for the positron) beam to a 1 μs - 100 mA beam.
- Total resolution under machine operating conditions of less than 100 μm (6σ).
- A high acquisition rate of more than 60 Hz.
- Simple design and low cost manufacturing.

The detection RF frequency of 2.856 GHz was determined in 1993. The electrostatic stripline pickup method was selected for the BPM in 1998. Finally, a detection method based on a circuit using a logarithmic detector will be selected soon. The BPM system will be in operation in 2001.

2 BPM

The selected pickup method uses a conventional electrostatic stripline monitor which is modified from the one developed in KEK (Fig. 1). Its aperture cross section is circular, and an electrode of the stripline draws an arc. The radius is 16 mm, so the aperture diameter is ϕ 32 mm. The BPM has four electrodes, and one electrode shares 50 $^\circ$ of a quarter section. To ensure alignment accuracy, all electrodes are machined with an octagonal alignment base as one component. The electrode thickness is 2 mm, which is thick and stable enough for accurate alignment.

Upstream of the stripline, an RF feedthrough is connected

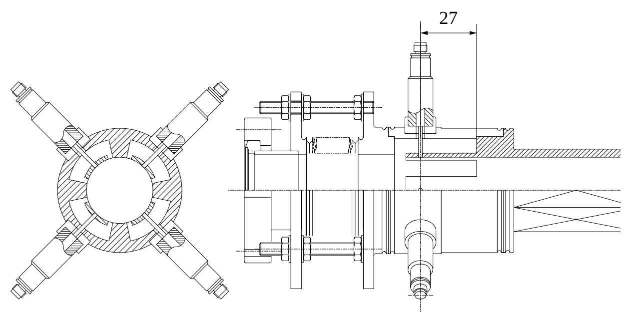

Figure 1: Schematic drawing of the BPM.

to the electrode in order to extract a signal voltage from a vacuum chamber. Downstream of the stripline, the electrode is shorted, i.e., 0 Ω termination. The stripline length is 27 mm. This length is close to one-quarter wavelength of the 2.856 GHz RF. Because there is little coupling with the transverse magnetic field, the higher order RF components that degrade the S/N ratio are eliminated.

A beam induced voltage is generated upstream of the electrode. The power is thus divided into two directions: to the feedthrough and downstream. The downstream power is then completely reflected and goes to the feedthrough. One pulse of the beam therefore generates two pulses of output (Fig. 2). These output pulses look like bipolar pulses whose separation is 180 ps. In the case of a multi-bunch beam, the BPM output looks like a 2.856 GHz sinusoidal wave. Its peak-to-peak voltage becomes 27.8 V/A.

The BPM is fixed as a part of a vacuum chamber which is inserted into a triplet of quadrupole magnets or a doublet of quadrupole magnets as shown in Fig. 3. The octagonal alignment base of the BPM can be closely inserted among the poles. The bore diameter of each quadrupole magnet is 40 mm, and the distance between the surfaces of the octagonal alignment base is 39.9 mm. Therefore, the alignment error is 50 μm for a position shift or 4 $^\circ$ for a rotation if there is no spacer between the pole and the octagonal alignment base.

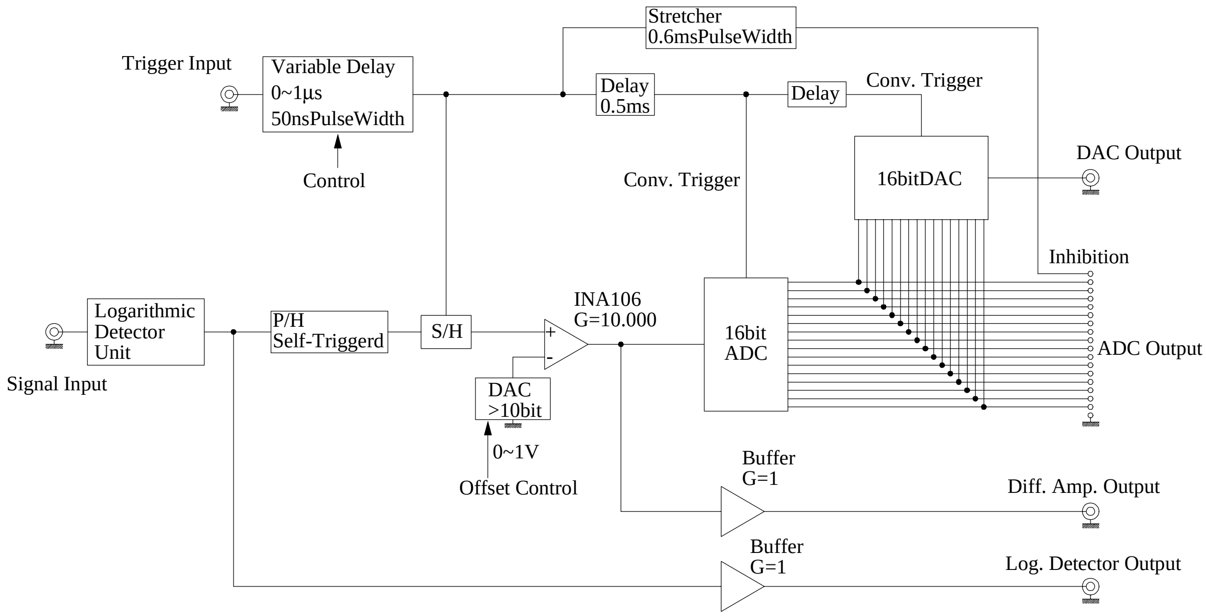

Figure 6: Block diagram of the detector module.

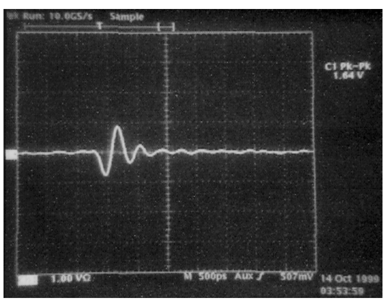

Figure 2: Output of the BPM. This is a waveform of a single bunch beam (500 ps/div., 1 V/div.).

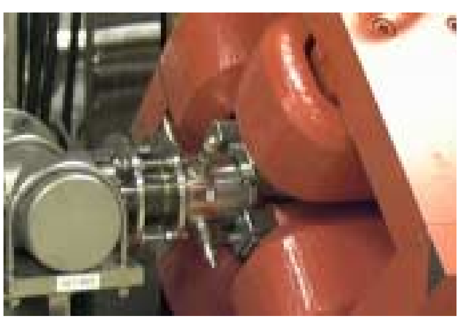

Figure 3: Photograph of the BPM inserted in quadrupole magnets.

3 SIGNAL PROCESSOR

The signal processor consists of two NIMs: the BPF (band pass filter) module, and the detector module (Fig. 4).

The BPF module has four band pass filters and each filter is composed of two cavities. Its center frequency, bandwidth, and flatness are 2.856 GHz, 10 MHz, and

Figure 4: Photograph of the detector module.

0.01 dB @ 600 kHz bandwidth (Fig. 5), respectively. The bandwidth is determined from the risetime ($\sim$40 ns) of the logarithmic detector (AD8313, ANALOG DEVICES) [1]. The flatness around the center frequency is important to minimize the temperature drift. Each BPF is tuned within 10 kHz of the center frequency at 34 $\pm$ 0.1 °C. The temperature of 34 °C is the normal environment temperature of the BPF module.

Figure 6 is a block diagram of the detector module. The principal processes are detection of a pure 2.856 GHz RF signal, a self-triggered peak hold, an externally triggered sample hold, and an analog-to-digital conversion. The signal processor needs an external trigger that is synchronized with the input signal, however we can use the logarithmic

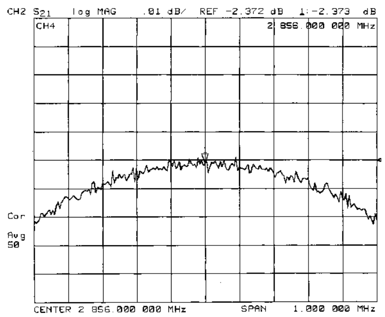

Figure 5: Transmission spectrum of the BPF (100 kHz/div., 0.01 dB/div.).

detector output as a trigger.

Logarithmic detector characteristics, for example, the temperature drift, dynamic range, and so on, differ between devices. Therefore, the logarithmic detector is installed in a case unit as shown in Fig. 7. This enables us to examine the logarithmic detector individually, or to select four logarithmic detectors that have similar characteristics. Figure 8 shows the output of the logarithmic detector unit when continuous wave RF power is input. The slope is tuned to 0.02 V/dBm between -45 dBm and -15 dBm. We can see that the dynamic range of the CH2 unit is narrower than that of the others. If the beam position is calculated [2] using this output directly, the position error due to nonlinearity of the slope will become ∼100 μm (Fig. 9). However, if third-order correction between -45 dBm and -15 dBm is applied, the position error is reduced to less than 10 μm.

The beam position measurement was done by sweeping the excitation current of a steering magnet X (Fig. 10). Position X changes by ∼2 mm, while position Y only changes slightly. If we subtract the linear component from the change in position Y, the standard deviation is obtained as σ = 3.9 μm. This value is considered the resolution under machine operating conditions, and is sufficiently smaller (6σ = 23.4 μm) than the guideline value (6σ = 100 μm).

Figure 7: Photograph of the logarithmic detector unit.

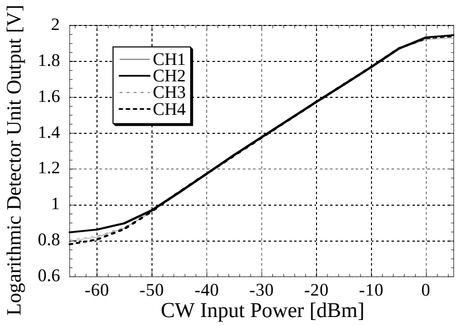

Figure 8: Output characteristic of the logarithmic detector unit.

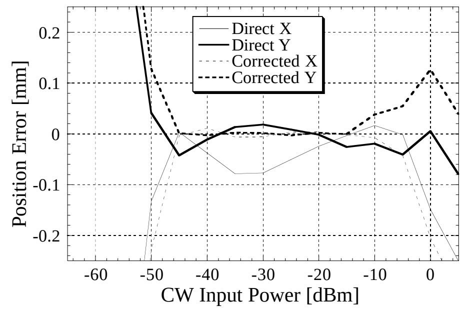

Figure 9: Calculated position error due to nonlinearity of the slope.

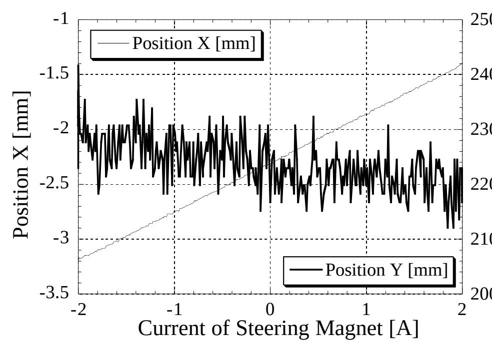

Figure 10: Measured beam position when the excitation current of steering magnet X was swept.

4 DATA ACQUISITION

The signal processor prepares two kinds of signal output for every channel. One is an analog output, and the other is a 16-bit digital output. The range of both outputs is from -10 V to 10 V. For the digital output, an inhibition signal is sent when the ADC is converting. If the computer system (we usually use a VME computer) detects the rise of the inhibition bit and acquires data after a delay of 0.6 ms, the maximum acquisition rate can be increased to 1 kHz.

5 REFERENCES

[1] Data Sheet of AD8313, ANALOG DEVICES.

[2] F. D. Wells et al. ”Log-Ratio Circuit for Beam Position Monitoring”, AIP Conf. Proc. **229**, p. 308 (1991).