Analysis on Beam Position Signals of PEFP 20 MeV Proton Linac

Kyungjean Min *, Jin Seok Hong, Hyeok-Jung Kwon, Yong-Sub Cho
Proton Engineering Frontier Project, Korea Atomic Energy Research Institute
1045 Daedeok Street, Yuseong-gu, Daejeon 305-353, Korea
**Corresponding author: kjmin@kaeri.re.kr*

1. Introduction

Beam Position Monitoring System of 20 MeV Proton Linac at Proton Engineering Frontier Project (PEFP) is composed of capacitive button pick-up and Log-ratio BPM(LR BPM) electronics of Bergoz Instrumentation. Calibration test to obtain sensitivities for conversion output voltage signal of LR BPM into the value of displacement were done prior to the beam position monitoring at the 20 MeV beam injection experiment. Calibration test for pick-up and electronics were done in separated as well as in combined and they were compared each other. We detected beam position signals in voltage unit for each single pulse and then we converted these data in voltage unit into displacement using sensitivities which were derived from above calibrations. These displacement data were analyzed under the consideration of radio frequency interference.

2. Methods and Results

2.1 PEFP Beam Position Monitoring System

Capacitive button pick-up for detecting 20 MeV proton linac beam is installed at the exit of fourth DTL (Drift Tube Linac) Tank. The pick-up is mounted on the 20 mm inner diameter beam pipe in the rotated direction, which means four buttons of the pick-up are rotated in 45 degrees over the beam pipe reference. The pick-up measures the imaginary charge which is induced by the electric field of beam particles [1]. The PEFP is using LR BPM electronics of Bergoz Instrumentation which shows two signals derived from logarithm of the ratio of opposite pick-up signals to obtain horizontal and vertical displacement [2].

2.2 Calibration and Sensitivity

To obtain reliable sensitivities, our calibration was performed in two ways. One way is getting each of sensitivities for pick-up and LR BPM electronics. The other is getting sensitivities by comparing output voltage signal of the LR BPM electronics with the displacement we move in the test bench which pick-up is connected with the LR BPM electronics.

The intrinsic sensitivity of capacitive button pick-up depends on its dimension. The formula to determine pick-up intrinsic sensitivity is given by

$$S = \frac{160}{Ln10}\frac{\sin(\frac{\phi}{2})}{\phi}\frac{1}{b} + \textit{higher order term} \quad (1)$$

where b is beam pipe radius and ϕ is angular width. This formula is given in the [3]. Angular width is the ratio of diameter of electrodes width to pick-up aperture radius. The parameters of the PEFP pick-up dimension are as follows.

Table I: PEFP Button Pick-up Dimension

radius of pick-up aperture	10mm
diameter of electrodes width	12mm
electrodes angular width	1.2 rad
beam pipe radius	10mm

From these parameters, pick-up sensitivity is obtained as 3.27 dB/mm.

LR-BPM electronics sensitivities were calibrated by comparing output voltage signals with powers which were controlled by attenuator [4]. The sensitivity of the LR BPM electronics we used in the beam experiment is 58mV/dB. When we multiply LR BPM electronics sensitivity by pick-up intrinsic sensitivity, we can get sensitivities which correspond to the one which pick-up is connected with the LR BPM electronics as 188mV/mm.

The sensitivities for the calibration when which pick-up is connected with the LR BPM electronics is presented in Fig.1 and Fig.2

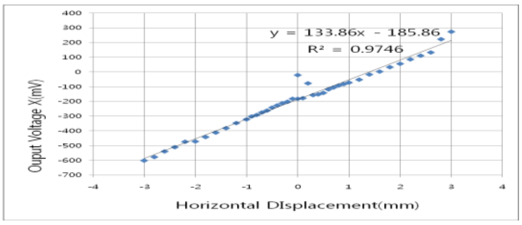

Fig. 1. Sensitivities of LR-BPM Electronics for horizontal direction.

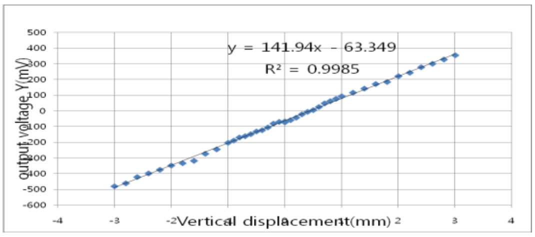

Fig. 2. Sensitivities of LR-BPM Electronics for vertical direction.

2.3 Beam Position Monitoring at the 20 MeV Linac Beam Injection Experiment

We measured beam position data for 50 ㎲ single pulse beam at the 20 MeV beam injection experiment. Among these data, we analyzed 22 cases of single pulse based on the sensitivities derived from above calculation.

As we can see in Fig. 3, Beam Position Monitor detects the beam position displacement for 50 ㎲ single pulse beam as well as RF signal position displacement. RF signals which were detected by BPM is divided into two kinds; one is 200 ㎲ RF of DTL and 50 ㎲ RF of RFQ (Radio Frequency Quadrupole). Since we are using log ratio technique [5], RF signal is also detected in the beam position monitor, no matter how its power is very small.

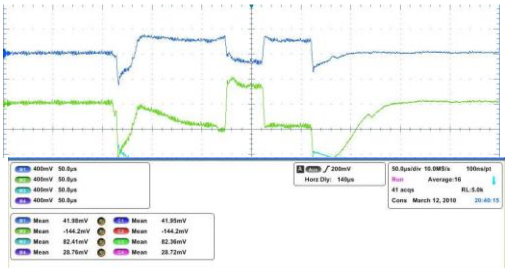

Fig. 3. Output beam position signal waveform
Ch1: horizontal position measured at the BPM PU close to the DTL
Ch2: vertical position measured at the BPM PU close to the DTL

To remove the RF signal interference, we subtract amplitude of RF position signal from amplitude of the beam position signal. Beam position offset distribution for 22 cases of single pulse beam are given in the Fir. 4 and Fig.5.

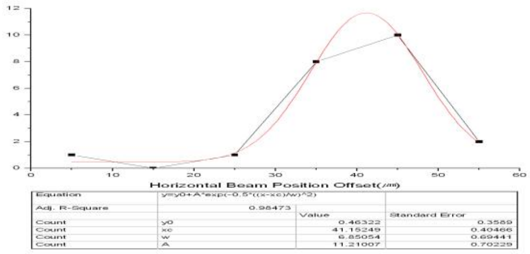

Fig. 4. The distribution of horizontal beam position displacement from beam pipe center.

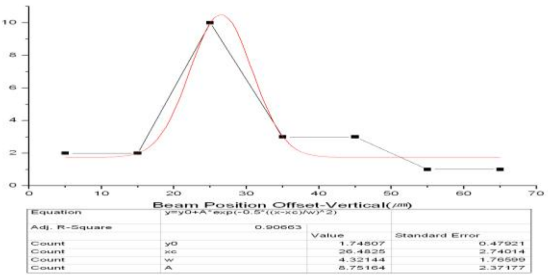

Fig. 5. The distribution of vertical beam displacement from beam pipe center.

3. Conclusions

We measured beam position of the PEFP 20 MeV proton linac beam. The results which were measured in voltage unit are converted into length unit using sensitivities which is obtained in the above calibrations. We used log-ratio technique to analyze the measured data, RF Interference gives dominant effects on determination beam position offset. Therefore, we compensate RF effects by subtracting RF position signal amplitude from the beam position signal amplitude.

Acknowledgement

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