DESIGN OF A BEAM POSITION MONITOR FOR THE BEAM TRANSPORT LINES BETWEEN THE TRISTAN AR AND THE MR

T.Ieiri, M.Arinaga, H.Ishii, K.Mori and M.Tejima
KEK, National Laboratory for High Energy Physics
Oho 1-1, Tsukuba-shi, Ibaraki-ken, 305 Japan

Abstract

This note describes design of a beam position monitor for the beam transport lines using a stripline electrode and a narrow-band signal processing. A prototype of a stripline chamber and a 70 MHz synchronous detector have been made and a part of their performances is also reported.

Introduction

The TRISTAN Main Ring (MR) requires higher luminosity. A more efficient injection to the MR is one of methods to increase the luminosity. A beam position monitor is necessary to guide a beam in the beam transport line from the Accumulation Ring (AR) to the MR. Screen monitors have been already installed to observe a beam profile and a beam position. These monitors are destructive, so that it takes much time to investigate a beam position of the whole line. A nondestructive position monitor is required.

The Beam Transport Lines[1] and the Beam

The transport lines carry a beam of 8 Gev energy from the AR to the MR. They have two lines, one for an electron beam and the other for a positron. Each line is about 170 m long. Since the AR is not a synchrotron but a storage ring, an extraction period of a beam from the AR is over one minute. The beam is one bunch with an rms bunch length of about 2cm or 66 ps. The number of particles are an order of 10^{10} to 10^{11}. The frequency spectrum of the bunch is continuous. Its amplitude is constant in a frequency region of $\omega\sigma_t \ll 1$, where ω is angular frequency and σ_t is a bunch length.

Design of a Beam Position Monitor

Design Principles

1)We have to measure charge amount of one shot pulse. A self-triggering from a beam pulse is useful to define a timing for the detection because a repetition rate of the pulse is not defined.

2)Pulsed kicker magnets of the AR and the MR are fired during the measurement. They create a bad noise environment. In order to avoid the noise, a narrow-band system is better than a wide-band system which detects a peak of a pulse.

3)No active components is installed in the tunnel for easy maintenance.

4)Required specifications for the position measurement are:

Accuracy	0.5 mm
Resolution	0.1 mm
Dynamic Range	30 dB
Beam Charge	1.28 - 32.0 nC.

Selection of Detected Frequency

A homodyne receiver is adopted, which directly rectifies an RF signal without frequency conversion. Since the noise spectrum of the kicker exists up to 30 MHz, detected frequency should be above 30 MHz. When the frequency is greater than 100 MHz, however, it is technically difficult to detect. On the other hand, sensitivity of a pick-up electrode such as a stripline is proportionally increased to frequency. However, a cable loss is also increased as frequency goes up. Therefore, the detected frequency is chosen to be 70 MHz.

A Stripline Electrode

There are two candidates for a pick-up electrode. One is a button and the other is a stripline. Since the transfer impedance or pick-up sensitivity is proportional to a surface area seen by a beam in a region that a detected wavelength is long enough[2], a stripline is more sensitive than a button. Therefore, a stripline electrode is adopted.

A stripline chamber is composed of four electrodes as shown in Fig.1. Each electrode is mounted at the position skewed by 45 deg. to the horizontal vertical planes. The stripline is 228 mm long and its end port is shorted. An angle seen by a beam is 45 deg. A feed-through of SMA type is used. The position sensitivity for the configuration is 17.05 mm. Assuming that a random error of 1% occurs at each electrode, a position error becomes 0.3 mm. It is hard to adjust an impedance of four electrodes within 1%. A bench calibration of the chamber is needed.

A TDR (Time Domain Reflectrometer) measurement is done to check the impedance of the stripline. A result is shown in Fig.2. A large reflection of about -0.2 occurs at a feed-through. This large reflection, however, will not be trouble in a region of 70 MHz. The detected frequency of 70 MHz is not the highest sensitivity but -10 dB lower than the top. The transfer impedance is 2.05 Ω at 70 MHz.

Coaxial Cable

Coaxial cables of MF-8D (Showa Co.,LTD.) are laid from a tunnel to the AR West Hall. A beam pulse directly come to the Hall. The cables are about 80 m to 200 m long. A measured attenuation for each cable at 70 MHz is 2.4 to 6.2 dB. A maximum deviation error among a pair of four cables is 0.3 dB or 3.5%, which has to be compensated.

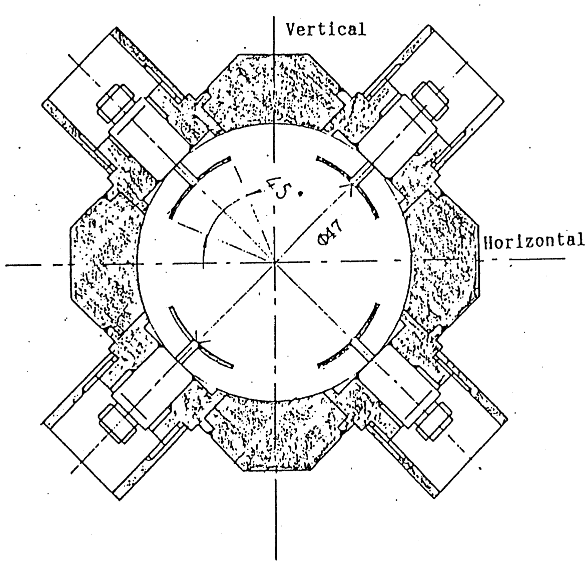

Figure1 Cross section view of a stripline test chamber

Detector Electronics

A prototype of a 70 MHz synchronous detector has been made. A block diagram of one channel is shown in Fig.3. When a pulse passes though a Band Pass Filter (BPF), it is converted to a ringing waveform of 70 MHz as seen in Fig.4 using a test pulse of 24.5 pC. The duration of the ringing is 140 ns determined by 10 MHz bandwidth of the BPF. The ringing waveform is rectified by a mixer. An area of the rectified pulse is proportional to charge amount of an input pulse. An ADC samples a charge of the rectified pulse with a gated pulse generated by a beam pulse itself. A calibration signal is also applied to the detector to compensate a gain difference of each channel. An AM/PM method[3] is also considered as an alternative method.

Summary

The beam position monitor in the beam transport lines is in progress. The monitor uses a narrow-band method to avoid an external noise. A beam test will be done early in the next year.

Acknowledgements

The authors would like to thank Dr. K.Satoh for promoting this project and Profs. S.Takeda and H.Nakayama for continuous encouragement.

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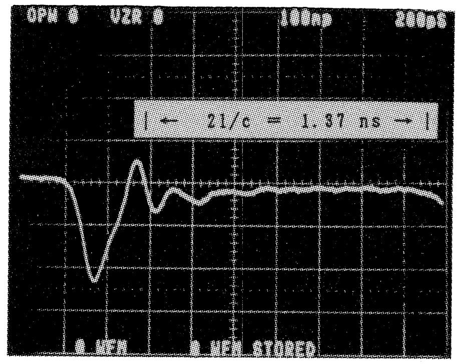

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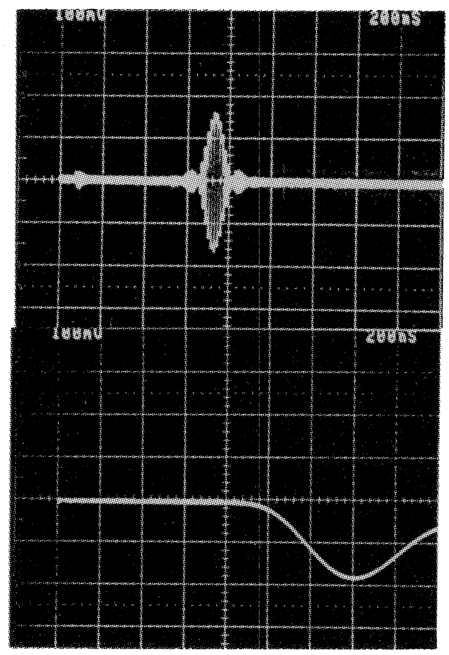
Figure 2 A TDR measurement of a stripline electrode. Scales are 200 ps/div and 0.1 ρ/div. Reference line is 50 Ω.



a)

b)

Figure 4 A typical waveform of detector using a test pulse of 24.5 pC. Scales are 200 ns/div and 100 mV/div. Scope is triggered by a trigger pulse for a pulse generator. a) Ringing b) Rectified

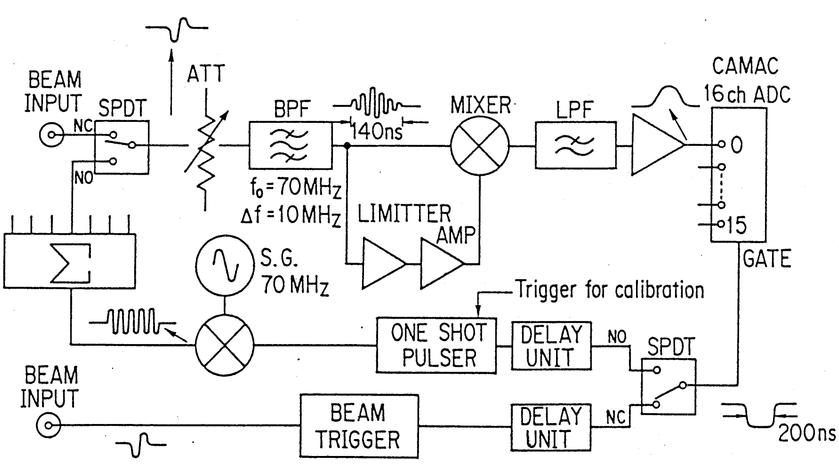


Figure 3 Detector electronics of beam position monitor.