

# Development of Bunch Feedback Systems for KEKB

E. Kikutani, T. Kasuga, Y. Minagawa, T. Obina, M. Tobiya  
National Laboratory for High Energy Physics, Japan  
L. Ma

Institute of High Energy Physics, Academia Sinica, Beijing, China

## Abstract

Recently, a new accelerator project at National Laboratory for High Energy physics, KEKB, has been approved. The KEKB machines consists of two storage rings in which an enormous number of bunches will be stored. Then coupled bunch instabilities will be one of the difficulties to overcome. We have already started to develop bunch feedback systems to cure these instabilities. Here we describe the concepts of the design together with the results of R&D works on the pickup system and front-end electronics.

## 1 INTRODUCTION

At National Laboratory for High Energy Physics (KEK, Japan), construction of a double ring collider, KEKB, for the B-physics, has started. The accelerator complex consists of a 3.5 GeV storage ring for positron, an 8 GeV storage ring for electron and a linear accelerator as an injector. The two storage rings will be housed in the existing TRISTAN Main Ring tunnel, whose circumference is about 3 km.

In order to accomplish an extremely high luminosity,  $10^{33} \sim 10^{34} \text{cm}^{-2}\text{s}^{-1}$ , thousands of bunches will be stored in each storage ring and bunch spacing will be only 2 ns at the final step of this project. Even though the bunch current of each ring is rather low (0.5 mA or smaller), the number of bunches is so large. The total current amounts to of the order of Amperes. Thus it is very likely that strong coupled bunch instabilities occur.

The main source of the impedance which causes the instabilities is an accelerating cavity. In order to avoid a disastrous situation, we are making efforts to design special cavities to make impedance of higher order modes very low. But even with these new cavities, impedances of some dangerous modes may remain high. Thus bunch feedback systems will be necessary to cure the instabilities.

## 2 CONCEPTS OF DESIGN

Main features of the feedback system are described below.

### Time domain or frequency domain?

There are three possible sources of the impedance which gives rise to the coupled bunch instabilities:

1. Higher order modes of accelerating cavities (transverse and longitudinal)

2. The fundamental mode of accelerating cavities (longitudinal)
3. Resistive wall impedance due to the beampipe (transverse)

We will utilize the *bunch by bunch* (time domain) feedback scheme for the first item and the *mode* (frequency domain) feedback scheme for the second<sup>1</sup> and third items. Because the bunch by bunch scheme will be relatively complicated, our study is mainly on this scheme.

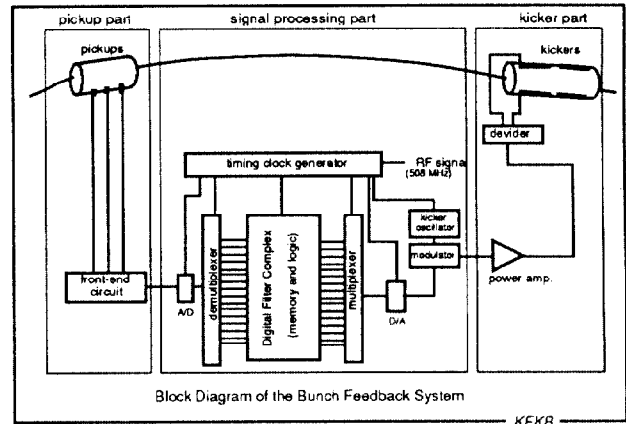


Figure 1: A block diagram of the feedback system.

### Digital signal processing

The functions of the signal processing part are (1) 90 degree phase shift which is necessary for the feedback, (2) noise filtering, (3) DC-suppress. It is, of course, possible to regard the third function as one part of the second function.

In our case, the data processing part is realized with digital systems for both the longitudinal and the transverse directions. The reason of this choice is easy adjustment of many parameters and relatively easy maintenance. In particular, the 90-degree phase shift is almost impossible with analog systems in our case.

<sup>1</sup>The instability due to the fundamental mode of the cavity is so strong if usual normal-conducting cavities are used in a ring with a large circumference. RF people at KEK are now developing a special cavity which has very low-Q. Our feedback system will be used if the instability is not sufficiently degraded by this cavity.

Main part of the signal processing part is the digital filter complex (digital-filter logic and memories) with a very high-speed de-multiplexer, which degrades the signal rate from an original one to its 1/16, and a multiplexer. The de-multiplexer, the multiplexer and the digital filter complex will be realized as custom IC's.

### Traveling wave kickers

As we explained previously, the bunch spacing of KEKB will be 2 ns at the final stage. Then the bandwidth required to the feedback system is 250 MHz, a half of the bunch frequency. If we use a resonator-type kicker, it can not be so wide-band. Instead, we use a non-resonator type, a traveling-wave kicker. The price of choosing the traveling-wave kicker is its low shunt impedance. We must prepare high power amplifiers for the system.

Considering these things the feedback system should be a system whose block diagram is shown in Fig. 1.

## 3 R&D WORKS

The feedback system is made up with 3 parts, a pickup part, a signal processing part and a kicker part as shown in Fig. 1. Our R&D studies were done mainly on the pickup part up to present.

### 3.1 Principles of oscillation detection

The pickup part consists of several pickup electrodes and a front-end circuit behind them. For both the longitudinal and the transverse directions, the input of the front-end circuit is a train of bipolar pulses from the electrodes. The pulse train is made by combining pulses from a series of the pickups with a power combiner. When the pulses from the electrodes are combined, timings of the pulses are displaced by one period of the detection frequency in order to simulate a small cut-piece from continuous sinusoidal wave by this pulse train. If the lengths of the cables are chosen as explained here, the combiner-cable system makes a low-Q band pass filter.

#### Longitudinal

A block diagram of the front-end circuit for the longitudinal position detection is given in Fig. 2. The phase difference between the pulse train from the pickup and the reference sinusoidal signal is detected by a double balanced mixer and a low-pass filter. The detection frequency is 1.5 GHz which is 3 times of the rf frequency.

#### Transverse

The front-end circuit for the transverse case uses the so-called AM/PM technique[1]. Band-pass filters, which are usually positioned at the entrance of an AM/PM circuit, must be very low-Q, because the length of the ringing generated by the filter must be shorter comparing with the bunch spacing. Thus we use the cable-combiner filter explained above.

A block diagram of the circuit is given in Fig. 3. The detection frequency is again 1.5 GHz. This frequency is

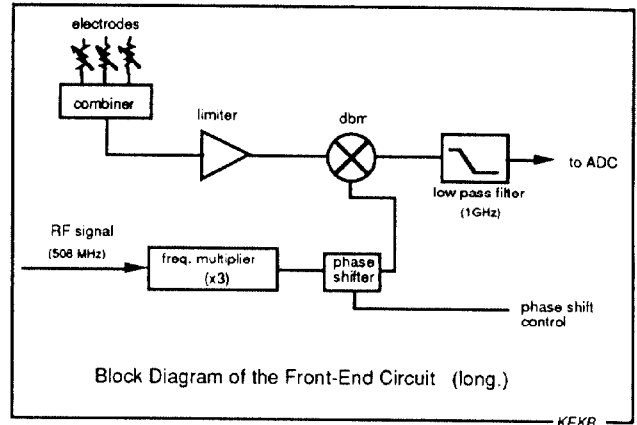


Figure 2: Front-end circuit for the longitudinal position detection.

amazingly high comparing with that of usual AM/PM circuits. But considering the very high bunch frequency, we can not use lower frequencies.

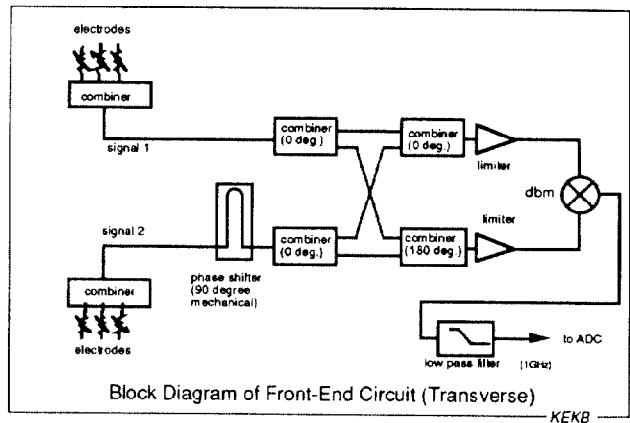


Figure 3: The front-end circuit for the transverse position detection.

There may be other schemes of the front-end circuit for the transverse case, for example, usual  $\Delta/\Sigma$  method, which is realized by a 180 degree power combiner and a limiting amplifier. We tried several methods. Among them the AM/PM technique was the best considering the voltage change as function of the position change.

### 3.2 Beam study

#### Signal from the electrodes

In order to check the function of these front-end circuits, we made experiments with the beams stored in TRISTAN Main Ring and Photon Factory Ring at KEK. The first check point is if we can make a clear pulse train for the front-end circuit. In our experiment, trains of striplines

were used<sup>2</sup>. The length of the stripline is 7.5 cm which is a quarter of the wavelength of the detection frequency, 1.5 GHz.

A picture in Fig. 4 shows an example of the pulse train just after the combiner. We can recognize a four-period pulse train. The small oscillation behind it has a much smaller amplitude than the main signal. Note that the pulse train lasts only 3.5 ns. This means that we can detect the oscillations of bunches individually by this technique if they are separated by at least 4 ns.

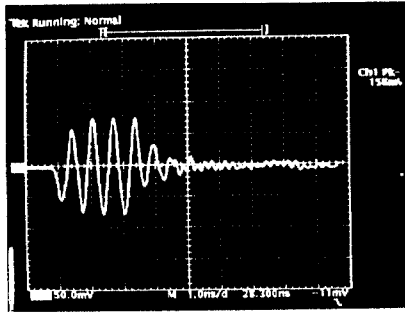


Figure 4: An oscilloscope photo of the output of the combiner. Four pulses are combined.

#### Acquired data (longitudinal)

We actually recorded the oscillation of a bunch stored in the rings. The experiment was performed in TRISTAN Main Ring for the longitudinal detection. Data taking was done with a 500 Msamples/s flash ADC (8-bit) which is packaged in a CAMAC module together with memories. The trigger for the AD-conversion was the ring-revolution clock, whose frequency is about 100 kHz (TRISTAN) because the number of stored bunch in the ring was only 1. The synchrotron oscillation was artificially excited by shaking the phase of one of accelerating units with the synchrotron frequency.

Figure 5 shows the fast Fourier transform of the recorded data. In this measurement the bunch current is about 0.4mA and oscillation amplitude is about 17 ps in rms.

We can clearly recognize a peak corresponding to the longitudinal tune of TRISTAN Main Ring, 0.11, and the S/N ratio is about 40dB. This figure is very important when we consider the function of the signal processing part. As explained previously, one of the functions of the signal processing part is noise filtering. But looking at this data, this function is less important because the noise is very low comparing with the oscillation signal.

#### Acquired data (transverse)

The experiment of the transverse oscillation detection was done in PF Ring. The data-taking system was the same with that in the longitudinal detection. The transverse oscillation was excited by kicking a bunch with a kicker electrode. Naturally, the frequency of the kicking signal

<sup>2</sup>This does not necessarily mean that we decided to use striplines as pickup electrodes in our system. We also studies the possibilities of using button electrodes.

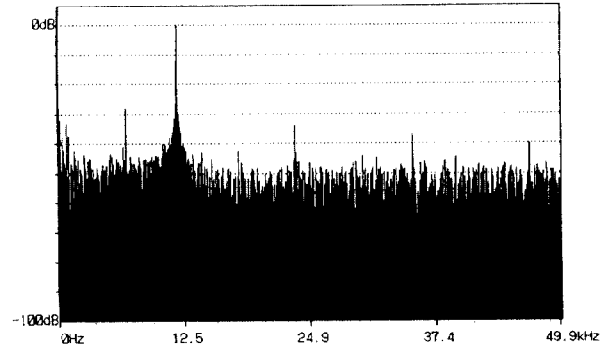


Figure 5: Frequency spectrum of recorded longitudinal oscillation.

is the betatron frequency. The oscillation amplitude was about  $100\mu\text{m}$ .

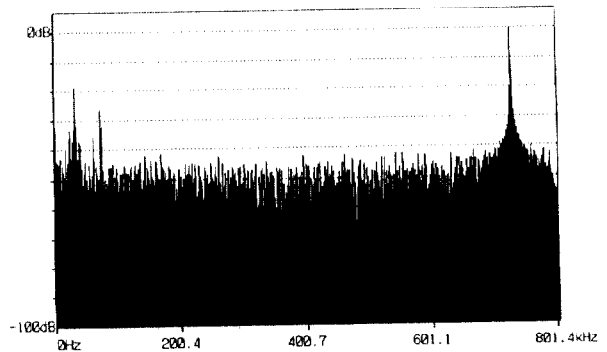


Figure 6: Frequency spectrum of recorded transverse oscillation.

Through these experiments, both in the longitudinal and the transverse directions, we obtain the results that our oscillation detection system can catch the beam oscillation up to the 250 MHz, namely, the bunch spacing of 4 ns. As we described previously, the bunch spacing will be 2 ns in the final step of KEKB. We must refine this system to be able to deal with a signal under a higher bunch-frequency environment.

## 4 SUMMARY

In order to cure coupled bunch instabilities which are very likely to occur in KEKB, we have made a conceptual design of the feedback systems. Also R&D works has started mainly on the pickup part. Through the study we have developed a technique to detecting a position of a bunch individually up to the bunch frequency of 250 MHz.

## REFERENCES

- [1] The AM/PM technique is explained, for example, in a paper by R.E. Shafer, Beam Position Monitoring, AIP Conference Proceedings 212.