Improvement of BPM Signal Processing Electronics Circuits for COD Measurement

Shigeki SASAKI[1], Mitsuhiro MASAKI[1], Masazumi SHOJI[1], Shiro TAKANO[1] and Kazuhiro TAMURA[2]

1) SPring-8/JASRI, 2) SPring-8/RIKEN

1. Introduction

During the commissioning period and period thereafter, the repeatability of the COD measurements was investigated, and found to be several-μm rms value [1]. The definition of the repeatability here is the rms value of the differences of two successive COD measurements. Since the interval of two successive COD measurement is 30 s, the repeatability defined above includes the rms resolution of the signal processing electronics and the small change of COD itself during the 30-s period.

Although the repeatability was smaller than 10 μm, current and filling pattern dependence were found to be larger than a hundred μm. Because of these large dependence, the tuning and adjustment of COD was forced to be done under the restricted condition, that stored beam current is 1 mA and the all the 2,436 buckets were filled with electron bunches; which is called "1-mA full-fill".

After inserting some elements in the signal processing electronics to resolve these phenomena, the current and filling dependence were reduced to less than the repeatability for any filling patterns and stored beam current.

The signal processing electronics are described first, followed by the description of the current and filling dependence with the applied solutions.

2. Signal Processing Electronics

The signal processing electronics circuits have two modes of operation, COD mode and single pass (SP) mode. The COD mode is used for COD measurements, whereas the SP mode is used for measuring turn by turn position of beams. These two modes are switched in front end (FE) modules, and are processed in the separate modules. The SP mode will not be described further in this report.

A schematic block diagram concerning to the COD mode is shown in Fig.1. The electronics are composed of FE modules and back end (BE) modules. In the FE modules the following components are installed; lowpass filters (LPF) with the cutoff frequency of 800 MHz, bandpass filters (BPF) of the center frequency of 508.58 MHz and the 3-dB bandwidth of 15 MHz, RF (Radio Frequency) switches (RF-SW) to switch between SP and COD mode, and to select one of the four electrodes for the COD mode. The output signals of the FE modules are fed into COD-BE modules.

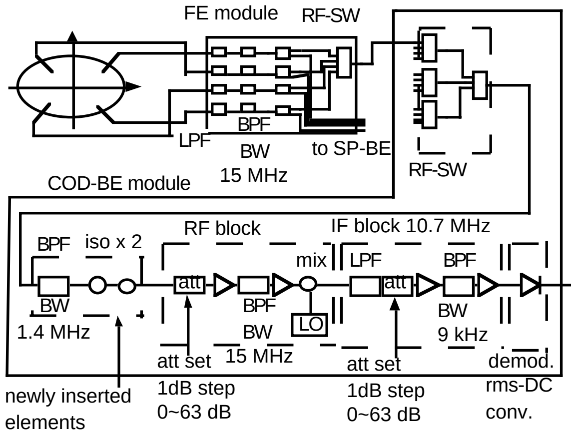

Fig. 1. Schematic diagram of BPM signal processing electronics circuits, COD mode.

The electronics in the COD-BE modules are a kind of super heterodyne demodulators with one step frequency down conversion, which consist of an RF low noise amplifier, frequency down converter, IF(Intermediate Frequency) amplifier and demodulator at IF frequency. We chose the carrier frequency of the RF block as 508.58 MHz, the same frequency as RF acceleration frequency of the storage ring, and the frequency of IF block as 10.7 MHz.

One COD-BE module covers 12 BPM sets, therefore, 12 FE modules are connected to one COD-BE module. The signal fed in the COD-BE module passes RF-SW first for selecting one of 12 FE. Then it is put into the RF low noise amplifier after passing a step attenuator (att) where the attenuation can be modified from 0 dB to 63 dB with 1 dB step. The output signal of the RF amplifier was fed into a mixer (mix) that works as a frequency down converter. The downconverted signal passes a step attenuator (att) of 1-dB step and attenuation range up to 63 dB, an IF amplifier, a bandpass filter of 9-kHz bandwidth and an IF amplifier again. Then the IF signal is demodulated with an rms-DC converter.

The modification applied to the circuit is indicated by newly inserted elements in Fig. 1. The inserted elements are a BPF with center frequency of 508.58 MHz and the 3-dB bandwidth of 1.4 MHz, two 20-dB isolation isolators with total isolation of more than 40 dB.

3. Current Dependence

The current dependence was a phenomenon such that the measured position changed when the RF-block step attenuator setting was changed according to the change of the stored beam current. An example is shown in Fig. 2. The cause of this phenomenon is the change of the standing wave ratio (SWR) between the pickup electrode and the entrance of the step attenuator through signal transmission coaxial cables.

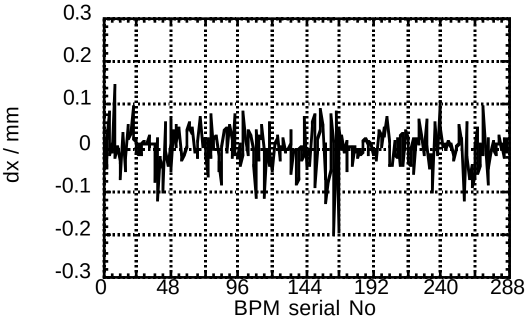

Fig. 2. Difference of the measured position data between "1 mA full-fill" (reference) and 19 mA full-fill condition. Horizontal axis is the BPM serial No along the storage ring. Vertical axis is the difference of BPM position data between two beam conditions.

A hundred-μm change of the measured position corresponded to the SWR value change of 0.01. The reflection condition change at the entrance of the attenuator caused this SWR change.

By inserting isolators upstream of the attenuator, the change of the reflection condition could not be transmitted back over the isolators, and the SWR between the pickup and the entrance of the isolators remain constant regardless of any change of attenuator settings. The isolation was designed to be more than 40 dB. To achieve this requirement, two isolators were inserted in series, each had more than 20-dB isolation. With this solution, the change of SWR value was expected to be less than 0.0001, corresponding to the change of measured position value of less than 1 μm.

4. Filling Dependence

The filling dependence was a phenomenon such that the measured position differed for different kind of bunch filling pattern of the stored beam, even for the same value of the stored beam current. An example is shown in Fig. 3. The cause of this was a saturation of electronics components before the 9-kHz IF-BPF; most plausible element was the mixer where the signal amplitude could be the largest.

The bandwidth of RF-BPF was too large compared with the revolution frequency of the storage ring, which was 209 kHz. The number of revolution frequency sidebands within the RF-BPF bandwidth could change from the unity to as many as 70 (=15 MHz / 209 kHz) depending on the filling pattern. On the contrary, the only spectral line which could pass the IF-BPF was the carrier.

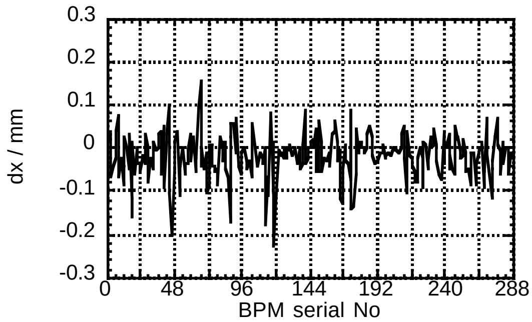

Fig. 3. Difference of the measured position data between 1 mA full-fill (reference) and 1 mA 1-μs bunch train filling condition. Horizontal axis is the BPM serial No along the storage ring. Vertical axis is the difference of BPM position data between two beam conditions.

The signal intensity of the carrier compontent remained constant for the same value of the stored beam current, independent of any filling patterns. The signal intensity which passed the IF-BPF should be constant for the same value of the stored beam current regardless of the filling patterns. However, the linearity of one or more components of RF block could not be sufficient for the variation of the signal intensity caused by the change of the filling pattern, because of the RF-BPF bandwidth.

The solution to avoid the saturation was to narrow the bandwidth of RF-BPF. If the bandwidth could be made less than 209 kHz, the possibility of the saturation could be totally excluded. However, the bandwidth of less than 1.4 MHz was chosen from the point of view of the technological reason and the saturation margin.

5. Effect of the Modification of the Electronics Circuits

Two kinds of components were inserted, a narrow band RF-BPF and isolators for the solution to the current and filling dependence. An example of measured position data difference at the different condition of the storage ring operation is shown in Fig. 4. for the improved electronics. For this example, both filling pattern and stored beam current were different from the 1-mA full-fill reference condidition. The differences of the measured value are almost within ±10 μm; the rms-value of several μm is expected for this plot.

After applying the modifications described above to the electronics, any clear current and filling dependence was not observed. The repeatability of COD measurements was unchanged.

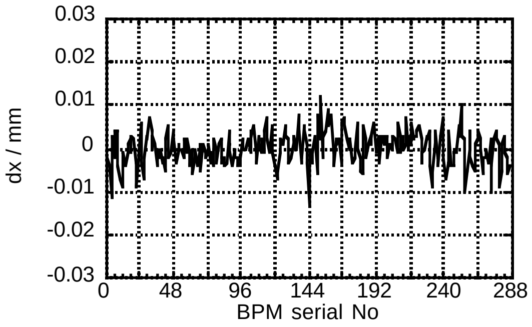

Fig. 4. Difference of the measured position data between 1 mA full-fill (reference) and "each of 12 equally spaced bucket addresses was filled one single bunch and one of them was followed by 47 trailing bunches, with total stored beam current of 70 mA", after modification of the electronics. Horizontal axis is the BPM serial No along the storage ring. Vertical axis is the difference of BPM position data between two beam conditions.

References

[1] K. Soutome and H. Tanaka, private communication.