A new digital beam position monitor in SSRF

CHENG Wei-Xing, LIU De-Kang
(Shanghai Institute of Nuclear Research, the Chinese Academy of Sciences, Shanghai 201800)

Abstract The newly developed Digital Beam Position Monitor (DBPM) system is introduced. The DBPM system differs with the conventional beam position monitor system in the use of DSP chips and the digital signal processing technology. It can be programmed on-line to select operation modes through EPICS control panel, and to measure various parameters of the third generation synchrotron radiation facility. This DBPM system can be used in the pre-injector LINAC, the transfer lines, the booster synchrotron and the storage ring. The electronic parameters of the DBPM system itself have been measured also.

Keywords DBPM, DSP, VME64x
CLC number TL544

1 Introduction

Third generation synchrotron radiation source provides a wide range of photon energy from vacuum ultraviolet to soft X-rays and supplies high brilliance. It also provides flexibility to accommodate a variety of operation modes. Therefore, a beam position monitor system has to ensure the adequate beam quality. The DBPM system introduced here can work in different modes, hence it can be used throughout the accelerator complex.

The proposed SSRF facility is a third generation complex. It has a 300 MeV LINAC, injecting to the booster where the electron accelerated to 3.5 GeV. The storage ring has a beam life time of more than 8 hours, which can produce VUV to X-ray synchrotron radiation. The machine's main parameters are listed in Table 1.

It's necessary to reduce the beam jitter to less than $\sigma/10$ of the vertical beam size in the ID sections of the storage ring, so the beam position should be measured at a period of sub-micron, which have to be provided at a few kHz bandwidth, in order to successfully operate a fast (global) orbit feedback. It's also very important to measure the beam orbit in turn-by-turn (TBT) mode; in this mode, many machine studies can be made. Therefore, the BPM electronics has to deliver position data with more than 0.5 MHz bandwidth. It's easy to change among different operation modes while DSP technology is used; the DBPM system introduced here can support the following operation modes:

Received date: 2002-09-16

Table 1 SSRF main parameters related to beam diagnostic[1]

Electron energy	3.5 GeV
Circumference of storage ring	396 m
Beam current:	
Multi-bunch mode	200-300 mA
Single bunch mode	5 mA
RF frequency	499.654 MHz
Harmonic number (storage ring)	660
Revolution frequency (storage ring)	0.757 MHz
Harmonic number (booster)	264
Revolution frequency (booster)	1.89 MHz
Injection period	1 Hz

(1) Pulsed Mode

Intended for injector and transfer line beam position monitor. The injection period of SSRF is 1 Hz; then in this mode, beam position will be sampled every 1 second.

(2) Booster Mode

Every BPM around the synchrotron will provide the position measurement. First, at a single BPM, the beam position at a fixed position is displayed in time domain. Second, the booster close orbit can be displayed at a selectable intervals.

(3) Turn-by-Turn Mode

One orbit position will be recorded per cycle.

(4) Closed Orbit Mode

Position measurements are taken continuously. Data is used for closed orbit display in the control room.

(5) Feedback Mode

Whole ring position measurements are taken in the same way as in closed orbit and processed continuously to provide position information to global feedback.

(6) Tune Mode

Data are taken in the same way as in turn-by-turn mode. However, software algorithm on DSP will calculate FFT and extract tune message of the machine.

2 DBPM electronics

The DBPM electronics is a four-channel system, which delivers high speed/medium precision and low to medium speed/high precision measurements. It mainly consists of three modules: a RF front end module, a digital receiver module and a digital signal processor (DSP) module. As is illustrated in Fig.1.

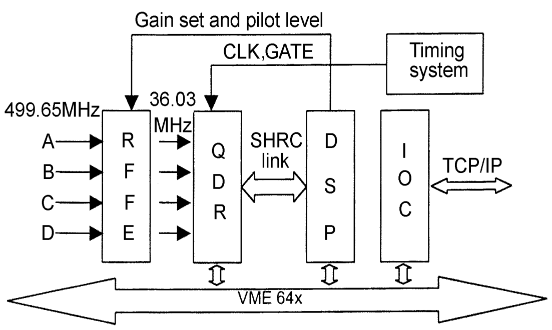

Fig.1 Block diagram of DBPM system.

2.1 RF front end[2]

There are four channels in each RF Front End module, connected with a four button BPM detector. The four channels tune to 499.654 MHz, which is the first harmonic of machine RF frequency. The four RF signals get mixed to an intermediate frequency of 36.029 MHz, and the bandwidth of RF front end module is 5 MHz. There are five 16 bit DACs in the module, four of them are used to set the four channels gain separately, while the fifth one was used to set the gain of pilot signal, which is produced internally. The pilot signal has the frequency of 498MHz and get mixed to 34.375 MHz. It facilitates on-line calibration and minimizes beam current dependence of the system.

2.2 Digital receiver[3]

The band limited IF signals are sent into QDR (Quad-Digital Receiver), where get sampled with a 12-bit ADC AD9042. AD9042 has a maximum sampling rate of 41 MHz. In our case A/D conversion is performed at 24.9 MHz for the storage ring BPMs and 15.14 MHz for the booster BPMs. The under-sampling technique is applied, which aliases the 36.029 MHz band limited IF signals from the third Nyquist zone down to 11.05 MHz for the storage ring BPMs, and IF signal from the fifth Nyquist zone down to 5.75 MHz for the booster BPMs. The coming processing of sampled signal includes translation of the signals to baseband as well as digital filtering and decimation of the data streams. These processings are all in a digital way. HSP50214B DDC (Digital Down-Converter) chips from Intersil Corp. is selected to do the processing. HSP50214B translates the digitized carrier and pilot IF signal to base band and then applies filtering and decimation. The process of filtering and decimation is very important: filtering defines system bandwidth, which in turn affects the measurement resolution; while decimation reduces the output data rate with respect to the input, thus easing the downstream digital signal processing requirement a lot. Each processing channel of QDR is equipped with an 8K FIFO. The data from DDC are stored in the FIFO. When the FIFO is full, the data will be sent to DSP card through SHARC Link port.

2.3 Digital signal processor

WS2126 DSP board from Wiese Corp. is selected, which have two SHARC DSPs (ADSP21062) from Analog Devices. The decimated and filtered data streams from the QDR sent to DSP, where the correction factors and beam position are calculated. Moreover, DSP program can do gain calibration and FFT (Fast Fourier Transformation). In feedback mode, the DSP module calculates the orbit corrections and performs the communication to the adjacent sectors of the storage ring.

2.4 IOC

The DBPM system is fully integrated in the EPICS (Experiment Physics and Industrial Control System[4]) control system, so IOC (Input-Output Controller) is used to communicate with the upper layer GUI (Graphic User Interface) and DSP driver. Real time database is running on IOC which communicates with required channels; these channels can be displayed and controlled in the console. Including the selection of operation modes, display of beam position and tune measurement in the control room, the archived orbit data can be stored with ChannelArchiver[4] for further analysis.

3 System specification

The system is well working and we do the measurements of system bandwidth, RF front end module linearity and long-term stability, which are very important for the BPM electronics. Agilent E4400B RF signal generator is used to simulate the four button signal from BPM detector, and IF output signal is measured with HP4396B Spectrum/Network/Impendence Analyzer.

3.1 Bandwidth

As illustrated in Fig.2(a), the RF front end module tuned to 499.654 MHz has the bandwidth of about 5 MHz (497.5-502.5 MHz), while Fig.2(b) shows the system bandwidth for turn-by-turn mode. The curves were measured by reading the IF signal amplitude while changing the RF frequency.

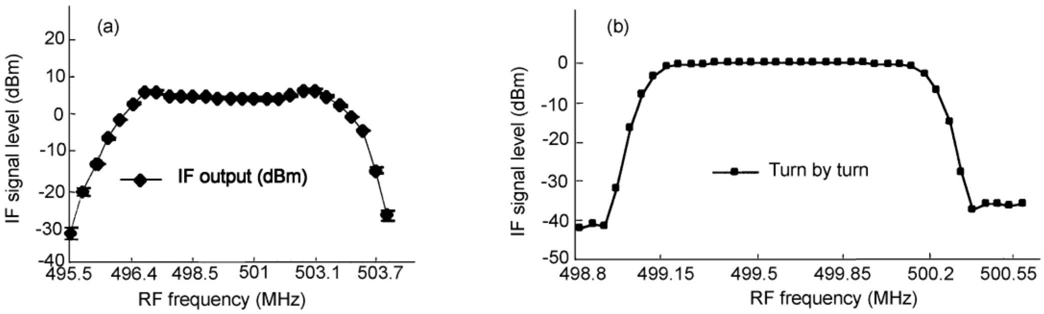

Fig.2 (a) Bandwidth of RF front end module; (b) system bandwidth for turn-by-turn mode.

The whole DBPM system's bandwidth differs for different operation modes. It is programmable by setting the DDC digital filter coefficient. The system bandwidth varies from several kHz to 1 MHz.

3.2 RF front end linearity

The gain of RF front end module is controlled by DSP program. With different setting of on-board DACs, the IF amplitude vs. RF amplitude relationship is measured. As shown in Fig.3, the RF front end module has a wide linear range from -70 dBm to about –5 dBm.

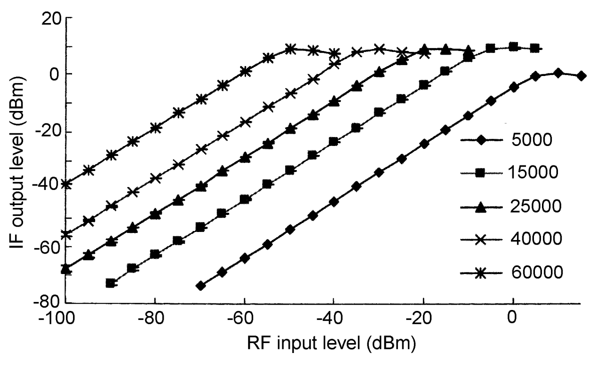

Fig.3 IF amplitude vs. RF amplitude relationship for different gain setting.

The spectrum of IF signal is shown in Fig.4. The 36.029 MHz carrier signal and 34.375 MHz pilot signal is clearly displayed. While changing the gain or the pilot level, the carrier signal level varies correctly.

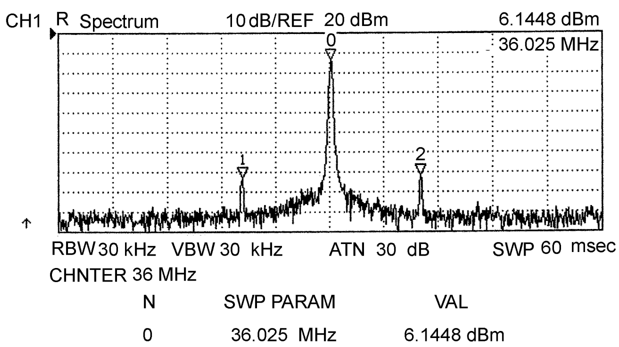

Fig.4 A spectrum of IF signal. Carrier signal @36.025 MHz; pilot signal @34.375 MHz.

3.3 Long term stability

Measurement of long term stability of DBPM electronics has been performed with constant input power level and a constant DBPM gain setting at the frequency of 499.654 MHz. The measurement lasted about 12 hours, and the long term stability is less than 2 microns (see Fig.5).

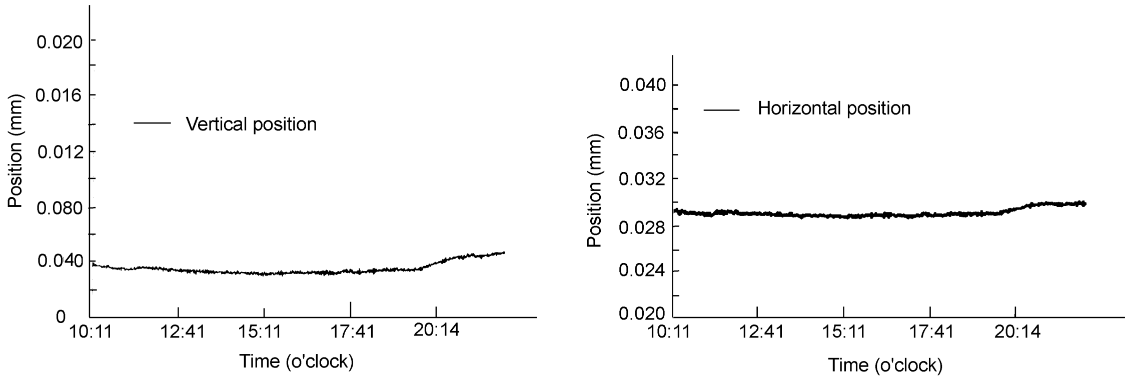

Fig.5 Long term stability of the SSRF DBPM system. It's within $\pm 1\mu m$ over a time period of 12 hours.

4 Conclusion

The DBPM has reached requirement of the third generation light source in all available operation modes. One set of such DBPM system can be used everywhere of the accelerator complex. This system can not only be used in position monitor, but also the beam current measurement system, tune measurement and position feedback system etc. Its complete integration into the EPICS based control system allows online re-programmability by the operators in the control room through BPM control panel.

References

1 SSRF Design Report. Shanghai Synchrotron Radiation Center, March 2001

2 RF Front-End Technical Reference Rev.1.0.3, Instrumentation Technologies, 2001

3 Quad Digital Receiver (QDR) Technical Reference Rev.1.0.3, Instrumentation Technologies, 2001

4 EPICS Homepage, http://www.aps.anl.gov/epics