MODERNIZATION OF THE BERGOZ MULTIPLEXED BPM SYSTEM FOR THE APS UPGRADE[*]

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Abstract

The APS upgrade includes improvements to the Bergoz Multiplexed BPM system, which presently suffers from an aging data acquisition system. The upgrade leverages off the development of an eight-channel data acquisition system featuring modern FPGA flexibility that was designed for the monopulse BPM system. This upgrade also provides an external clock signal synchronized to the APS revolution clock that will eliminate the aliasing caused by the Bergoz asynchronous multiplexing interacting with different accelerator fill patterns. The upgrade will revitalize this system and demonstrate a cost-effective approach to improved beam stability, reliability, and enhanced postmortem capabilities. In this paper we will discuss the upgrade system specifications, design, and prototype test results.

INTRODUCTION

The Advanced Photon Source Upgrade (APS-U) project includes improvements to the commercial narrowband (Nb) Bergoz multiplexed Beam Position Monitor (BPM) systems [1], which were installed in 2000. The APS storage ring now makes use of 80 Bergoz modules that are connected to 10-mm buttons on a large-aperture, standard elliptical (42 mm by 85 mm) vacuum chamber. This NbBPM system presently suffers from an aging data acquisition system. The upgrade leverages off the development of an eight-channel data acquisition system featuring modern field-programmable gate array (FPGA) flexibility that was designed for the monopulse BPM system [2]. The new FPGA-based Beam Signal Processor (BSP100) will replace the old data acquisition system and controls for the existing Bergoz receivers located at P1s on the standard elliptical vacuum chambers.

The upgrade will revitalize this system and demonstrate a cost-effective approach to improved beam stability, reliability, and enhanced postmortem capabilities.

The noise floor, fill-pattern dependence, and intensity dependence of the prototype upgrade NbBPM system will be investigated.

UPGRADE SYSTEM SPECIFICATIONS

Beam stability improvement is an important part of the APS-U project, which will be supported by new and upgraded BPM electronic systems. Listed in Table 1 [3] are APS-U beam stability performance and goals for ID sources. To achieve these goals, the obsolete BPM electronics for the NbBPM, located at the standard elliptical vacuum chambers, will be replaced with a modern system providing improved resolution and drift characteristics.

Table 1: APS-U Beam Stability Performance and Goals

		AC rms motion 0.01-200 Hz		AC rms motion 0.01-1 k Hz		Long-term drift (One Week)	
		µm rms	µrad rms	µm rms	µrad rms	µm rms	µrad rms
Horizontal	Present	5.0	0.85	5.0-7.0*	NA	7.0	1.4
	Upgrade	3.0	0.53	6.0	1.14	5.0	1.0
Vertical	Present	1.6	0.80	3.7*	NA	5.0	2.5
	Upgrade	0.42	0.22	0.84	0.44	1.0	0.5

* Measurement up to 767 Hz

DESIGN

The BSP100 is a standalone Experimental Physics and Industrial Control System (EPICS) input/output controller (IOC), an FPGA-based (Altera Stratix® II), a C-sized VXI form factor, with eight high-speed 14-bit digitizers (Analog Device AD6645) running at 88 MSPS (one-fourth of the APS rf frequency) [2, 4]. The baseline design replaces the aging Bergoz data acquisition with the BSP100. The position signals from four Bergoz BPMs will be digitized with a single module. The BSP100's FPGA has five major blocks, the APS timing system receiver, the acquisition control block, the preliminary processing block, the continuous signal processing block, and the triggered processing block.

The turn-by-turn average from the preliminary processing block, which is same as that in the monopulse BPM system, is passed through a first-order low-pass filter with a cutoff frequency of about 1.4 kHz. Then it is converted to the engineering units and sent to several other blocks for processing, as shown in Figure 1.

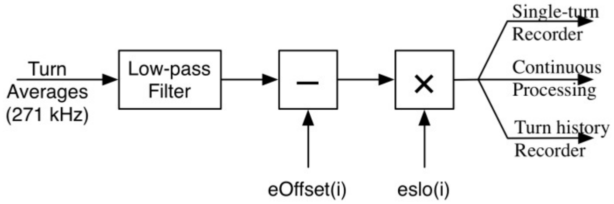

Figure 1: BSP100 Bergoz signal processing block diagram.

In the continuous processing block (shown in Figure 2), acquired data from the Bergoz BPMs will be available at EPICS rate and at a fast data stream. The BSP100

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provides a 100-Mb/s TAXI-compatible link that carries data to the feedback system.

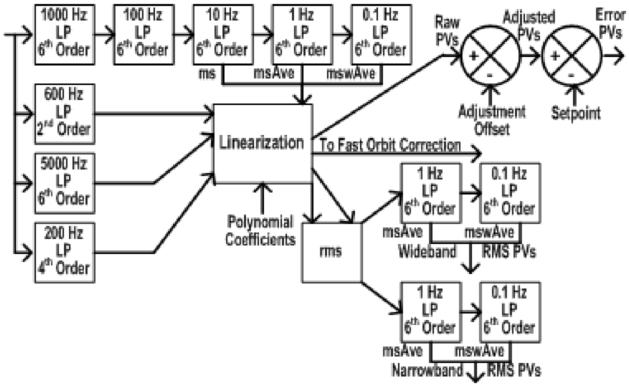

Figure 2: Continuous signal processing block diagram.

The BSP100 provides one second (262144 samples) turn-by-turn beam history, a virtual digital oscilloscope (4096 samples @ 88 MHz), single-turn acquisition, and slow beam history for machine studies and postmortems.

PROTOTYPE TEST RESULTS

The prototype of the NbBPM with BSP100 was installed at sector 38. The four 10-mm-diameter pickup electrodes were mounted on the standard elliptical vacuum chambers and connected to the 4-into-1-into-4 splitter with a variable attenuator between the four-way combiner/splitter, as shown in Figure 3. This setup minimized the physical noise from real beam motion, and only electronics noise was measured. Varying the attenuator simulated change in the intensity and noise.

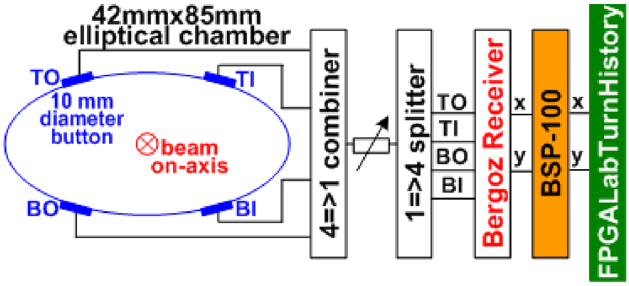

Figure 3: Measurements setup at Sector 38.

The signals from the 4-into-1-into-4 splitter combo went to the Bergoz receiver with BSP100 interface and simulated a beam on-axis. The FPGALabTurnHistory controlled the BSP100 module to clock the Bergoz BPM taking data using 324- or 24-singlet fills and eliminating aliasing lines caused by the Bergoz multiplexer beating against the fill pattern. The Bergoz receiver operated properly to an external frequency of 33.94 kHz, while varying an attenuator over the range 0 to 50 dB.

The sensitivities of 10-mm-diameter buttons in the standard elliptical chamber on horizontal and vertical planes are 0.058 mm^{-1} and 0.055 mm^{-1}, respectively [5]. The calibration factor formula of NbBPM is

$$d = \frac{1}{\text{Gain}}\frac{1}{\text{Sensitivity}}, \tag{1}$$

where d is the calibration factor, Gain is the Bergoz BPM module X/Y gain, and Sensitivity is the vacuum chamber sensitivity.

The gains of the Bergoz modules used in the measurement are $\text{Gain}_x = 0.148\,\text{V}/\%$ and $\text{Gain}_y = 0.161\,\text{V}/\%$.

The overall calibration factor of the NbBPM and the electronics system is 1.165 mm/V and 1.129 mm/V on horizontal and vertical planes, respectively. They were used in the following measurements.

The Fill Pattern Dependence

Figure 4 illustrated the root-mean-square (RMS) of the cumulative integral of the power spectral density (PSD) with 24- or 324-singlet fill patterns on the vertical plane. It shows the fill pattern dependence. The performance on the horizontal plane was similar.

The Intensity Dependence

Figures 5 and 6 represented the RMS of the cumulative integral of the PSD for various attenuations on the horizontal and vertical planes with 24- or 324-singlet fill patterns, respectively. They show the intensity dependence.

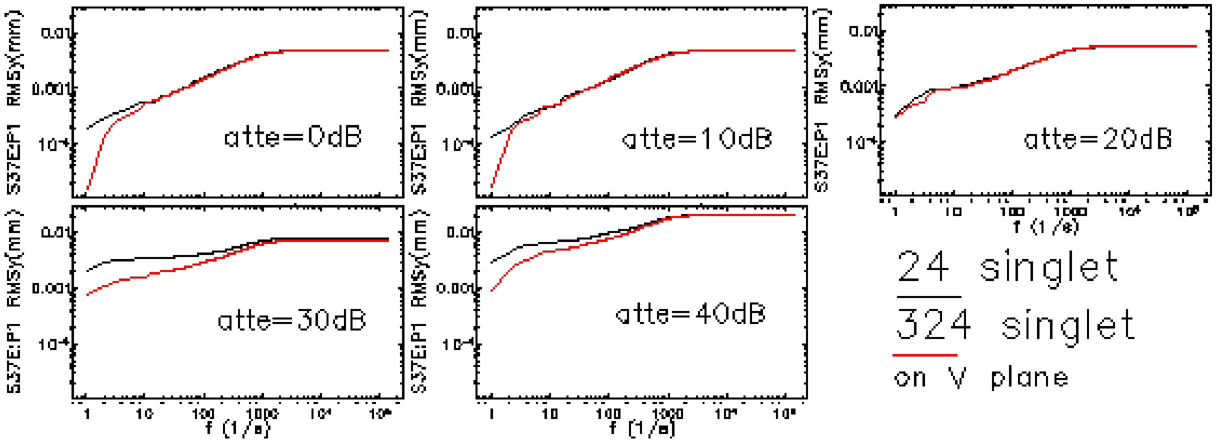

Figure 4: Cumulative RMS for different fill patterns on the vertical plane.

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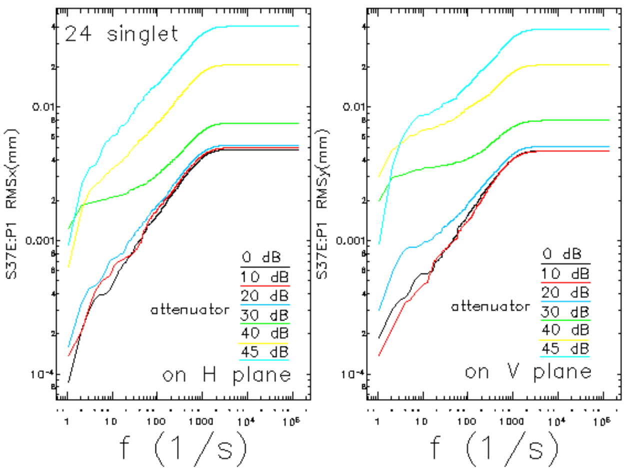

Figure 5: Cumulative RMS for different intensities with a 24-singlet fill.

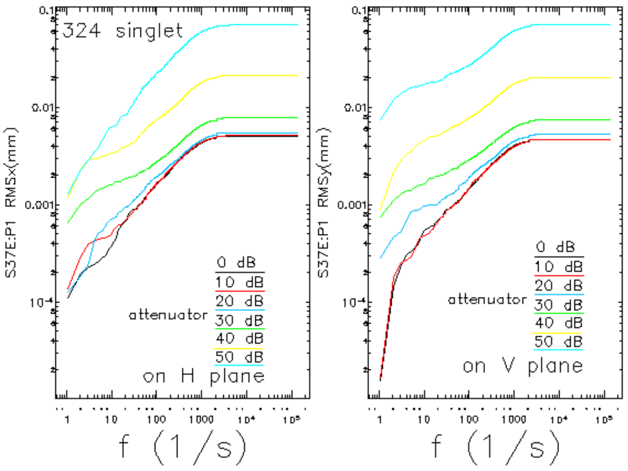

Figure 6: Cumulative RMS for different intensities with a 324-singlet fill.

The Synchronous and Asynchronous

Using the existing data acquisition system, aliasing spikes were observed in some P1 NbBPMs located at the standard elliptic vacuum chambers. The aliasing is caused by the beating of the Bergoz internal clocks with various other processing clocks residing within the NbBPM chassis and by different accelerator fill patterns, especially the hybrid fill pattern [6].

The upgrade prototype with BSP100 was provided an external clock signal synchronized to the APS revolution clock with the expectation of eliminating the aliasing. The noise data were taken with the 24-singlet fill pattern, shown in Figure 7.

There is no obvious difference on the vertical plane at sector 38 for the 24-singlet fill pattern with and without the external clock synchronized to the APS revolution clock. It may be because the aliasing appeared serious only in some sectors, especially for a hybrid fill.

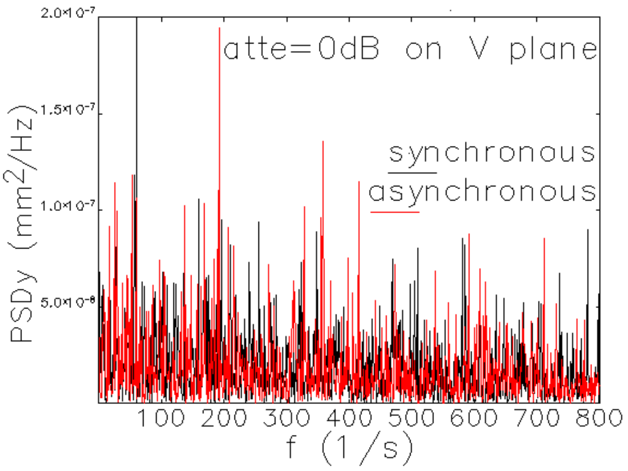

Figure 7: PSD for a 24-singlet fill on the vertical plane with and without the external clock synchronized to the APS revolution clock at sector 38.

SUMMARY

Using the 4-into-1-into-4 splitter with a variable attenuator between the four-way combiner/splitter, a prototype of an NbBPM with BSP100 was connected to the 10-mm-diameter buttons mounted on the standard elliptical chamber. A varying-intensity on-axis beam was simulated by changing the attenuator. The noise was measured with 24- and 324-singlet fill patterns. The intensity dependence and fill-pattern dependence were studied. More data for different fill patterns and off-axis beam will be conducted in the future.

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