A low-latency sub-micron resolution stripline beam position monitoring system for single-pass beamlines

R. J. Apsimon, B. Constance, A. Gerbershagen, CERN, Geneva, Switzerland
J. Resta López, IFIC, Valencia, Spain

Abstract
A low-latency, sub-micron resolution stripline beam position monitoring system has been developed for use in single-pass beamlines. The fast analogue front-end signal processor is based on a single-stage RF down-mixer and is combined with an FPGA-based system for digitisation and further signal processing. The system has been deployed and tested with beam at the Accelerator Test Facility at KEK. Performance results are presented on the calibration, resolution and stability of the system. A detailed simulation has been developed that is able to account for the measured performance.

Stripline BPMs

Components:
- Resistive coupler
- 180° hybrid
- 90° hybrid
- Band-pass filters
- Mixers
- Low-noise amps

BPM Processor Design

Schematic of BPM processor module

Digital Hardware

The FONT5 digital board is built around a Xilinx Virtex-5 FPGA. It features 9 14-bit ADCs clocked at 357 MHz; the sample clock has a variable delay in increments of 70 ps to facilitate sampling of the peak of the processor output signals. A serial interface is used for communication with the custom control software. Presently 164 samples are returned per beam extraction.

Position Determination

As part of the LO-based processing scheme, the LO input to each processor is phased so that the arrival of the bunch coincides with the peak amplitude of the LO. This condition is achieved when the sum is maximized; the sumQ is therefore very close to zero and is maximally sensitive to any phase offset between the LO and the bunch.

For stripline BPMs, the position of the bunch is proportional to the ratio of the difference to the sum. However, a change in the LO phase is observed to produce a spurious change in the measured position. The ratio of the sum to the sumQ is approximately equal to the phase offset in radians and is used to remove the contribution of the phase offset to position.

Table of BPM response to LO phase variations

<table>
<thead>
<tr>
<th>BPM</th>
<th>Phase sensitivity (microns per degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FONT51F</td>
<td>0.1</td>
</tr>
<tr>
<td>FONT52F</td>
<td>0.3</td>
</tr>
<tr>
<td>MQF15X</td>
<td>1.6</td>
</tr>
<tr>
<td>MQD14X</td>
<td>0.6</td>
</tr>
<tr>
<td>MQF15F</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Resolution Determination

The three BPMs are assumed to have the same resolution. The positions in two of the BPMs are then used to predict the position in the third. The residual is the predicted position subtracted from the observed position; the resolution is the standard deviation of this (0.43 microns).

References
[3] www-pnp.physics.ox.ac.uk/~font/
[4] D. Bett et al., these proceedings, WEPPP068