

# CLOSED-ORBIT CORRECTION USING THE NEW BEAM POSITION MONITOR ELECTRONICS OF ELSA BONN

J. Dietrich and I. Mohos, Forschungszentrum Jülich GmbH, Germany

J. Keil, Physikalisches Institut, Universität Bonn, Germany

## Abstract

RF and digital electronics, developed at the Forschungszentrum Jülich/IKP were integrated to form the new beam position monitor (BPM) system at the Electron Stretcher Accelerator (ELSA) of the University of Bonn. With this system the preservation of the polarization level during acceleration was currently improved by a good correction of the closed-orbit. All BPM offsets relative to the magnetic quadrupole centers were determined by the method of beam-based alignment. The optics functions measured by the BPM system are in good agreement with theoretical predictions.

## 1 INTRODUCTION

The 3.5 GeV Electron Stretcher Accelerator at Bonn University was recently upgraded for the acceleration of polarized electrons [1]. During the beam acceleration several strong depolarizing resonances have to be crossed. Steering the beam through the magnetic quadrupole centers of ELSA can reduce the strengths of one type of resonances connected with the vertical closed orbit distortions. A common technique to determine the magnetic axis of a quadrupole relative to the axis of the beam position monitor is the method of beam-based alignment [2]. To make use of this method a BPM system with a good resolution and long term stability is required which can also be used at low currents of some mA typically for the operation of ELSA with polarized electrons. The new BPM electronics forming a 28 BPM orbit measurement equipment are integrated in the control system of ELSA.

## 2 FRONT-END ELECTRONICS

The BPM front-end electronics [3] were developed at the Forschungszentrum Jülich/IKP and produced by KFKI in Hungary. Each station consists of an RF narrowband signal processing unit and a data acquisition and control unit with capabilities for data preprocessing. Both units are enclosed in an RF-shielded crate with power supply and placed close to the four-button monitor chambers in order to reduce RF interference on the button signals. Altogether 28 monitor stations are connected via four optically coupled serial fieldbuses to the VME host computer.

### 2.1 RF Signal Processing Unit

A narrowband superhet RF electronics (Fig.1) detects the amplitudes of the four button signals at the fundamental frequency of  $f_{RF} = 500$  MHz. At the input adjustable attenuators equalize the attenuation of the four channels and lowpass filters remove the higher harmonics of  $f_{RF}$  from the signal spectrum. An RF multiplexer with programmable button sequence scans the four buttons. The succeeding low noise narrowband preamplifier ( $B = 5$  MHz,  $G = 20$  dB) rejects the image range. For high signal levels a switchable 30 dB attenuator can be inserted. A balanced mixer transposes the desired frequency range to the intermediate frequency, where narrowband filters reduce the bandwidth to  $\approx 200$  kHz and an amplifier with controlled gain enhances the signal level appropriate for demodulation.

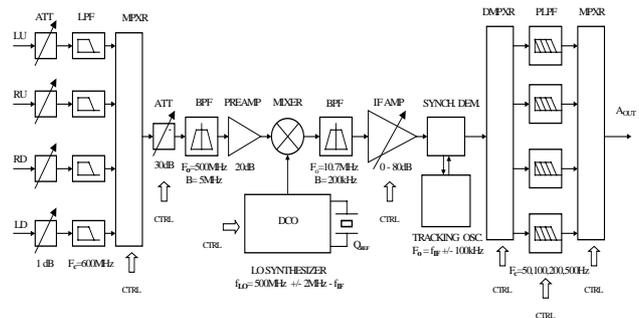


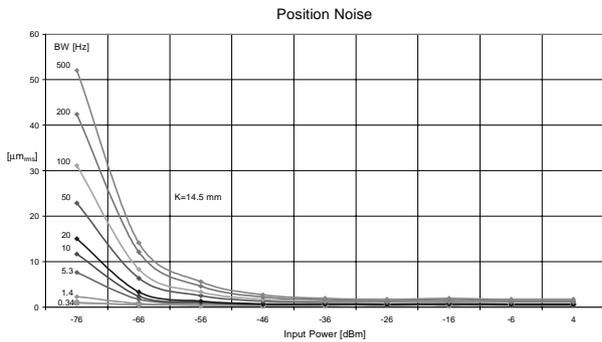
Figure 1: Block diagram of the RF signal processing module

On-board remote-controlled synthesizer generates the LO signal applied to the mixer, determining the band-center frequency of the signal processing.

The band-center frequency is adjustable in the range of  $500 \text{ MHz} \pm 2 \text{ MHz}$  with steps of 50 kHz. Frequency changes within the IF bandwidth will be automatically tracked in real time. The output signal of the synchronous demodulator with a linearity of  $\approx 0.5\%$  is proportional to the rms value and carries level changes with frequencies up to 500 Hz. The gain control range of the processing chain is about 100 dB.

Signal level dynamic range of the electronics is between  $-80 \text{ dBm}$  and  $+10 \text{ dBm}$ . The typical equivalent beam position noise is  $x_{\text{rms}} < 0.5 \mu\text{m}$  at  $P_{\text{in}} = -46 \text{ dBm}$  and  $B = 10 \text{ Hz}$  assuming that the BPM sensitivity is  $K_{\text{BPM}} = 14.5 \text{ mm}$  (Fig. 2).

Figure 2: Equivalent rms position noise



## 2.2 Data Acquisition Unit

The data acquisition (DAQ) unit consists of an 8 bit microcontroller with 64 kbyte EPROM, 32 kbyte RAM, a built-in timer and a 1 Mbit/s asynchronous serial interface with galvanic isolated twisted-pair transceiver (Fig. 3). A 12 bit ADC digitizes the demodulated electrode signals and 12 bit DAC controls the gain. Several bits are used for timing and bandwidth control and a 3-wire interface for the synthesizer.

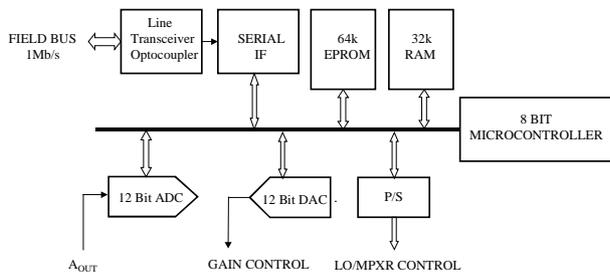


Figure 3: Block diagram of the data acquisition and control module

The built in firmware of the DAQ-unit controls the data acquisition and timing functions and performs some basic preprocessing tasks. The host controls the firmware and the timers by means of R/W registers containing numeric and mode parameters.

## 3 DATA PROCESSING

### 3.1 Low Level Data Preprocessing

After sequential digitizing of the four button signals the horizontal and vertical positions are computed. In automatic gain control mode a gain correction value will be prepared for the next cycle. Subsequently a digital lowpass filter algorithm reduces the signal bandwidth. Its cutoff frequency is programmable in 13 steps. The overall bandwidth can be reduced from 500 Hz down to 0.1 Hz. The sampling interval is selectable between 1-256 ms. The number of the samples is programmable for limited (1-4095) or continuous sample stream. On request of the host the acquired and preprocessed data will be transferred in real time, or can be buffered in the 4 kS RAM for slower read or later use.

An optional plug-in can be added to the front-end electronics containing a 4 MB flash memory and an arithmetic processor. Using a downloaded dataset and the raw data delivered by the DAQ-unit, the unit performs scaling, offset and nonlinearity correction according to the BPM chamber geometry.

### 3.2 BPM Host Computer

The BPM system was integrated in the architecture of the control system of ELSA, which is organized hierarchically in three layers with distributed intelligence. The presentation level is based on HP9000/700 workstations running HP-UX as the operating system. Its purpose is to display the status of the machine and to hold the distributed database. The GUI is based on the X-Window system and OSF/Motif. The process level is connected via Ethernet with the presentation level and is used for data preprocessing from devices using VMEbus boards running the VxWorks real-time operating system on Motorola 68K CPUs. The lowest level is the fieldbus level for the direct communication with the devices.

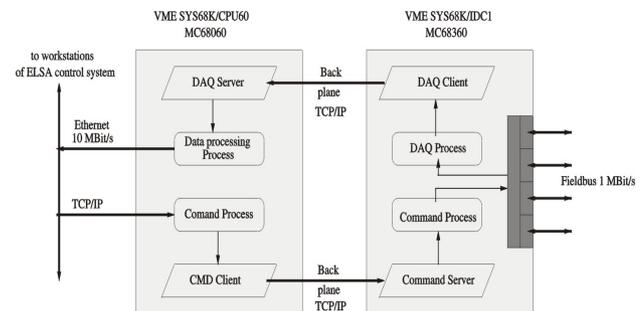


Figure 4: Architecture of the high level data acquisition system

In the case of the BPM system the front-end electronics are connected with four fieldbus lines to a VMEbus communication controller board based on the MC68360 (QUICC) processor. His purpose is to trigger the data acquisition and to read back the measured positions from the BPM stations. Due to the limited floating point capabilities of the QUICC a dedicated MC68060 CPU is used for the high level data processing. The communication between the two VME boards is done over the backplane using TCP sockets (Fig. 4).

### 3.3 High Level Data Processing

In the free run mode the data acquisition of all BPM stations is triggered in regular intervals by the fieldbus host computer and their data is read by the host. The data of all BPMs is immediately passed over for to the BPM controller CPU. A low priority process read periodically the actual BPM status values. Commands for changing of BPM settings are passed over to the server process using a second TCP connection.

The BPM controller CPU corrects first for unequal electrode attenuations [4] and linearizes the response of the electrode configuration using a combination of a look-up table and a two-dimensional local polynomial approximation of second degree. Closed orbit data is transferred to the workstations and can be displayed and further analysed. Several different orbit correction algorithms like harmonic correction, least square correction using singular value decomposition (SVD), MICADO, and local bumps are available.

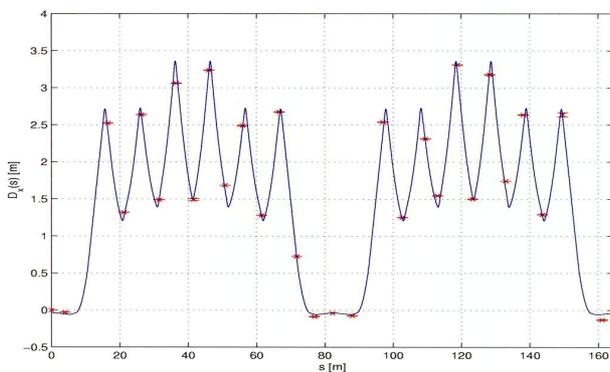
## 4 RESULTS

### 4.1 BPM Offsets

The technique of beam-based alignment [2] was used to determine the magnetic centers of the quadrupoles, which define the zero position of the nearby BPMs. This is very important for ELSA, because the resonance strengths of the imperfection resonances depend on the correction of the vertical closed orbit during resonance crossing. Offsets of several millimeters were found by this method. The reproducibility of the zero positions is approximately 100  $\mu\text{m}$ .

### 4.2 Dispersion Function

The horizontal dispersion function  $D_x(s)$  was determined by changing the RF frequency and measuring the shift of the closed orbit (Fig. 5). The measurement for standard tunes of ELSA and is in good agreement with the theoretical predictions. The measured rms-value of  $D_x(s)$



is about 6 cm.

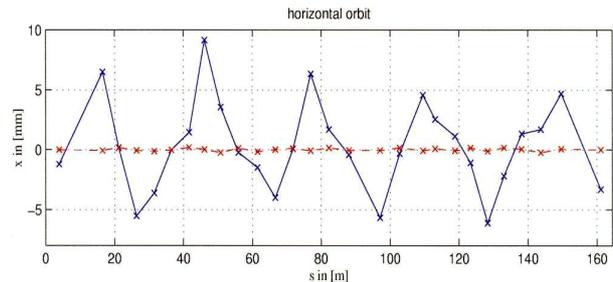
Figure 5: Theoretical (solid line) and measured (data points) dispersion function  $D_x(s)$

### 4.3 Orbit Correction

Before orbit correction the orbit distortion was reduced by a good alignment of the quadrupole and dipole

magnets. For the closed orbit 20 horizontal and 18 vertical steerer magnets were used. The uncorrected orbit with  $x_{\text{rms}} = 2.46 \text{ mm}$  and  $z_{\text{rms}} = 0.93 \text{ mm}$  was reduced after five iterations to values of  $x_{\text{rms}} = 0.126 \text{ mm}$  and  $z_{\text{rms}} = 0.141 \text{ mm}$  using the SVD orbit correction algorithm. As an example the uncorrected and corrected orbit is shown in Fig. 6.

Figure 6: Uncorrected (solid) and corrected (dashed) horizontal closed orbit



## 5 CONCLUSIONS

The close placing of the RF and data acquisition electronics to the pick-up reduces effectively the RF interference and allows utilizing the remarkable noise performance of the front-end unit. The galvanically decoupled fieldbus eliminates the disturbances caused by the potential difference between the monitor chambers and the host and enhances the reliability of the data transfer. Software development on the user's side is not necessary for the low-level acquisition, control and preprocessing. The distributed and time-overlapped data processing improves the overall system performance. It is possible with the new BPM system to correct the closed orbit of ELSA up to rms values of 130  $\mu\text{m}$  in the horizontal and 140  $\mu\text{m}$  in the vertical plane.

## REFERENCES

- [1] Steier, C. et al.: "Acceleration of Polarized Electrons in ELSA", EPAC 98
- [2] Röjssel, P.: "A beam position measurement system using quadrupole magnets magnetic centra as the position reference", NIMA 343 (1994) 374
- [3] Mohos, I. et al: "500 MHz Narrowband Beam Position Electronics for Electron Synchrotrons", AIP Conf. Proc., No. 451, 1998
- [4] Chung, Y. et al: "Offset Calibration of the Beam Position Monitor Using External Means", AIP Conf. Proc., No. 252, 1991