CONTROL AND DATA PROCESSING OF THE DISTRIBUTED 500 MHz NARROWBAND BEAM POSITION MONITOR SYSTEM OF ELSA

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Abstract

The preservation of the polarization level during acceleration of the electron beam is currently the main topic at the Electron Stretcher Accelerator (ELSA) of the University of Bonn. It can be improved by a good correction of the closed-orbit relative to the magnetic quadruple centres using the method of beam-based alignment. Beam position monitor electronics, developed in the Forschungszentrum Jülich/IKP for ELSA are integrated to form the 28 BPM orbit measurement equipment. The deviation of the closed orbit measured by the BPM system was reduced to an rms-value of 140 μm.

1 INTRODUCTION

The 3.5 GeV Electron Stretcher Accelerator (ELSA) at Bonn University was recently upgraded for the acceleration of polarized electrons [1]. During the energy ramp several strong depolarizing resonances have to be crossed. The strengths of one type of resonances connected with the vertical closed orbit distortions can be reduced by steering the beam through the magnetic quadrupole centers of ELSA. A common technique to determine the magnetic axis of a quadrupole relative to the axis of the beam position monitors (BPM) 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 is also able to be used at low currents of some mA.

2 SYSTEM ARCHITECTURE

The new BPM electronics forming a 28 BPM orbit measurement equipment are integrated in the control system of ELSA. The control system of ELSA is organised 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 data base. The process level is used for preprocessing data from devices using VME processors 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. A dedicated VME crate for the BPM system uses a serial communication board based on the MC68360 communication controller and a MC68060 CPU for high level data processing. The front-end devices are connected with four fieldbus lines to the communication controller. The communication between the two processors is done over the VME backplane using mailbox interrupts (Fig. 1).

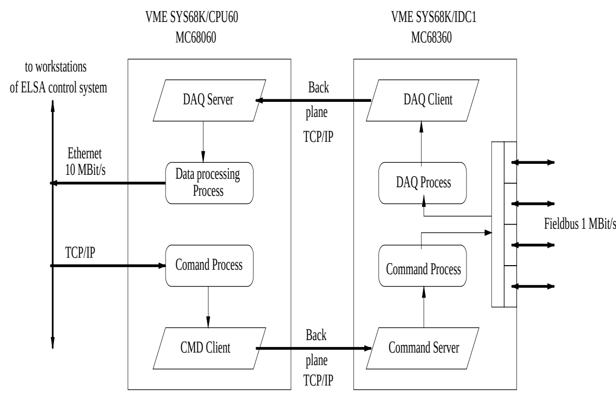

Figure 1: Architecture of the high level data acquisition system.

The data communication between the VME processors and the workstations is done via a fibre optics link using TCP and UDP protocols with 10 MBit/s. The orbit data and BPM status information is displayed on workstations running a GUI based on the X-Window system and OSF/Motif.

3 FRONT-END ELECTRONICS

Front–end electronics each consisting of an rf narrow-band signal processing unit and a data acquisition and control unit with data processing capability are placed close to the four-button monitor chambers [3]. The monitor stations arranged in four subgroups are connected via galvanically decoupled serial fieldbuses to the host.

3.1 Analog Electronics

Narrowband superhet rf electronics (Fig. 2) process the fundamental components of the button signals. At the input analog rf multiplexer with programmable button sequence scans the four buttons. Low noise narrowband preamplifier (B=5 MHz) amplifies the signal of the selected button. For high signal levels a switched 30dB attenuator can be inserted. Mixer transposes the desired frequency range to the intermediate frequency, where narrowband filters reduce the bandwidth to ~200 kHz and amplifier with controlled gain enhances the signal level appropriate for demodulation.

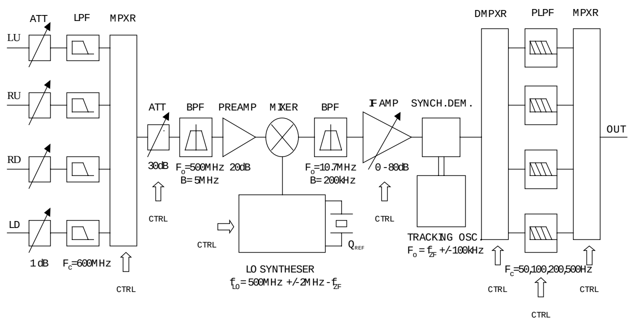

Figure 2: Block diagram of the rf signal processing module.

On-board remote controlled synthesizer generates the LO signal applied to the mixer. Its frequency determines the band-center frequency of the signal processing. Frequency changes within the IF bandwidth will be automatically tracked by the demodulator in real time.

Band-center frequency adjustments can be achieved in the range of 500MHz ± 2MHz with 50kHz steps. The output signal of the linear synchronous demodulator 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

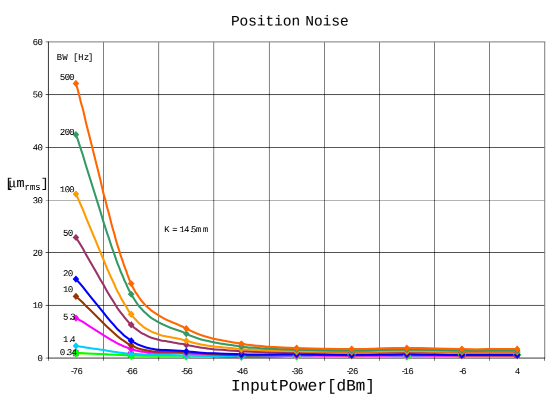

Figure 3: Equivalent rms position noise.

between –80dBm and +10dBm is allowed. The typical equivalent beam position noise is <0.5 μm_{rms} @ P_{in}= -46 dBm, B=10 Hz and K=14.5 mm (Fig. 3).

3.2 Data Acquisition

The Data Acquisition Unit (Fig. 4) consists of a 8bit microcontroller with 8kbyte EPROM and 32kbyte RAM and built-in timer, half-duplex 1 Mbit/s asynchronous serial interface with galvanic isolated twisted-pair transceiver for data communication, 12 bit ADC for digitizing of the demodulated electrode signals and 12 bit DAC for gain control, several bits for timing and bandwidth control and a 3-wire serial interface for synthesizer control.

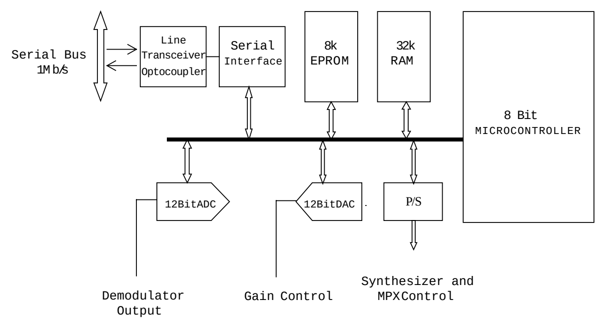

Figure 4: Block diagram of the data acquisition and control module.

The timer of the microcontroller controls the rf multi-plexer and the timing phases of the acquisition. The sampling rate can be set by means of remote command between 1-256ms corresponding to the selected lowpass filter.

4 DATA PREPROCESSING

The built in firmware of the front-end daq unit performs some basic computing tasks. After digitizing of the button signals the horizontal and vertical positions are computed. In automatic gain control mode the measured values are compared with a reference and a gain correction value will be prepared for the next cycle. The scan timing and the step gain control are synchronised. Four button signals will be measured in each cycle with the same gain, therefore consistent data are used for position computing. Subsequently a digital lowpass filter algorithm reduces the signal bandwidth. Its cutoff frequency is programmable in 14 steps. The overall bandwidth can be reduced down to 0.1Hz. On request of the host the acquired and preprocessed data will be transferred in real time, or can be buffered in the 4kS RAM for slower read or later use.

5 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. The BPM stations send as a response on the trigger the measured values as a sequence of data blocks on the four fieldbus segments to the host. The complete data block of 28 BPMs is passed over to the BPM controller CPU using a TCP/IP network connection. A second process with a lower priority sends periodically the actual status and BPM settings to the control system. Commands for settings and changing of hardware parameters of the BPM stations are passed over to the server process using a second TCP/IP connection.

The BPM controller CPU corrects first for unequal electrode attenuations [4] and linearizes the nonlinear 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 analyzed. Several different orbit correction algorithms like harmonic correction, least square fit, MICADO, and local bumps are available.

Furthermore data traces with the signals of all BPMs can be acquired and saved to disc for off line analysis. The sampling interval can be up to 1 ms covering 4096 positions.

6 CALIBRATION

The strengths of the imperfection resonances depend on the correction of the vertical closed orbit during resonance crossing. The technique of beam-based alignment [4] was used to determine the magnetic centers of the quadrupoles which define the zero positions of the nearby BPMs. To locate the magnetic axis of the quadrupole with the beam, a small change of the focusing strength (≈ 1 %) with an additional power supply was applied. The orbit was moved to different positions using a local four corrector bump. If the beam passes through the magnetic center of the quadrupole, the position shift due to the change of the focusing strength vanishes at the 28 BPMs. An example of a measurement is shown in Fig.5**.**

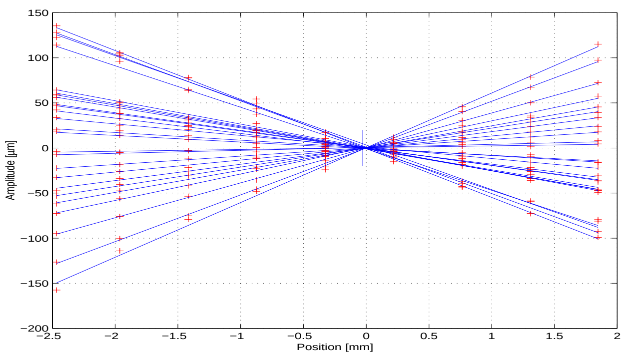

Figure 5 : Shift in position due to a 1 % change of the gradient in quadrupole QD15 for different beam bump amplitudes.

The zero position of the BPM is determined from the analysis of all zero crossings of the BPMs weighted with the errors from a linear regression for each BPM. The reproducibility of the zero positions of the BPMs determined by this method is approximately 100 µm mainly due to statistical fluctuations.

7 ORBIT CORRECTION

Before orbit correction the orbit distortion in the vertical plane was reduced by a good alignment of the quadrupole and dipole magnets. For the closed orbit correction 20 horizontal and 18 vertical steerer magnets were used. The uncorrected orbit with x_{rms}=2.46 mm and z_{rms} = 0.93 mm was reduced after five iterations to values of x_{rms} = 0.126 mm and z_{rms}= 0.141mm using a least-square orbit correction algorithm based on the singular value decomposition. The uncorrected and corrected orbit is shown in Fig. 6.

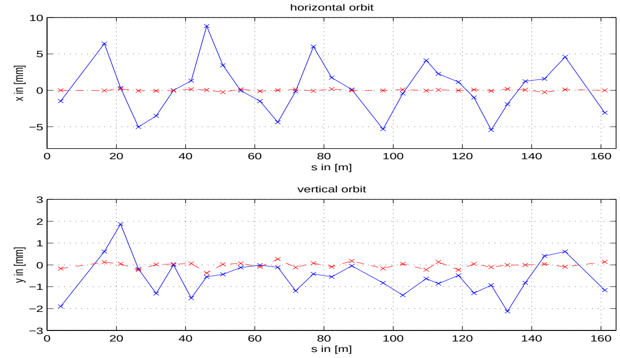

Figure 6: Uncorrected (solid) and corrected (dashed) closed orbit.

First measurements with polarized electrons showed, that after the orbit correction the polarization at the first strong imperfection resonance at 1.32 GeV could be almost completely preserved without additional means like harmonic correction.

8 CONCLUSIONS

The close placing of the rf and data acquisition electronics to the pick-up buttons reduces effectively the rf interference and allows to utilize 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 performances.

It was possible with the new BPM system to correct the closed orbit of ELSA up to rms values of 140 µm in both planes.

9 REFERENCES

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