DELTA Beam Position Monitor

S. Brinker, R. Heisterhagen, K. Wille
Accelerator physics
University of Dortmund

Abstract

For the electron storage ring DELTA[1] (Dortmund ELectron Test Accelerator) a beam-position-monitor system based on button pickups has been designed. Two different concepts for the monitor electronics have been developed obtaining a long-term stability better than +/- 150 μm and a short-term resolution below +/- 10 μm. There are no hybrids integrated in the electronic circuits as all four button signals should be amplified and digitized to provide redundancy. First, a concept using four separated electronic branches, one for each button, was tested. Then a concept with a multiplexer in front followed by only one amplifier was designed.This concept, the electronic circuits and the measurements will be presented.

1 General elements of the BPM

The beam-position-monitor system of the DELTA synchrotron and storage ring is based on pickup monitors with four pickups[2] (fig 1.). The required short time resolution is about +/- 10 μm. The absolute accuracy has to be less than +/- 150 μm during some weeks [2][5].

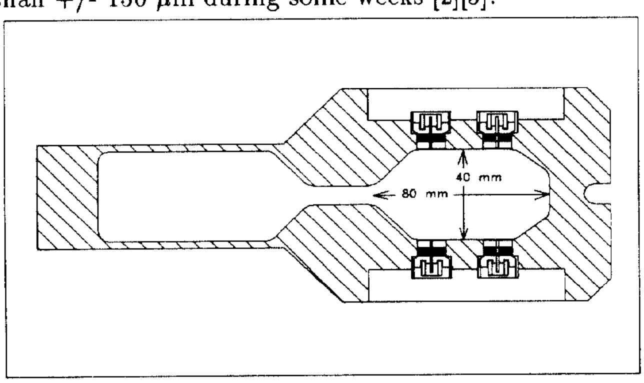

Figure 1: *Cross section of the DELTA beam position monitor.*

The dependence of the pickup signals on the beam position will be subject to further investigations, but in the central region of the monitor a linear approximation will be sufficient. In the vicinity of the orbit, the linear aproximation holds [1]

$$\Delta x = \alpha * \frac{s1 + s2 - s3 - s4}{s1 + s2 + s3 + s4} \quad (1)$$

$$\Delta z = \alpha * \frac{s2 + s3 - s1 - s4}{s1 + s2 + s3 + s4} \quad (2)$$

where α is the so called 'monitor constant' and s1...s4 are the signals received from the four pickups. α depends on the geometry of the monitor and is estimated to be less then 20 mm for the DELTA monitor. The following investigations refer to this value of α.

The monitor frequency is choosen to be 500MHz because it is the lowest frequency component in any mode of operation with different numbers of bunches [5].

The pickup signal is estimated to be [3]

$$U_{Pickup}[mV] = 0.5 * I_{beam}[mA] \quad (3)$$

with centered beam.

2 The BPM concept

It was decided to amplify each pickup signal separately as it is possible to calculate the beam position from only three of the four signals. The advantage is redundancy.

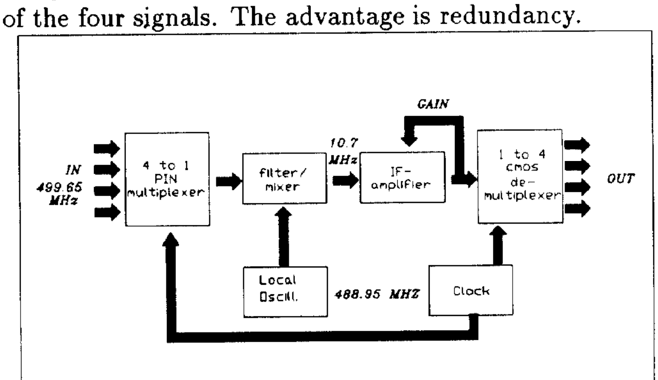

Figure 2: *Scheme of the BPM electronics*

A concept was developed with only one intermediate frequency (IF) amplifier and a four-to-one PIN switch multiplexer in front, which is subject to the following account. (fig. 2)

[1] Other contributions of DELTA to this conference
[2] The pickups were developed by the ESRF.

0-7803-0135-8/91$01.00 ©IEEE

3 The mixer circuit board

The pickups are connected to the filter/mixer unit by semi-rigide cables with SMA connectors. The filters are of the low-pass type of 5th order for protecting the following PIN switch from high frequency components of the pickup signal. The low passes are made in hybrid technique, combining printed inductivities and discrete chip capacitors (fig 3). Using discrete capacitors is necessary since the dimensions of printed capacitors are too large for mounting all four filters on one side of a standard circuit board, with sufficient distance. The subsequent multiplexing is performed by a PIN switch using a 100Hz clock signal. The output signal is mixed down to the intermediate frequency of 10.7MHz and then sent to the coaxial output channel.

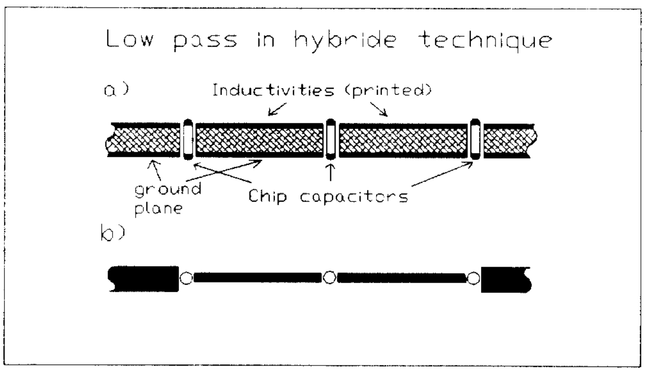

Figure 3: *Low-pass filter with chip capacitors and printed inductivities.*
a) Cross section of the circuit board
b) top view of the circuit board.

4 The IF amplifier board

The IF amplifier consists of two gain-controlled integrated circuit amplifiers followed by a fixed-gain amplifier and a fast rectifier (demodulator). The demodulated signal is distributed to two circuits: 1) One part of the signal is averaged over a long time and used for the gain control of the two leading amplifiers. Therefore, the output signal is independend of the beam current resp. the average of the four pickup signals. 2) The other part of the signal is demultiplexed to the four output channels, each averaged by a long-time-constant RC filter. This four 'DC' signals are sent to the output of the board.

5 The local oscillator board

The local oscillator is of the phase-locked-loop type, consisting of a crystal reference oscillator, a voltage controlled oscillator (VCO) of about 500MHz, a 1:256 divider and a phase comparator. The resonance frequency of the VCO is determined by a stripline resonator tuned with a voltage-variable capacitor, known as "varactor". The 500MHz signal is amplified by a Monolythic Microwave Integrated Circuit and distributed to four coaxial outputs by a power divider. One local oscillator provides four mixer boards because there will be four BPM electronics in one rack.

6 Measurements

The long-time frequency drift of the local oscillator is less then 10^{-6}, respectively 500Hz. Therefore there will be no problem with the narrow-band crystal filter (7kHz bandwidth) in the IF amplifier.

Fig. 4 shows the arrangement for testing the BPM electronics. The input signals are provided by a signal generator, a power divider and, if necessary, some attenuators. The analysis is done by a multi-channel millivolt meter conected to a personal computer.

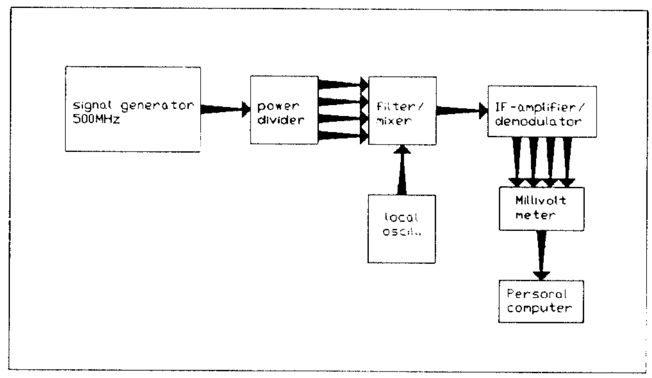

Figure 4: *Test arrangement for the BPM electronic.*

Fig. 5 exhibits the relative drift in μm during four days. The drift was less then +/- 15μm.

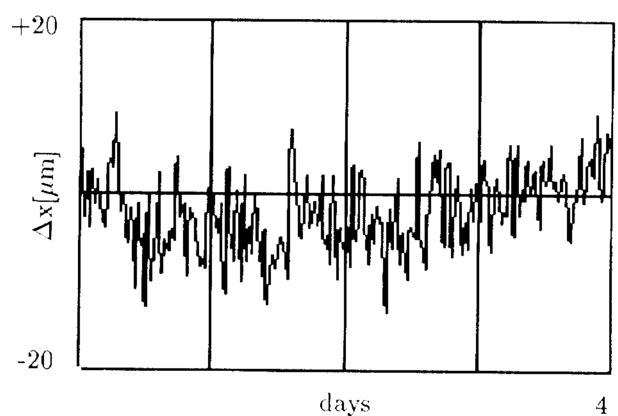

Figure 5: *Drift of the BPM electronics during four days.*

Fig. 6 shows the dynamic range of the BPM electronics. Figured is the evaluated position of the simulated beam versus the average pickup voltage. One can see that the linear range runs from 0.66mV to 118mV. This represents a beam current varying from about 1.3mA to 240mA (see eq. 3) with an error of less than +/- 25μm.

Since the sensitivity of the IF amplifier can be choosen in a wide range, it is possible to shift the lineare range to higher beam currents, for example 500 mA. If necessary, this can be done after measuring the prototype of the DELTA monitor.

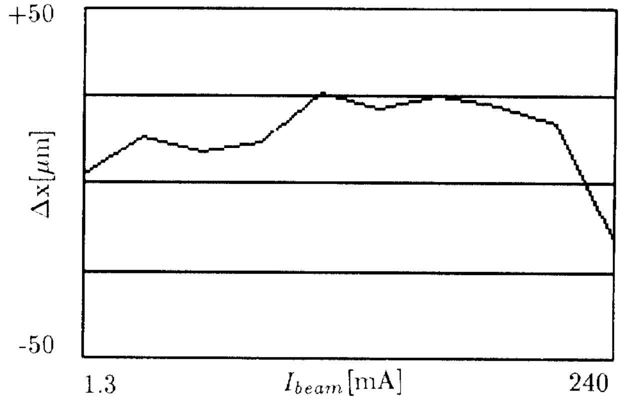

Figure 6: *Linearity of the BPM electronics in the range of beam currents from 1.3 mA to 240 mA.*

Fig. 7 is a plot of the distribution of 1000 measured values with constant signal input. It is a measure of the electronic noise. The standard deviation is less then 5μm.

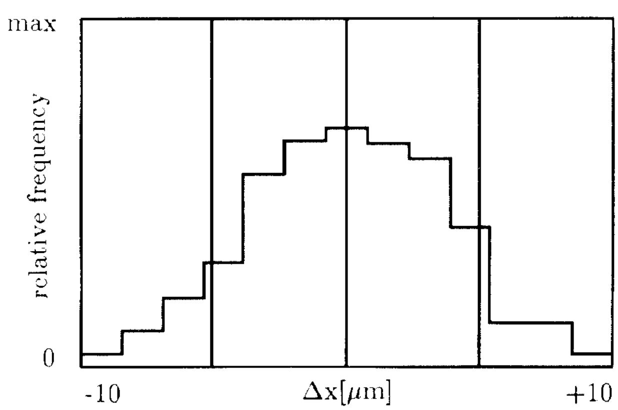

Figure 7: *Resolution of the BPM due to electronic noise.*

7 Conclusion

A prototype version of the BPM electronics was tested. For a fixed monitor constant α of 20 mm, a resolution of less then +/- 5μm is achived. Both, the deviation from linearity and the drift are less then +/- 25 μm. The overall deviation is less then +/- 50μm. Therefore the electronics fulfils the required demands.

8 References

[1] J. Borer, C. Bovet: Computer response of four pick-up buttons in an elliptical vacuum chamber, LEP Note 461, 1983.

[2] DELTA Group, Status Report 1990.

[3] S. Brinkmann, R. Heisterhagen, K. Wille: Report on the Electronics for the BPM, DELTA Internal Report 1990.

[4] S.Brinker, Detailed Description of the BPM electronics, DELTA Internal Report 1991 (in preparation).

[5] S.Brinkmann, L. Falck, N. Marquardt, K.Wille: Design Study of the Beam Position Monitor for the ESRF, 1988.