PERFORMANCE OF THE ELBE BPM ELECTRONICS*

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Abstract

The radiation source ELBE is based on a superconducting LINAC. Initially it was designed to operate in CW mode with repetition rates either 13 MHz either 260 MHz. Later it was decided to operate the accelerator with reduced repetition rates for diagnostic reasons and for certain users. Now it is possible to operate with bunch frequency 13/n MHz, where n can be 2,4,8,16,32,64 and 128. It is required that the BPM system supports any of these operation modes. A core element of the BPM electronics is a logarithmic detector AD8313 made by Analog Devices Inc. The logarithmic detector is a direct RF to DC converter rated up to 2.5 GHz. Initial design of the BPM electronic was sophisticated only for CW operation with repetition rate more than 10 MHz, since bandwidth of the AD8313 is about of 10 MHz. Additionally a sample and hold amplifier is built in to provide enough time for an ADC to make measurements. The sample and hold amplifier is synchronized with a bunch frequency. In the paper we present results of the modified BPM electronics test.

THE BPM ELECTRONIC

The BPM electronics is based on the logarithmic detector AD8313 from Analog Devices [1], which is a direct RF to DC converter rated up to 2.5 GHz. Thus the BPM electronic is built without mixing down the RF signal of the BPM. The electronics operate at the fundamental frequency of the accelerator, which is 1.3 GHz. The electronics is placed in two different 19`` chassis around accelerator outside the accelerator cave. An HELIAX® type RF cables connect BPMs to the RF front end. The cables have attenuation in a range 5÷6 dB at 1.3 GHz. The BPM signal goes through the bandpass filter with 3 dB bandwidth of 8 MHz. Then it is amplified with constant RF gain of about 25 dB to be matched to the linear range of the AD8313. The range goes from –65 dBm up to –5 dBm. The output of the logarithmic amplifier is matched to the ADC working range with the trim gain. The trim gain consists of adjustable gain and adjustable offset. So that four channels on one board are adjusted with difference typically 5%. Later the difference is taken in to account by software. One digit of the ADC corresponds to 8 μm beam displacement. Principal scheme of the BPM electronics is depicted on Fig. 1.

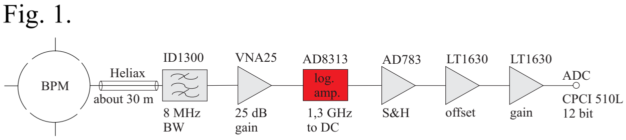

Figure 1: The electronics scheme.

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Main characteristic of the BPM electronics is show on Fig. 2, where the electronics output is plotted as a function of the RF input. We decided to put four channels on a board, since the cross talk from channel to channel was measured to be less then -20 dB, which is low enough.

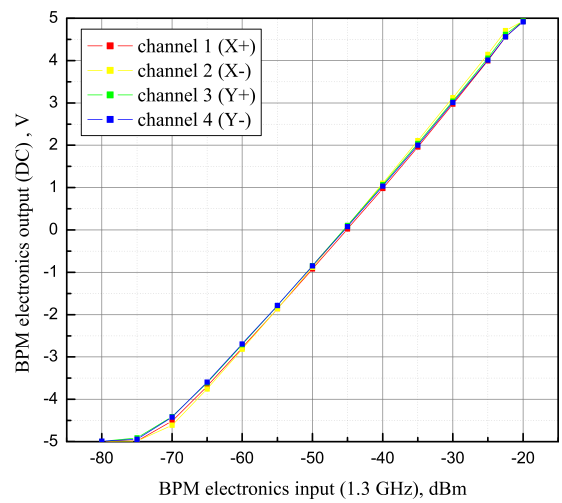

Figure 2: The electronics response curve.

THE LOW REPETITION RATE PROBLEM

The logarithmic detector has output bandwidth of about 10 MHz. With a bunch repetition rate of 13 MHz the AD8313 provide a DC output, which can be simply amplified and sampled by an ADC. When the bunch repetition rate becomes less than certain the logarithmic detector output shows the pulsed structure as well. Such situation is demonstrated on the Fig. 3. A short pulse generator drives the logarithmic detector. The generator was connected to the channel 1 of the oscilloscope. Output of the AD8313 evaluation board is on the channel 2. On the upper oscillogram the generator frequency is high enough to make the AD8313 output just a DC signal. On the lower oscillogram the generator frequency is reduced in factor four and is less than the logarithmic detector bandwidth. As one can see in this case every pulse of the generator is transformed by AD8313 in to another more broad pulse but not in to DC signal. In a case with an electron beam and real signal from the BPM the width of the logarithmic detector pulsed output is defined by the bypass filter bandwidth or in another words by its quality factor. The real signal has 100 ns flat top. The ADC used for the data acquisition has a sampling time of 400 ns. Obviously even with proper timing the ADC does not have enough time to measure the signal correctly. For that reason a sample and hold (S&H) amplifier is built in between the logarithmic detector and the trim gain operational amplifier. There is a logical trigger, which is derived from the bunch frequency and the macropulse signal, to control the S&H. Every BPM board has a delay line to compensate for a different arriving time of an electron bunch to different BPMs. The accurate S&H timing allows holding maximum of the AD8313 signal providing enough time for the ADC sampling. Certainly the ADC uses external clock linked to the bunch frequency.

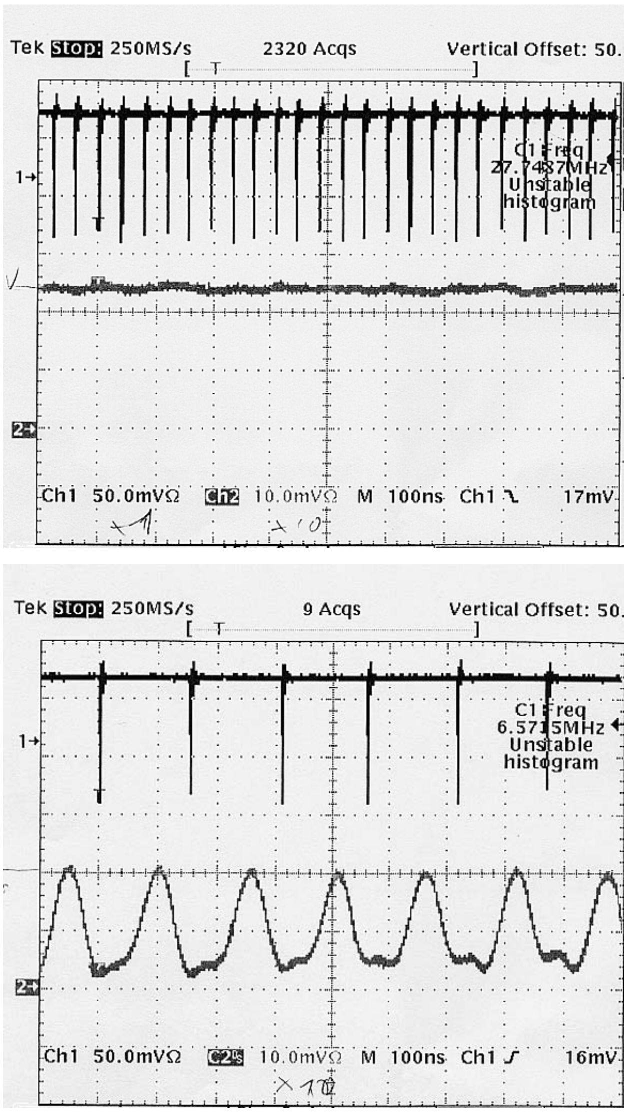

Figure 3: The AD8313 response at the different bunch frequency.

The sampling frequency of the ADC is constant and equals 101.5625 kHz, which is 13/128 MHz; this is the lowest possible bunch frequency. Changes in the board layout can introduce some extra noise and affect the beam position measurements. Because of this the modified BPM electronics were tested again, main criteria of the test is the BPM accuracy and its resolution.

ACCURACY OF THE POSITION MEASUREMENTS

To measure the beam position monitor accuracy one have to supply an "ideal beam", in other words the beam used for such measurements have to have stability degree much better than the assumed accuracy. Otherwise one could not distinguish between the beam motion and the electronics noise. All BPM electronics prototypes have demonstrated the accuracy in the range between 10 μm and 30 μm. Since it is not easy to make a beam stable better than 10 μm we have measured the BPM accuracy with the help of stable RF generator. For these measurements the generator via one-to-two splitter was connected to the RF cables, which normally connect two opposite BPM channels (X+ and X-) to the RF frond end. Because of the bandpass filter the frond end sees only one 1.3 GHz component of the broadband BPM signal. Thus the generator operating at 1.3 GHz was representing the ideal beam. Dependence of the 1.3 GHz component power of the BPM signal from the average beam current is known very well. Thus adjusting the generator power level we could simulate different current of the beam. The BPM DAQ system was used in the measurements as well. There is a LabVIEW application, which uses data from the DAQ and calculates position of the electron beam as a function of time within the macropulse. These are real time measurements of the beam position with the sampling rate of 101.5625 kHz. The noise in the position signal is caused by the electronics noise only. Thus we know to which beam displacement corresponds the electronics noise. The position signal was measured for several milliseconds at different RF power level of the generator. For every measurement standard deviation from the mean value was calculated. The standard deviation is the accuracy of a single position measurement. Results of the measurements are shown on the Fig. 4.

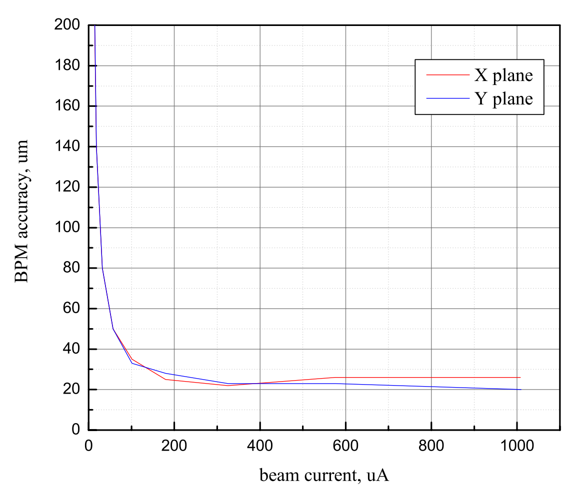

Figure 4: BPM accuracy.

The accuracy is better than 100 µm when the average beam current exceeds 25 µA. We would like to note here that the resolution of 100 µm was required and generally resolution is better than accuracy. Another important point is that we are interesting first in a stable accelerator operation and second we are measuring average position of a macropule, then the accuracy and the resolution are better in factor $N^{-1/2}$, where N is the number of measurements within the macropulse.

OFFSET MEASUREMENTS

Tolerances of the BPM manufacturing cause the electrical centre of the BPM to be different from the mechanical one. Electrical chains of the electronics working on the opposite electrodes of an BPM are also slightly different. These are the reasons for the offset in the beam position measurements and their current defence. The BPM was designed so that we can measure both this effects and take them in to account. The procedure was already described in [2] and is similar to the one used at CEBAF, JLab. One of the Y plane electrodes is driven by RF generator and signal from X plane electrodes are measured and equivalent X position is calculated. Results of such measurement for one BPM are shown on Fig. 5. If the BPM were a perfectly symmetric and the different chains of the electronics were identical we would not measure any “beam” displacement. The offset is measured for both planes for every BMP and is later taking in to account for position calculation by the BPM software.

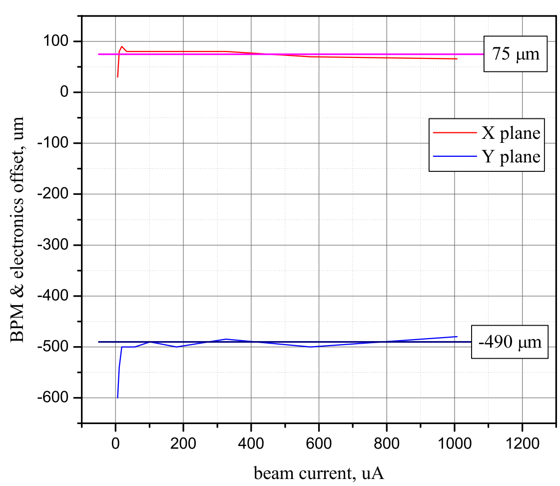

Figure 5: Measured BPM offset.

LONG-TERM STABILITY

Reproducibility of any accelerator is an important issue. Certainly have optimised the accelerator for a some application and having the optimal beam trajectory one want to be sure that next time running the machine for the same application one has the same optimal trajectory. Besides during a run it is important to see if there is a drift of the accelerator components. Thus if an operator see a beam displacement during a run or after loading accelerator settings he want to be sure that the beam displacement is the real one and is not just the BPM electronics drift. To understand the long-term stability degree of the electronics the technique described in the section about accuracy was used. This time the generator output power was constant and the equivalent beam position was measured for several hours. Results of the measurements are shown on Fig. 6.

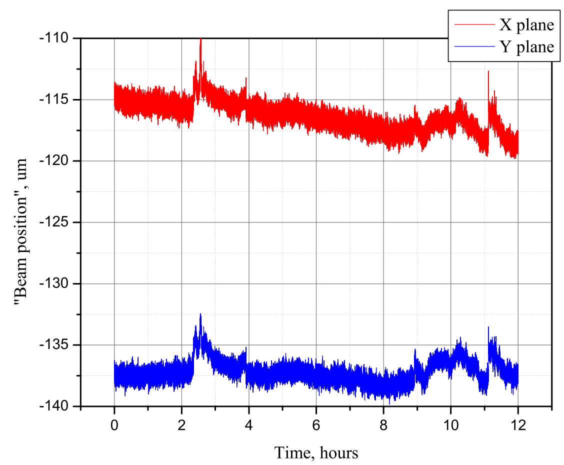

Figure 6: Long-term stability of the BPM.

The BPM electronics drift corresponds to a beam displacement of about 5µm was measured within 12 hours measurements period.

ACKNOWLEDGMENTS

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REFERENCES

[1] www.analog.com
[2] P. Evtushenko et al., Proceedings of DIPAC 2001Grenoble, 2001