INSTRUMENTATION FOR HIGH FREQUENCY CAVITY BPM IN CALIFES

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Abstract

The probe beam linac of the CTF3 test facility, named CALIFES, is developed by the CEA Saclay, the LAL Orsay and CERN to deliver short bunches (0.75 ps) with a charge of 0.6 nC to the CLIC 12 GHz accelerating structures. To setup the machine and obtain a precise beam handling, six high resolution beam position monitors (BPMs), based on a radiofrequency reentrant cavity with an aperture of 18 mm, are installed along the linac. The associated electronics is composed of an analog signal processing electronics with a multiplexing to control the six monitors. Due to mechanical tolerances, dipole mode frequencies are different for each BPMs, 100 MHz intermediate IF frequency is, therefore, used so that monitors operate in single and multi-bunch modes. Digitalised signals from acquisition boards are made available to the operation crew thanks to the OASIS interfaces. In this paper, the BPMs acquisition and the signal post processing, to extract the beam position, will be discussed and first beam tests will be presented.

INTRODUCTION

The probe beam electron linac, named CALIFES [1], is a part of the CLIC Test Facility (CTF3), aiming at demonstrating the two beam acceleration concept with 12 GHz travelling-wave structures. It will operate either in single bunch mode or in multi-bunch mode with a bunch spacing of 0.66 ns.

Six Beam Position Monitors (BPMs) with an aperture of 18 mm are installed along the linac. They are based on a radiofrequency reentrant cavity [2] with an associated electronics.

The beam-based alignment and feedback systems, essential operations for the future colliders, require high resolution BPMs. The simulated results are encouraging. The resolution, in the single bunch mode, was calculated around 5 μm with a dynamic range of ± 5 mm [3].

With cost reduction in mind, signal processing and acquisition electronics using multiplexing was proposed and is being developed to control the six monitors. In order to specify the beam position in single bunch and multi-bunch modes, from BPM signals, a signal post processing with a digital down-conversion (DDC) is employed to get a precise determination of digitized waveforms.

In this paper, the BPM system acquisition and the signal post processing of this monitor designed for CALIFES is described. Installation and first measurements with beam will be also reported.

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CALIFES BPM FRONT END

Coaxial reentrant cavities have been chosen for the beam orbit measurement − single bunch or 1.5 GHz bunch trains − because of their mechanical simplicity and excellent resolution. In 2008, six cavity BPMs with their electronics were installed in the CTF3/CLEX building.

The reentrant cavity BPM (see Fig.1) designed for CALIFES has the monopole and dipole modes frequencies around 3988 MHz and 5983 MHz respectively with low loaded quality factors to ensure broadband characteristics [3].

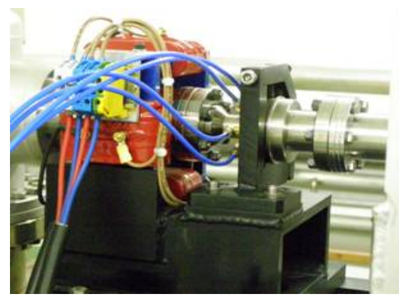

Figure 1: BPM and its steerer installed along the linac.

The six reentrant cavities BPMs of CALIFES are connected in parallel on two electronic crates. These crates are equipped with RF switches and adjustable attenuators. Signals from the cavity are detected by the signal processing, using single stage down-conversion electronics. More details are found in [3]. Switches are used to select one BPM over six; the two crates allow the visualisation simultaneously of two BPMs. For each selected monitor, analog output signals are the rectified Σ signal and I/Q IF signals: Ix, Qx, Iy and Qy. They are sent to acquisition boards (Acqiris boards) which have either four or two channels with 10 bits and a sample rate of 8 Gs/s. Switches and attenuators are driven by two VMOD-IO cards, each one equipped by four VMOD-TTL modules. Signals, sampled with Acqiris boards are readout on Open Analogue Signal Information System (OASIS) [4].

ARCHITECTURE FOR THE ACQUISITION SYSTEM

The BPM signals are interfaced directly in OASIS system that manages the connections and the acquisition settings. Like this, the waveforms can be visualized with working set menus (all these signals need to be previously defined in the database of the control system).

The acquired waveforms are exported into the control system by a device server written with the CERN Front-

End Software Architecture (FESA) framework. The server implements the properties specified by OASIS. From software point of view, acquisition of raw signals, coming from Acqiris boards, will be only available via the OASIS generic viewer. From there, we decided to use a Java application for the signal post processing and the graphics interface for users.

SIGNAL POST-PROCESSING

The Σ signal, which depends on the beam intensity, is measured by a direct detection using a Schottky diode detector installed in the signal processing electronics. To know beam charge, only a calibration factor is needed.

To determine the beam position in single bunch and multi-bunch modes, several steps on the digitized waveforms are required. First, a value V_0 corresponding to the ADCs offset will be added to digitized signals. As the dipole frequencies of the six BPMs have some dispersion around a few ten MHz, due to mechanical tolerances, an intermediate frequency IF is used. This IF frequency, coming from I/Q demodulator to the ADC boards, was chosen around 100 MHz. A method of signal post processing using a digital down conversion (DDC) was, therefore, developed thanks to a Java application. Frequency of digitized waveforms can be measured with OASIS properties. Once experimental IF carriers have been determined, the DDC is employed to calculate magnitude and phase. The raw waveforms (IQ signals), from analog signal processing of a given channel, are multiplied by a local oscillator (LO) of the same frequency ω_{if} to yield a zero intermediate frequency. Real and imaginary parts of each IF are then sent to a 60 coefficient, symmetric, finite impulse response (FIR) low pass filter with 40 MHz-3 dB bandwidth and the output signals become I_{DDC} and $Q_{DDC.}$ To specify the position and tilt signals a rotation θ from I_{DDC} and Q_{DDC} is calculated. The IQ phase θ is the angle between the IQ basis and the position tilt basis and is determined by the following equations (see Eq 1 and 2).

$$\cos(\theta) = \frac{I_{DDC_n}(t)}{A} = \frac{I_{DDC_n}(t)}{\sqrt{I_{DDC_n}(t)^2 + Q_{DDC_n}(t)^2}} \quad (1)$$

$$\sin(\theta) = \frac{Q_{DDC\,n}(t)}{A} = \frac{Q_{DDC\,n}(t)}{\sqrt{I_{DDC_n}(t)^2 + Q_{DDC_n}(t)^2}} \quad (2)$$

where n is the sample which represents the peak of the A amplitude signal for a significant beam offset around 1 mm.

The position P and tilt T signals are, therefore, given by the following relation (see Eq 3):

$$\begin{pmatrix} P \\ T \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} I_{DDC_n} \\ Q_{DDC_n} \end{pmatrix} \quad (3)$$

Normalization is carried out on the "Position" (P) channel with the ratio Px/Σ and Py/Σ.

Figure 2 shows the different steps used to determine the position of the beam.

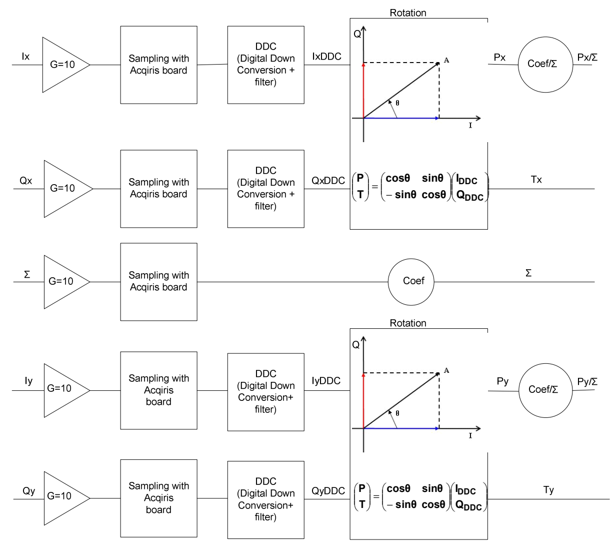

Figure 2: Schematic of signal post-processing.

Results (position and charge) are sent on a graphic window under Java and in a file to be used with MATLAB.

The calibration of BPMs, which is a mandatory step used only at the beginning of the commissioning phase, will be done with a dedicated software developed by the CEA with MATLAB.

FIRST BEAM MEASUREMENTS

April 2009, first beam tests and measurements were done. Command of switches and attenuators and reading of signals from BPMs was carried out with success. Figures 3 and 4 show the signals from CALIFES BPMs read with the OASIS viewer.

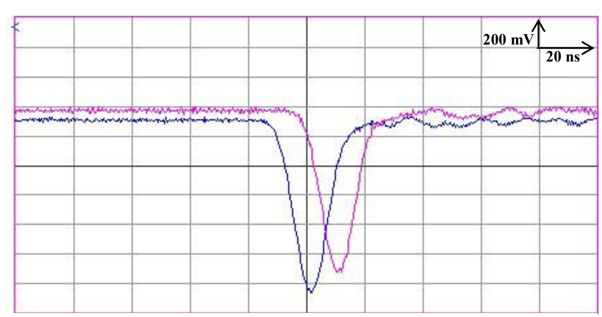

Figure 3: Visualisation of Σ signals of two BPMs.

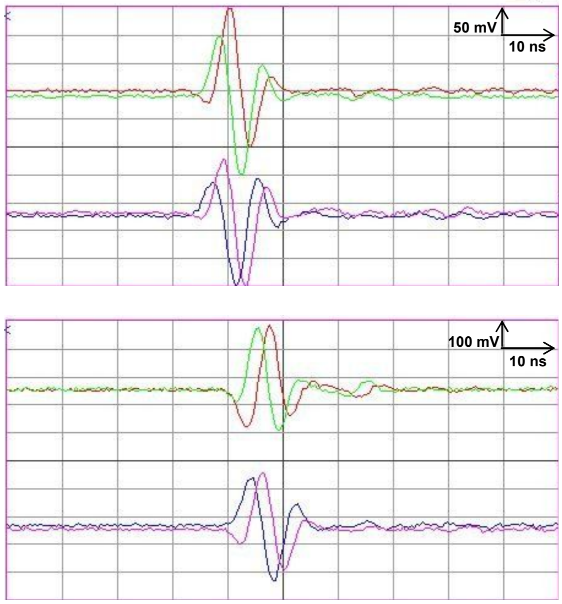

Figure 4: Visualisation of I and Q signals of two BPMs in vertical and horizontal frame in "10 bunches mode".

CONCLUSION

CALIFES BPMs use high frequency cavities (around 3988 MHz for the monopole mode and 5983 MHz for the dipole mode). To allow operation, in single and multi-bunch modes, of six different cavities with an unavoidable eigen frequencies dispersion keeping in mind a cost reduction, a multiplexed signal processing unit necessarily based on an IF translation and an DDC were developed. In April 2009, signals from the signal processing electronics were displayed with the OASIS viewer. Final signal post-processing and interface Java applications are under development and should be tested during the next beam time.

In the next studies, BPM calibration will be carried out. Charge will be calibrated with the measurement given by the Integrating Current Transformer (ICT) installed at the gun output. As the six BPMs use the same electronics and as cables were measured to get the same attenuation, coefficients will be the same for the six BPMs along the linac. Steerers will be used to calibrate beam position and a relative beam position will be determined by a transfer matrix between steerers and BPM.

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