MOPD10

A Calibration Method For The RF Front-end Asymmetry Of The DBPM Processor

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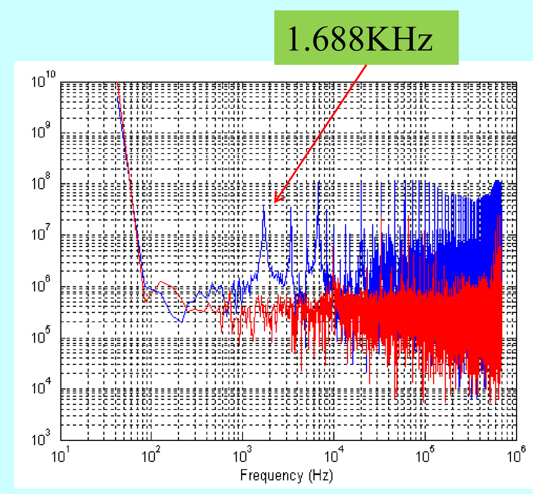
Abstract

Digital Beam Position Monitor (DBPM) processor, designed to measure the beam positions in the LINAC, the booster and the storage ring of a particle accelerator, has been used in many synchrotron radiation facilities. Channels asymmetry, which deteriorates the performance of the DBPM, is inevitable since the RF front-end needs four exactly same blocks. Recently, an RF Front-end board for DBPM has been made with calibration circuit which clears the switching noise. The calibration method will be described in detail, including an overview of the RF board. The beam current dependence, which is sensitive to channels asymmetry, decreases from 160um to 25um after the calibration in the lab test

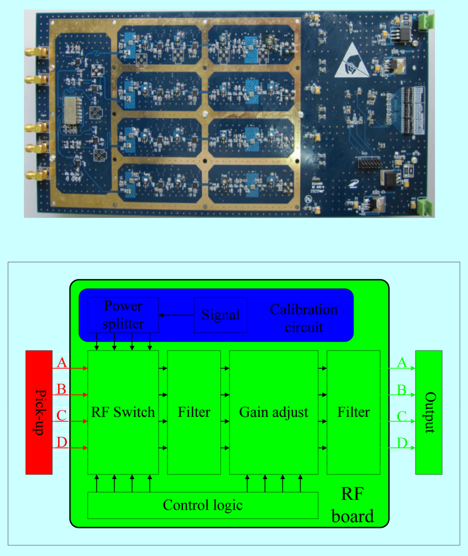
Introduction

Four exactly same process blocks are needed in DBPM, therefore channels asymmetry which deteriorate the performance of the DBPM is unavoidable. There are two widely used ways to suppress the influence. One is channels share technology or channels switch technology, such as MX-BPM and Libera . They both suppress the effect of the channels asymmetry. However, the resolution of the wide-band beam position information (Turn by Turn, for example) will be decrease due to the switching noise which cannot avoid, (Libera, for example). Figure shows the switch noise of TBT data captured from Libera in storage ring of SSRF.



Switches on (blue)and off(red)

RF board



Schematic and picture of the RF board

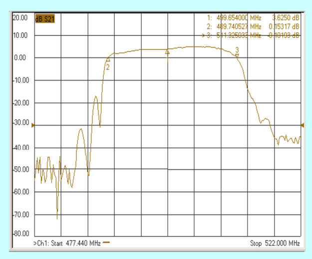
RF signals process part

●Filter part:

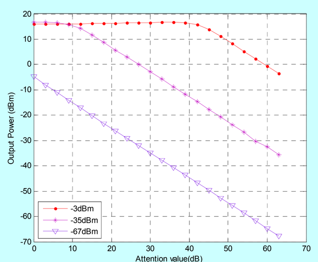
- ➢ Central frequency: 499.654 MHz
- ➢ Band width: 694KHz

●Gain control : Adjusted rang is 60dBm.

●Control logic: Control RF switches and dynamic rang



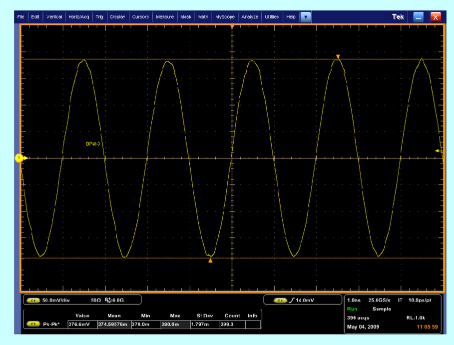
Frequency response



Gain control test

Calibration part

The calibration circuit consist of a signal generator, a RF switch and control logic. Waveform of the standard signal is sine whose frequency is 499.600 MHz. Amplitude rang of the output from 0 to -50dBm. The standard signal divided into four almost same signals by power splitter.

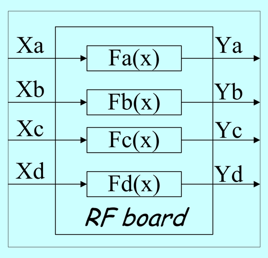


Waveform of standard signal

Calibration method

The calibration method is to fit the amplitude response function of the four channels. Then the coefficients of function is used to correct the asymmetry signals.

Crosstalk of four channels is very small, so the RF board could treat as four independent functions, as showed in right figure .



The amplitude response function are :

$$Y_a = F_a(X_a) \quad (1)$$
$$Y_b = F_b(X_b) \quad (2)$$
$$Y_c = F_c(X_c) \quad (3)$$
$$Y_d = F_d(X_d) \quad (4)$$

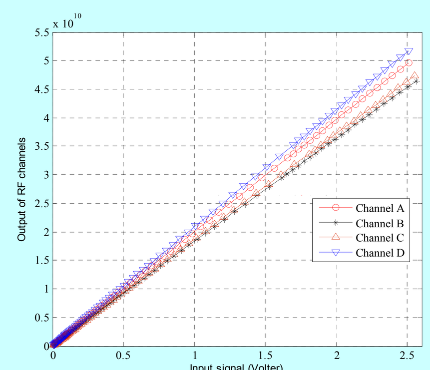
where

Y_a, Y_b, Y_c, Y_d : Output of the RF board

X_a, X_b, X_c, X_d : Input of the RF board

$F_a(X), F_b(X), F_c(X), F_d(X)$: Response functions

Figure shows the amplitude response of four channels.



Amplitude response of four channels

According to the sharp of the curves, piecewise linear function could be used as the target function (right Equation).

The target function is :

$$F(X) = \begin{cases} k_1X + m_1, & x_0 \le X \le x_1 \\ k_2X + m_2, & x_1 \le X \le x_2 \\ \cdots & \cdots \\ k_nX + m_n, & x_{n-1} \le X \le x_n \end{cases}$$

where

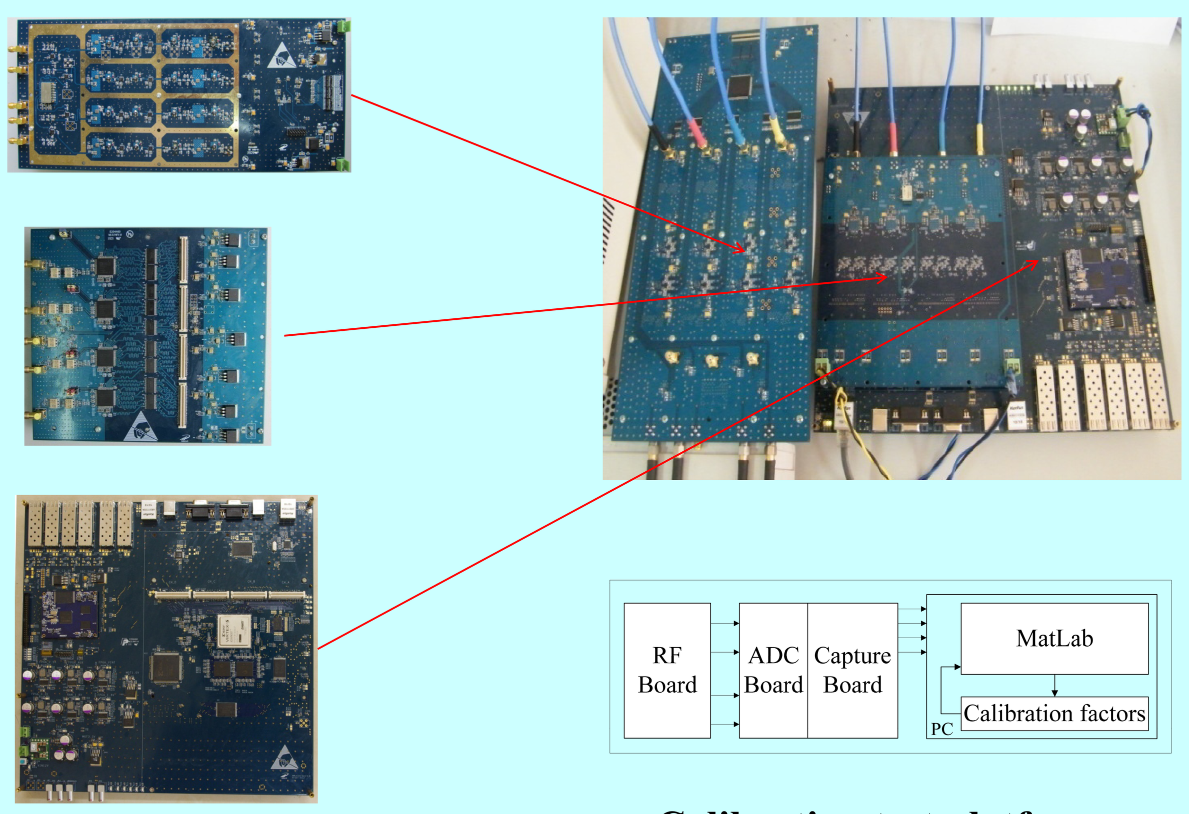
$k_1, k_2 \ldots k_n$: *Slope coefficients*

$m_1, m_2 \ldots m_n$: *Offset coefficients*

$x_1, x_2 \ldots x_n$: *Input signal*

n : *Sectionsof the curvedivided*

Calibration test



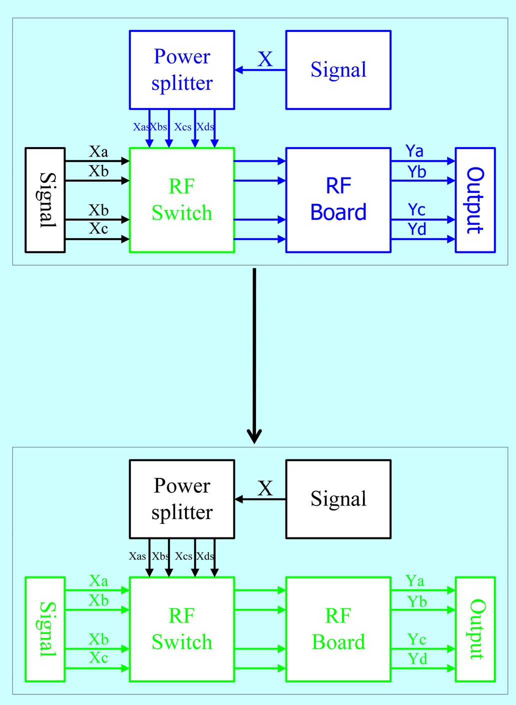
Calibration test platform

Step 1. fitting the correction factors

The input of the RF processing circuit is switched to be the calibration signals(right figure, blue parts). The amplitude of four output are acquired from PC . Target function is used to calculate the correct factors.

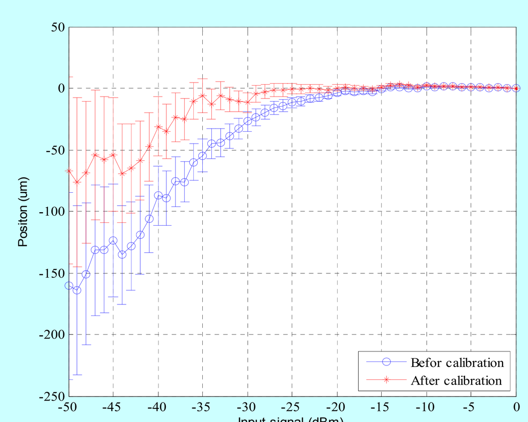
Step 2. Correct the asymmetry

RF switches are set to normal mode (right figure, green parts). Input signal of the RF processor comes from a signal generator which is used to simulation the output of the BPM pick-up. In this mode, the input signal will calibrate with the factors.



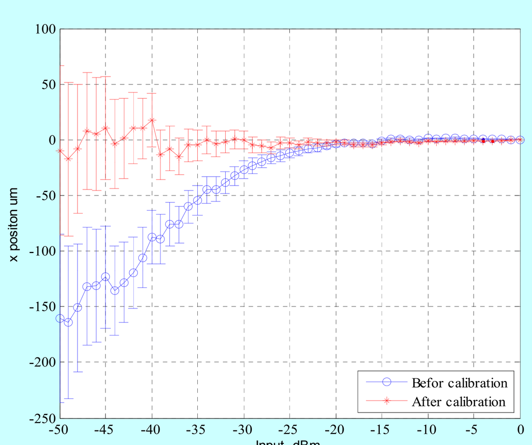
Calibration results

Beam current dependence used to evaluate the calibration method. Figure shows the calibration results. In this test linear function used as the fitting function. Beam current dependence decreases from 160um to 75um after calibration.



Beam current dependence (linear function)

To increase the fitting precision piecewise linear function was used as the target function. As shows in figure the curve will smoother than the left one. Beam current independence decreases from 160um to 25um.



Beam current dependence (piecewise linear function)

Conclusions

◆The calibration is valid.

◆The more sections the curve was divided, the better calibration precision the calibration would get.

◆Next goal is to implement the calibration method in the FPGA.