# Development of Spill Control System for the J-PARC Slow Extraction

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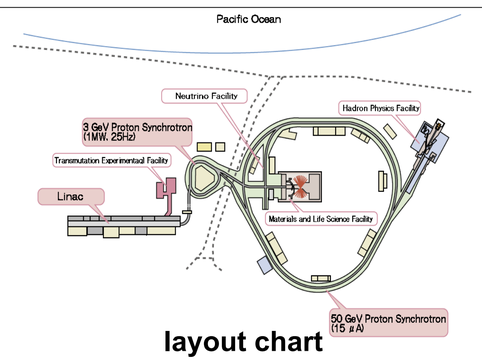
## Introduction

From J-PARC main ring (MR), 50GeV Proton Synchrotron, accelerated proton beam is slowly extracted, delivered to Hadron Experimental Facility and used for experiments of nuclear physics and particle physics. The slow extraction beam is required a flat structure and low ripple noise for hadron experiments. This requirement is realized using EQ and RQ, these are the quadrupole electromagnets, and feedback unit. We have developed the feedback unit using DSPs and carried out beam test. This presentation reports the spill feedback unit and the feedback techniques for slow extraction.

aerial photo

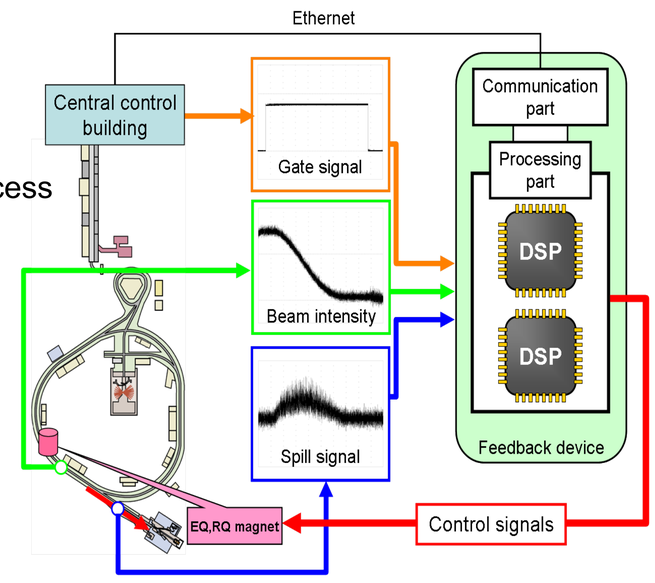



layout chart

## Spill Feedback

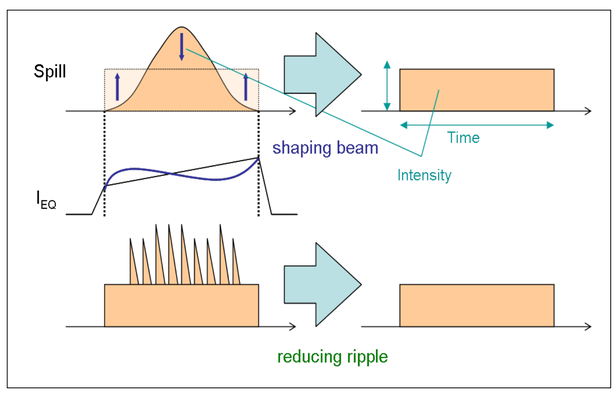
### •Feedback System

- Digital feedback using DSPs
- Input signals
  - –Gate signal: Enable control process
  - –Beam intensity: residual beam intensity in ring
  - –Spill signal: extracted beam intensity
- Output signals
  - –Ramping pattern to EQ and RQ
- Select Digital(16bit TTL)/Analog



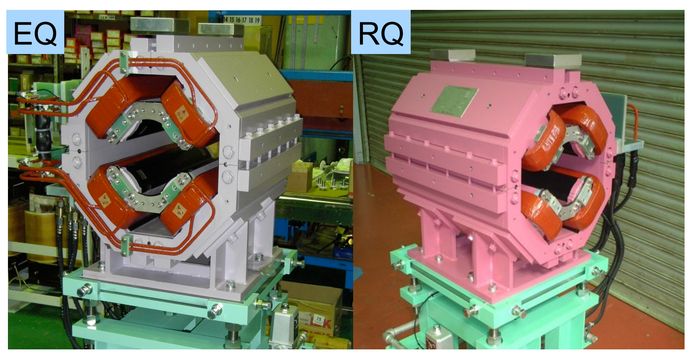

### •Extraction Q Magnet (EQ)

- Control horizontal betatron tune to make flat beam
- Reduce ripple noise lower than hundreds Hz




### •Ripple Q Magnet (RQ)

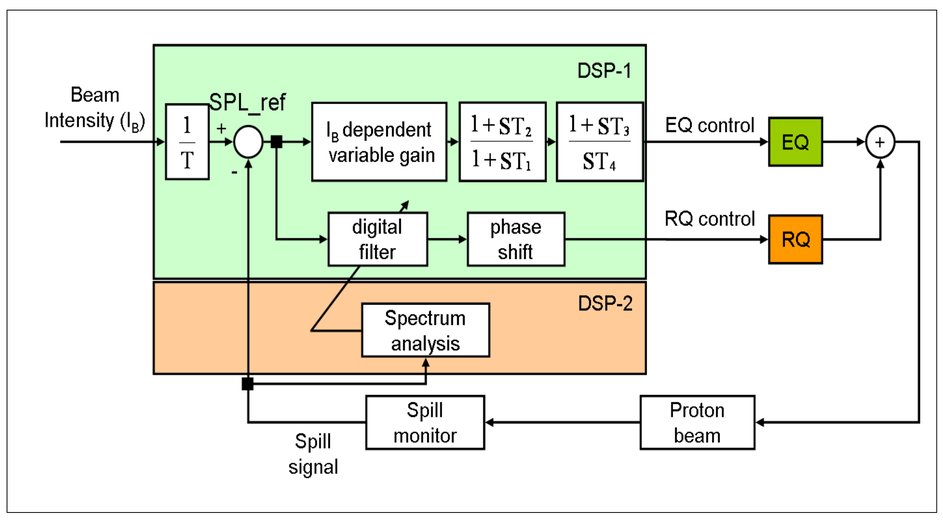
- Reduce ripple higher than few kHz
- Response is faster than EQ




### •Feedback Unit

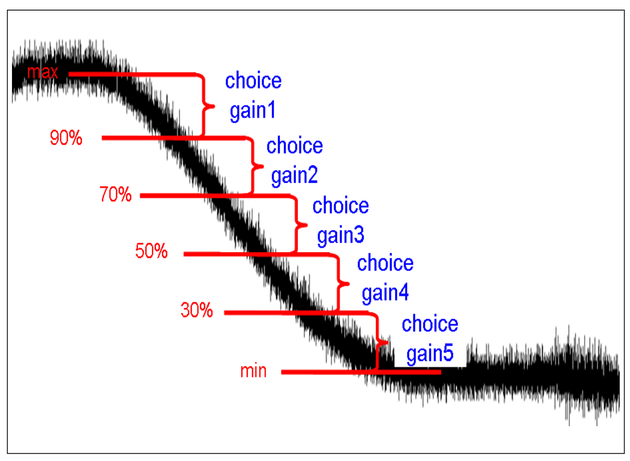



### •Feedback Algorism




$$SPL\_ref = \frac{MaximumBeamIntensity}{ExtractionTime(T)}$$

### •$I_B$ dependent variable gain



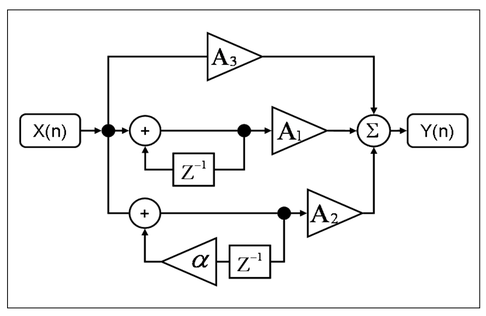

Use the optimum gain according to the beam intensity ($I_B$)

- Circuit board
  - –DSPs are TMS320C6713
  - –DSP1: feedback calculation
  - –DSP2 : power spectrum analysis
  - –Dual port memory: exchange data and control parameters between DSPs and Ethernet CPU.
- Ethernet CPU
  - –SUZAKU-V410
  - –Embedding Linux
  - –Remote control by EPICS
- I/O ports
  - –Select Digital(16bit TTL)/Analog
  - –TTL → Opt by KEK-VME
- Sampling rate
  - –From 1kHz to 200kHz is available

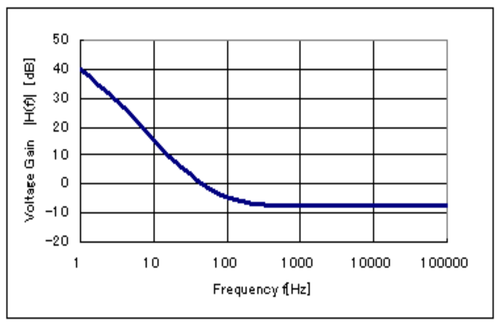
### •Transfer Function

Analog Transfer function of KEK-PS

$$\frac{1+ST_2}{1+ST_1}\frac{1+ST_3}{ST_4}$$

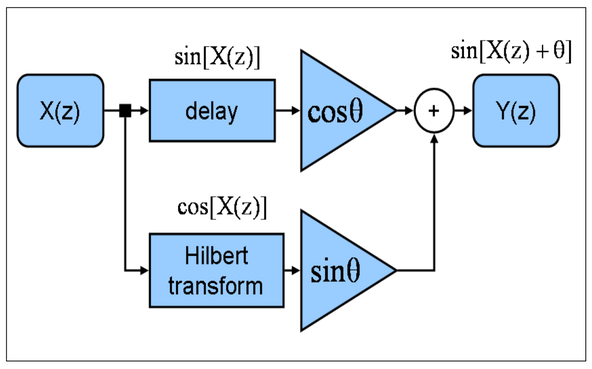



Digital transfer function for digital processing



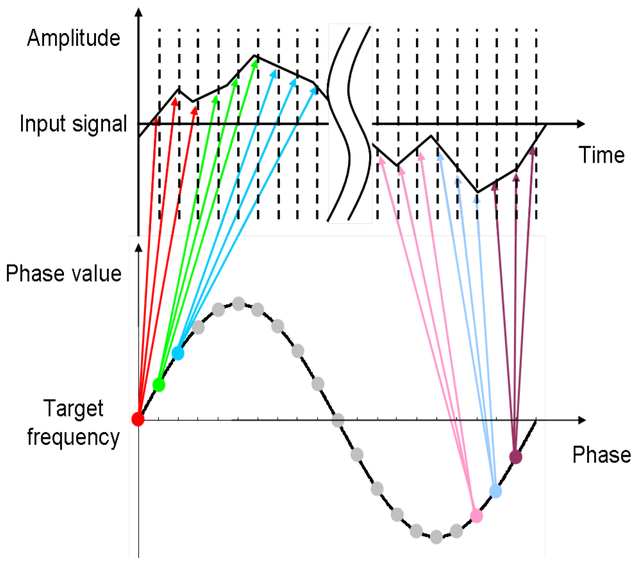

Frequency characteristic ($f_s$ = 120kHz)

### •Band Pass Filter and Phase Shifter




- Delay input signal by π/2 with Hilbert transform
- Reduce the ripple by reverse phase ramping pattern

- **PSD Method for spectrum analysis**
  - – Obtain multiply-accumulate at the end of sampling period
  - – Suitable for real time control

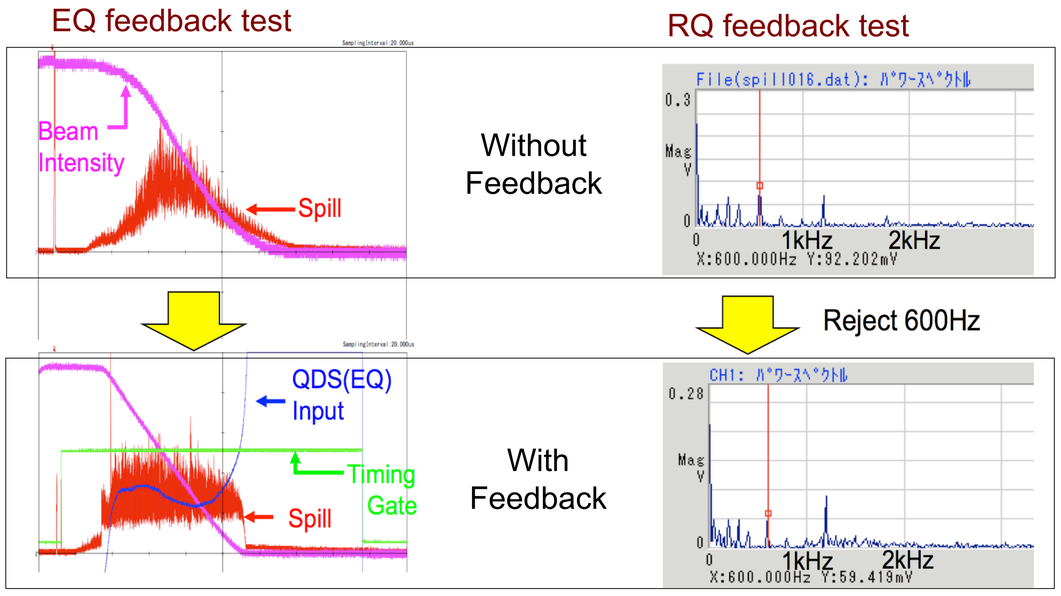



ref. Y. Murata et al., "A New Method for Digital Power Spectrum Analysis", NIM

## Beam test

The third integer resonance mode in HIMAC is same as J-PARC

Result of spill feedback test




### Foresight

- Remote control from the central control room
- Adoptive feedback control by PSD

**J-PARC/MR slow extraction schedule**

**feedback beam extraction : October,2009**