NEW AUTOMATIC BUNCH CURRENT SENSITIVE FAST ATTENUATOR FOR RF FRONT-END OF BUNCH-BY-BUNCH FEEDBACK SYSTEM AT SPRING-8

K.Kobayashi, T.Nakamura, JASRI/SPring-8
1-1-1, Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5198, Japan

Abstract

We currently developing a new bunch current sensitive automatic attenuation system for the RF front-end of the bunch-by-bunch feedback system in the SPring-8 storage ring. It controls the attenuation of the signal from high current bunch to avoid the saturation of RF front-end and for equalization of the feedback gain of hybrid beam filling modes consist of few-mA singlet bunches and sub-mA bunch trains. To achieve more attenuation level and more flexible operation, we are now developing a new attenuation system with a voltage variable and a digital controlled attenuator devices. This paper describes the new attenuation system and its test results.

INTRODUCTION

The SPring-8 bunch-by-bunch feedback system has been developed for suppressing transverse beam instabilities to realize top-up operation since January 2004 [1]. The block diagram of the feedback system is shown in Fig. 1. There are 2436 RF buckets in SPring-8 storage ring, and various filling modes are served for experiments of users. Table 1 shows typical filling modes in SPring-8 for the user operation. We have already developed and installed a bunch current sensitive automatic attenuator with a RF mixer as a variable attenuator, a discriminator and FPGA based 1-turn delay with the attenuation level of 15 dB [2]. However this attenuation level is not enough for hybrid filling modes with higher bunch current singlets and lower bunch current trains which are recently requested by users.

Table 1: Filling modes in SPring-8 storage ring. The total current of the ring is 100mA. Filling type 'hybrid-V' has not been achieved yet

Mode	Filling: train, filling of train	Filling: train, #of bunches	Filling: #of singlet	Bunch current(mA): train	Bunch current(mA): singlet	Ratio: singlet /train	Attenuation(dB): train	Attenuation(dB): singlet
multi				0.05			0	
203 bunches				0.50			20	
11 bunch train * 29				0.31			20	
4 bunch train * 24				0.30			20	
hybrid I	1/7	348	5	0.24	3.00	12.5	20	35
hybrid II	2/29	168	26	0.38	1.40	3.0	20	35
hybrid III	1/14	174	12	0.46	1.60	3.5	20	35
hybrid IV	4/58	168	53	0.28	1.00	3.6	20	35
hybrid V	4/7	1392	1	0.06	10.00	166.7	0	45

PRESENT CONDITIONS

Automatic Current Sensitive Attenuator

The feedback system is driven by the signal from a beam-position-monitor (BPM), and the level of this signal is proportional to the product of the position and the current of the individual bunch. The system is adjusted to the bunch current of 0.05mA/bunch which is the minimum bunch current in all the filling modes, this value is at multi-bunch filling. In the other filling modes, bunch current is nearly one order bigger than the multi-bunch filling mode, therefore we manually switch fixed attenuators between the BPM and RF amplifier of the input stage of feedback system to reduce the strength of the signal.

However, hybrid filling has high contrast of the bunch current, the feedback system with the fixed attenuator cannot handle both bunches simultaneously because of the saturation by large signal, or the shortage gain by large attenuation.

To overcome this problem, we made a simple bunch current sensitive automatic attenuator with a mixer, discriminator and an 1-turn digital delay with the ADC-FPGA-DAC board [2] (see Fig. 2). And operations of hybrid filling modes on I through IV in the Table 1 are achieved with this system.

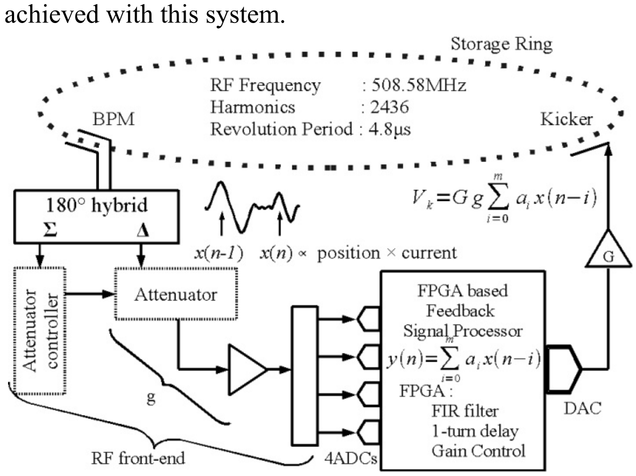

Figure 1: SPring-8 Bunch-by-Bunch Feedback system.

Filling Modes

The hybrid filling mode-V (in Table 1) is longed by users, to fulfil needs for time response experiments and high photon duty experiments simultaneously. But this filling mode has not been achieved yet. The reasons for this are following:

a) Present system has not enough feedback strength to achieve high feedback damping rate for single-bunch (>10mA), and has not so widely dynamic range.

b) The bunch current contrast between singlet and train part is about 45dB, the feedback system cannot work well because of the saturation of input signal under the present attenuation system.

The problem above a) will be solved in sight to introduce the developed high efficiency strip-line kicker and to employ the high power amplifier [2]. As the problem b), a range of the present automatic attenuate system is only about 15dB, therefore we need development of new system to deal with above high current contrast.

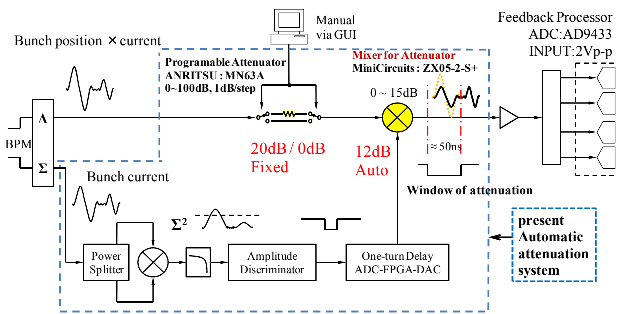

Figure 2: Present attenuation system.

DEVELOPMENT SYSTEM

Specifications to Request and Select Devices

The time structure of the hybrid filling IV and V (in Table 1) is shown in Fig. 3.

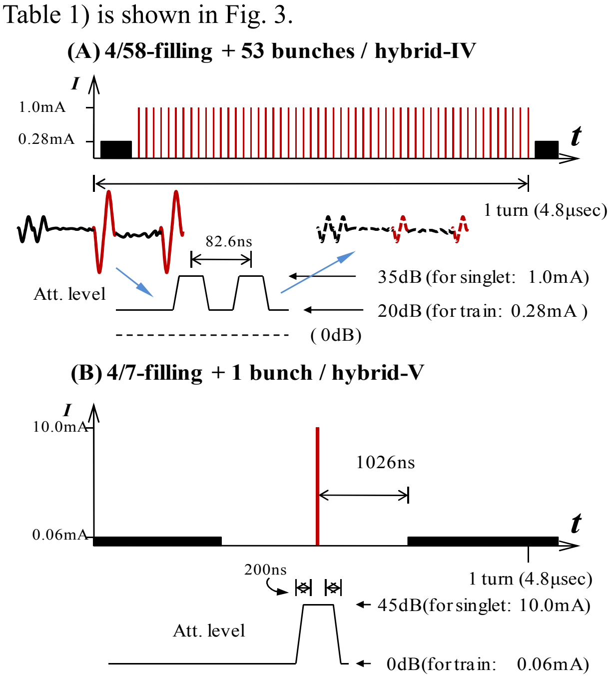

Figure 3: Hybrid filling and Attenuation Level.

As Table 1 and Fig. 3, it is necessary to switch the attenuate level from 0 to 15dB or in reverse within 50ns, on the other hand, 200ns is enough to switch for 45dB attenuation around 10.0mA-singlet.

We chose following devices as the candidates for the variable attenuator to fulfil such a request:

- HMC470LP3E [3];
  GaAs 5-Bit DIGITAL Control Attenuator (DC-3GHz)
  Range: 0-31dB
  Insertion Loss: <1.3dB
  Switching time: <180ns
  RF Input Power: 20dBm (Max: +27dBm)
- HMC346MS8GE [3];
  GaAs Voltage-Variable Attenuator (DC-8GHz)
  Range: 0-32dB
  Insertion Loss: <1.5dB
  Switching time: <8ns
  RF Input Power: 8dBm (Max: +18dBm)

HMC346MS8GE has 8ns switching time, which value is enough to treat the hybrid filling mode-IV. But only this one, it cannot stand high power input and cannot realize over 45 dB attenuate level. We also employ HMC470LP3E, which has 180ns switching time, it satisfies to switch around 10mA singlet and has power resistant. Using these devices we developed a prototype of the new attenuation system, and verified specifications by the test signal.

Test Bench

A prototype block diagram of new automatic bunch current sensitive fast attenuator is shown in Fig. 4. In Fig.4, "Pulse expander" is constructed using LV-TTL logic ICs, it works as an amplitude discriminator with LV-TTL's threshold level and which function is to expand a input pulse appropriate width for the next stage. The ADC-FPGA-DAC board samples this expanded output pulse. On the board, the pulse is more stretched and delayed almost one-turn period of SPring-8 storage ring, and the board produces both 5-bit digital code for the DIGITAL attenuator and analog voltage output for the Voltage Variable attenuator.

EVALUATION

Using this prototype system, following static and dynamic characteristics are obtained. The attenuate level was varied between 0dB and 45dB. The frequency of test input was between 200MHz and 800MHz. This is the range of the input signal to the ADCs of the feedback system, which employs "RF direct sampling scheme" to eliminate down conversion stage before ADCs [4]. As shown in Fig. 5 and Fig. 6, a static response of gain is steady, and a variation of phase shift is within plus/minus 5 degree. These characteristics are far exceeds those of the simple mixer in present system. Additionally it can work under the condition attenuation level which value is set 45dB. Simultaneously, the switching time between 0 and 20dB (HMC470LP3E) or between 0 and 15dB (HMC346MS8GE) is met the requirements from hybrid filling modes (see Fig. 7).

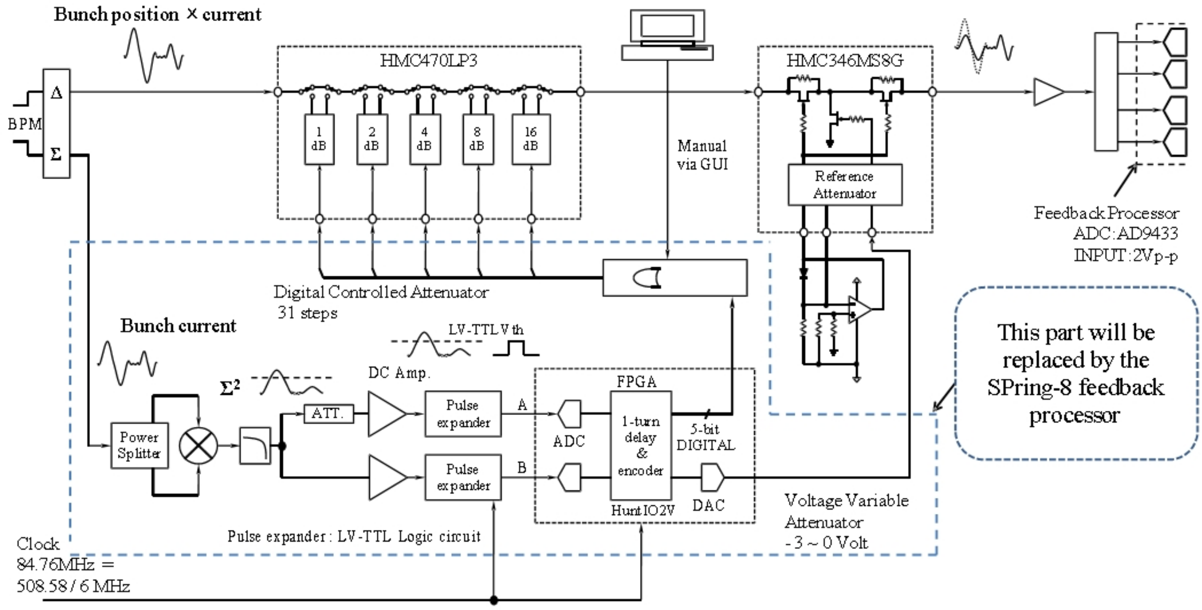

Figure 4: Test Bench for new attenuation system.

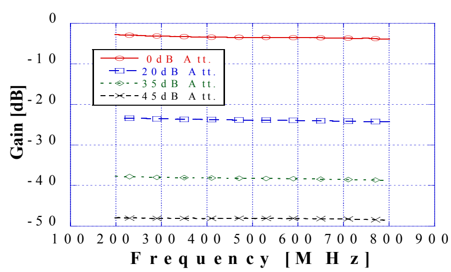

Figure 5: Gain response of attenuators vs. Signal frequency.

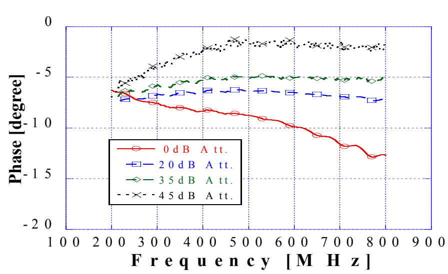

Figure 6: Phase shift of attenuators vs. Signal frequency.

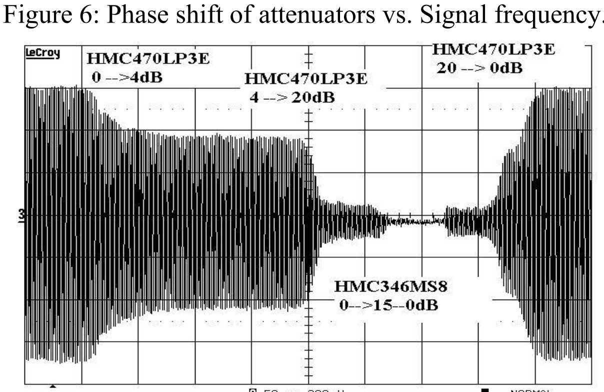

Figure 7: Test for switching speed with sinusoidal signal (508MHz). Horizontal scale is 50ns/div.

SUMMARY

As the result of the test bench, the new attenuation system can attenuate signal level between 0dB and 45dB. Especially over 15dB attenuate level, new system surpasses present system in both the gain response and the phase shift. As the switching speed, new system does not cause any problems. We conclude this new system is able to handle the hybrid filling with 10mA singlet and 0.06mA/bunch train part.

We will introduce this new attenuation system after a beam test, before long. High power amp and high efficiency kicker are also ready. And we have a plan to construct this new encoder and one-turn delay part (Fig. 4, inside of blue dashed line) into the SPring-8 bunch-by-bunch Feedback digital processor.

REFERENCES

[1] T. Nakamura, K. Kobayashi, "FPGA Based Bunch-by-bunch Feedback Signal Processor", Proc of ICALEPCS'05, Geneva, Switzerland, PO2.022-2 (2005).

[2] T. Nakamura, T. Fujita, K. Fukami, K. Kobayashi, C. Mitsuda, M. Oishi, S. Sasaki, M. Shoji, K. Soutome, M. Takao and Y. Taniuchi, Z. Zhou, "Filling of High Current Singlet and Train of Low Bunch Current in SPring-8 Storage Ring", Proc of EPAC08, Genoa, Italy, THPC127, (2008)p.3284.

[3] http://www.hittite.com/.

[4] T. Nakamura, K. Kobayashi, Z. Zhou, "Bunch by Bunch Feedback by RF Direct Sampling", Proc of EPAC08, Genoa, Italy, THPC128, (2008)p.3287.