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COMPARISON AMONG DIFFERENT TUNE MEASUREMENT SCHEMES AT HLS-II STORAGE RING*

L. T. Huang*, T. Y. Zhou*, Y. L. Yang, J. G. Wang, P. Lu, X. Y. Liu, J. H. Wei, M. X. Qian, F. F. Wu†, B. G. Sun‡
National Synchrotron Radiation Laboratory,
University of Science and Technology of China, 230029 HeFei, China

Abstract

Tune measurement is one of the most significant beam diagnostics at HLS-II storage ring. When measuring tune, higher tune spectral component and lower other components are expected, so that the tune measurement will be more accurate. To this end, a set of BBQ (Base Band Tune) front-end based on 3D (Direct Diode Detection) technique has previously developed to improve the effective signal content and suppress other components. Employing the BBQ front-end, four different tune measurement schemes are designed and related experiments performed on the HLS-II storage ring. Experimental results and analysis will be presented later.

INTRODUCTION

The electron storage ring is the major part of HLS-II, and some of its main parameters are shown in Table 1 [1].

Table 1: Main HLS-II Storage Ring Main Parameters

Parameter	Value
Energy	800MeV
Beam current	300mA
RF frequency	204MHz
Revolution frequency	4.534MHz
Emittance	40nm*rad
Tune(fractional part)	0.45/0.35

The fractional part of the tune for a storage ring can be measured by observing the betatron sidebands on either side of the revolution harmonics [2]. The past tune measuring method is usually to put the signals from the beam position pick-up directly into the spectrum analyzer after some addition, subtraction, filtering and amplification processing, and then analyze the spectral data to obtain the fractional part of the tune. In general, beam pulse signals from the position pick-up is very narrow in the time domain, resulting in energy dispersion in a wide spectrum. This way only uses one betatron sideband, which causes most of the betatron energy to be wasted. This means that substantial beam excitation is necessary in this method, which can lead to significant emittance degradation, so the system cannot be used during normal operation [3]. To solve this problem, 3D technique was initially developed at CERN for LHC to meet the requirements for measuring the tune of beam betatron oscillations with amplitudes below a micrometre [4]. The core of 3D technique is simple peak diode detector that can time-stretch the narrow beam pulses from the pick-up into slowly changing signals, meaning it's capable of moving most of the betatron energy to the baseband and improving the used betatron sideband intensity [5]. Using the BBQ front-end based on 3D technique, four different tune measurement schemes are designed for comparative experiments.

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† Corresponding author (email: wufangfa@ustc.edu.cn)
‡ Corresponding author (email: bgsun@ustc.edu.cn)

3D AND BBQ FRONT-END

3D technique uses two simple envelope detectors (also known as peak diode detector) connected to opposing electrodes of a pick-up. Followed by two DC blocking capacitors and a high impedance differential amplifier, a simplified BBQ front-end is completed, as shown in Fig. 1.

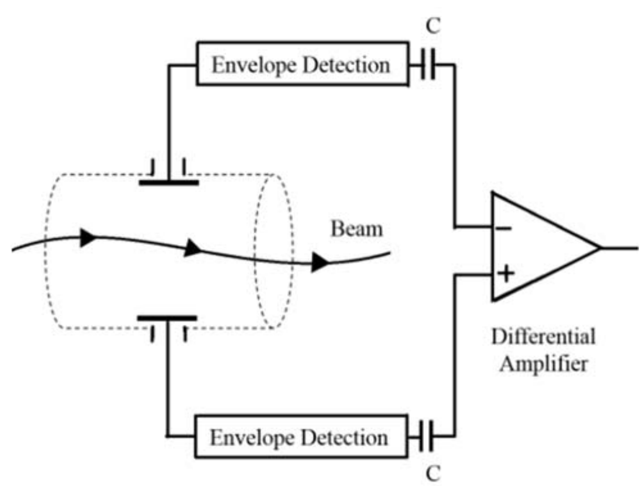

Figure 1: A simplified BBQ front-end schematic block diagram.

Based on the schematic block diagram above, a BBQ front-end was developed previously for HLS-II storage ring (see Fig. 2). The left two green parts are two peak diode detectors. The right box contains the rest: two capacitors and one differential amplifier.

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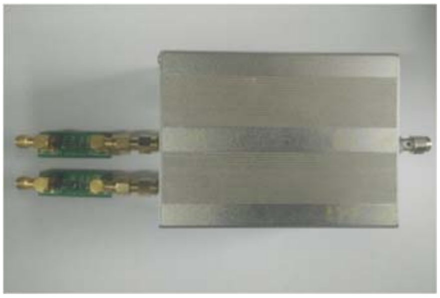

Figure 2: BBQ front-end physical picture.

FOUR TUNE MEASUREMENT SCHEMES

Scheme 1

Scheme 1 is the simplest one of four different tune measurement schemes (see Fig. 3). Sweep-frequency excitation (SFE) is used to excite the beam to generate proper betatron oscillations through stripline kicker. Without BBQ front-end, the signals from four electrodes of the stripline BPM are directly putted into the spectrum analyzer after some addition and subtraction processing.

Scheme 2

Considering the large noise in the low frequency, a 204MHz down mixer is added, which can move the whole spectrum down by 204 MHz, as shown in Fig. 4. It means smaller effective betatron signals and meanwhile lower noise. So a low noise amplifier is employed to strengthen the signals.

Scheme 3

Scheme 3 is one scheme using BBQ front-end (see Fig. 5). The signals, after addition processing, are firstly inputted into BBQ front-end.

Scheme 4

One common feature of the above three schemes is the addition processing, which means the final signal contains both horizontal and vertical tune information. Scheme 4 gives up the addition processing and uses two BBQ front-ends: one for horizontal tune information and another for vertical tune information.

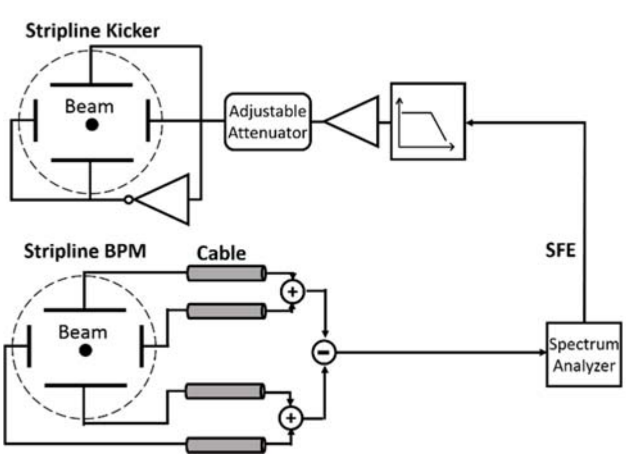

Figure 3: Scheme 1 schematic block diagram.

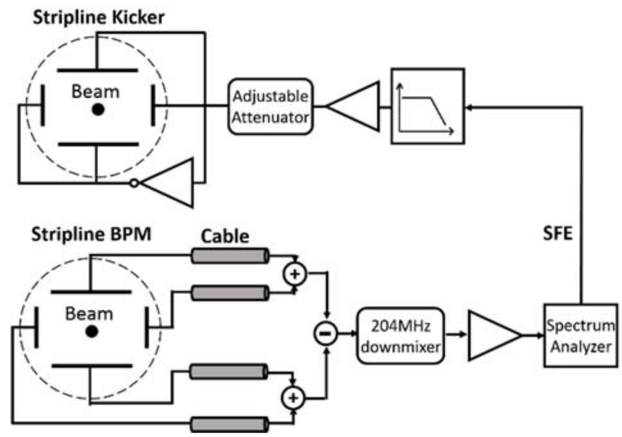

Figure 4: Scheme 2 schematic block diagram.

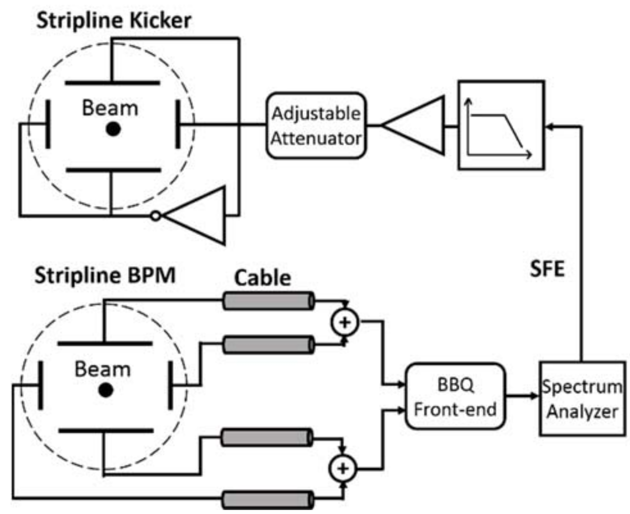

Figure 5: Scheme 3 schematic block diagram.

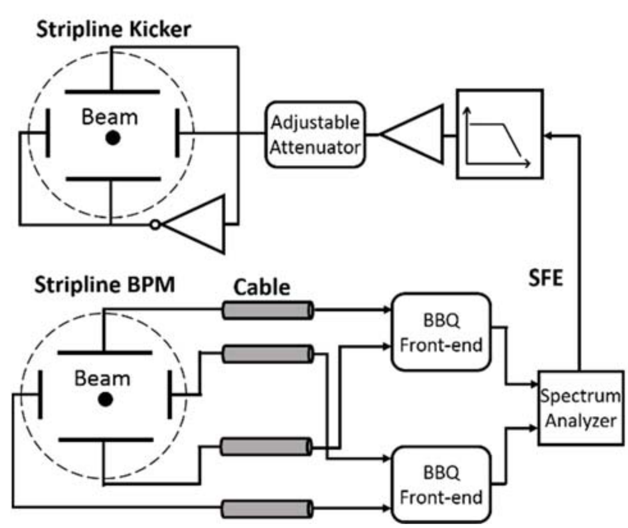

Figure 6: Scheme 4 schematic block diagram.

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RELATED RESULTS AND ANALYSIS

The result of scheme 1 with 0dBm SFE is shown in Fig. 7. It can be seen that the effective betatron sideband is quite weak and submerging in the noise (with SNR less than 10 dB).

In order to reduce the influence of noise, scheme 2 uses a down mixer to filter the low frequency noise. The result is shown in Fig. 8. It is clear that scheme 2 has higher SNR (more than 10 dB) when using lower excitation (-13 dBm SFE).

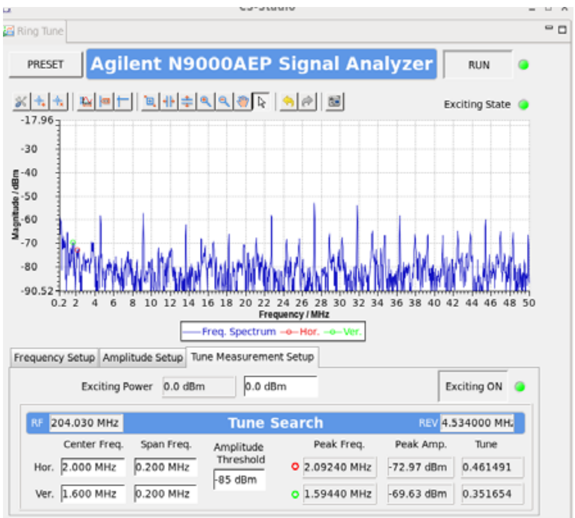

Figure 7: Result of scheme 1 (0 dBm SFE).

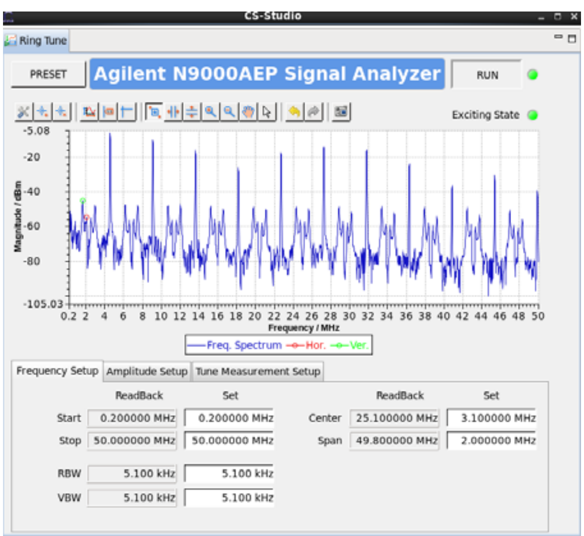

Figure 8: Result of scheme 2 (-13 dBm SFE).

In order to improve the effective betatron sideband intensity near the baseband, scheme 3 uses a BBQ front-end to convert the energy of betatron oscillation into the baseband, and the result under -13dBm SFE is shown in Fig. 9. It can be obviously seen that BBQ front-end indeed moves the betatron energy to the baseband, compared to the result of scheme 2. It makes the intensity of the effective sideband much higher than scheme 2 and the SNR is about 20dB as a result, althouth the energy of the noise is also converted to the baseband at the same time.

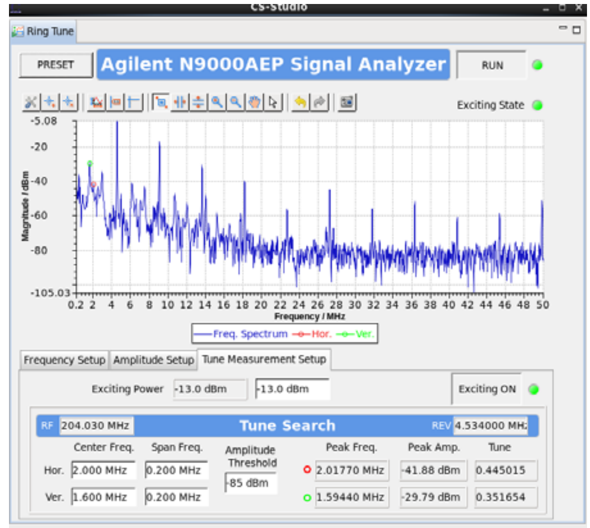

Figure 9: Result of scheme 3 (-13 dBm SFE).

Scheme 4 measures horizontal and vertical tune respectively, as shown in Fig. 10. Although it needs two BBQ front-ends, it obtains higher SNR than scheme 3. The key is the lower noise in the baseband.

Comparing the results under different SFE powers between scheme 2 and 3, it is found that scheme 3 can observe the tune precisely using lower SFE power (-40dBm) than scheme 2 (-34dBm), which proves the SNR improvement of BBQ front-end (see Fig. 11). 3D technique indeed makes the tune measurement more sensitive than before.

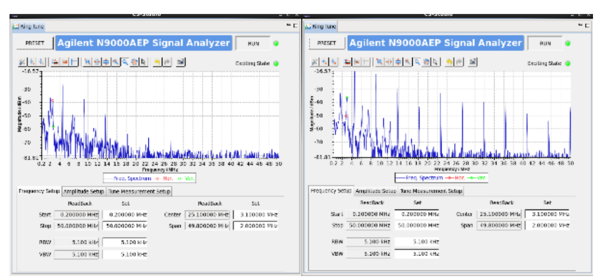

Figure 10: Result of scheme 4 (-13 dBm SFE). (left) horizontal tune; (right) vertical tune.

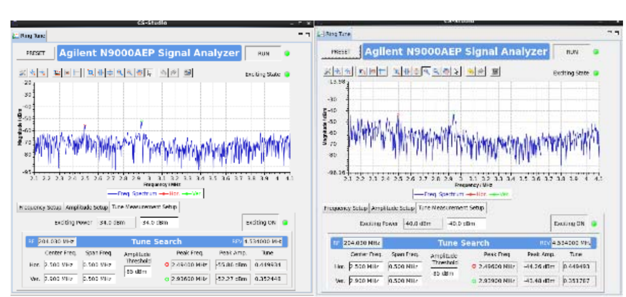

Figure 11: Comparison between scheme 2 and 3. (left) scheme 2 (-34 dBm SFE); (right) scheme 3 (-40 dBm SFE).

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CONCLUSION

This paper proposes four different tune measurement schemes based on BBQ front-end. Experimental results prove BBQ front-end indeed increases the betatron frequency content in the baseband, leading to higher sensitivity of tune measurement than before. Scheme 4 has the best performance in four schemes, but cost nearly twice that of scheme 3. Compromising performance and cost, scheme 3 is relatively the best choice with enough sensitivity (observe the obvious betatron sideband under -40dBm SFE) and low cost.

REFERENCES

[1] J. J. Zheng *et al.*, "Applications of the Tune Measurement System of the HLS-II Storage Ring", in *Proc. IPAC'16*, Busan, Korea, May 2016, pp. 2892-2894.

[2] M. Gasior and R. Jones, "High Sensitivity Tune Measurement by Direct Diode Detection", in *Proc. DIPAC'05*, Lyon, France. Pp. 312-314.

[3] L. T. Huang *et al.*, "Test of the Tune Measurement System based on BBQ at HLS-II Storage Ring", in *Proc. IPAC'18*, Vancouver, BC, Canada, pp. 4926-4928. doi:10.18429/JACoW-IPAC2018-THPML111

[4] M. Gasior, "Faraday Cup Award: High Sensitivity Tune Measurement using Direct Diode Detection", CERN, Geneva, Switzerland, Rep. CERN-ATS-2012-246, Apr. 2012.

[5] M. Gasior and R. Jones, "The Principle and First Results of Betatron Tune Measurement by Direct Diode Detection", CERN, Geneva, Switzerland, LHC-Project-Report 853.