EXPERIMENTAL STUDY OF TUNE VARIATION AT THE STORAGE RING OF SRRC

K. T. Hsu*, Jenny Chen, C. H. Kuo, K. H. Hu, C. C. Kuo, K. K. Lin, T. S. Ueng
Synchrotron Radiation Research Center
No. 1 R&D Road VI, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan, R. O. C.

Abstract

Tune variations at the storage ring of SRRC have been investigated experimentally by using of turn-by-turn beam position data and precision tune extraction algorithm. Tune extraction algorithms that require small number of turns are used to give instantaneous tune of the storage ring. Amplitude dependent tune shift and temporal behavior of tune shift due to various environment factors is explored. Preliminary results and discussion will present in following paragraphs.

1 INTRODUCTION

Time dependent variation in tune is important on various beam physics aspects. Two standard algorithms provide the tune from a time series of N consecutive values of the particle trajectory: the average phase advance (APA) in phase space and the fast Fourier transform (FFT) of turn-by-turn position data. However, both methods have intrinsic error is proportional to 1/N [1]. However, in some applications one requires higher frequency resolution in as few turns as possible [1,2,3]. The initial beam deflection smears out too quickly, either by filamentation or by radiation damping. The amplitude dependent tune shift so call detuning is one of the outcomes of the lattice non-linearity [4,5]. There are several sources cause tune varies as function of time. Power supply ripple is one of the sources that are also investigated in this report.

2 INSTANTANEOUS TUNE EXTRACTION ALGORITHM

Instantaneous tune extraction algorithm is based on J. Laskar [1] proposed the search of the maximum of the continuous Fourier transform so call numerical analysis of fundamental frequency (NAFF) method. The NAFF algorithm are successful applied to study various nonlinear beam dynamics in SPEAR [2,3]. The NAFF is applied to a subset of numerically or experimentally obtained turn-by-turn trajectories starting at turn m containing N turns

f_n , where n = m, … m+N-1,

f_n represents turn-by-turn data for one of the canonical variables. We search for the fundamental frequencies $\nu_{m,N}$ that maximize the absolute value of the correlator

$$I(\nu_{m,N}) = \sum_{n=m}^{m+N-1} f_n \exp(-i2\pi \bullet \nu_{m,N})\chi_{m-n}$$

These frequencies extracted from the numerical tracking data asymptotically converge for N → ∞ to the tunes associated with invariant surfaces in the phase space.

$$\chi_{m-n} = \sin(\frac{\pi \bullet (m-n)}{N})$$

Where χ_{m-n} is the weighting function to improve the precision of extracted tune. Having computed $\nu_{m,N}$, this way chi square fit the amplitude $a_{m,N}$ in the fitting function

$$f_n = \sum_k a_{m,N}^k \cos(2\pi \cdot \nu_{m,N}^k n + \psi_{m,N}^k)\chi_{m-n}$$

The instantaneous amplitude $a_{m,N}$ can be computed by chi-square fitting with measured position fn. The amplitude can also obtained by using Hilbert transform of the measured data.

3 MEASUREMENT

Turn-by-turn beam position monitors is based on 500 MHz log-ratio detector. The signal picked up by the BPM was processed by the log-ratio detector that was described in the reference [6]. Turn-by-turn beam position are recorded by the transient recorder. One of the injection kickers in the horizontal plane was used to excite stored beam. Beam excitation in vertical plane is done by applied burst tone in vertical betatron frequency with selective amplitude and burst counts. To study the tune variation due to power supply, the beam excitation should be synchronize with power line and varies the phase relative to AC phase. The data acquisition cycle at fixed phase with respect to AC to avoid the influence of the 60 Hz ripple in the magnet field for the other study. The trigger control and data acquisition is done on VME crates. The system functional block diagram is shown in Figure 1. The client software, which is running on control console, coordinates the operation of the system and collects the data. Then the collected data set is

* e-mail: kuotung@srrc.gov.tw

analyzed on console computer by MATLAB script file for NAFF analysis. Figure 2 shown the test results of NAFF analysis for horizontal plane near fifth order resonance, it is shown a clear chromaticity modulation appear. The tune extraction error with N=256 is less than 0.00005 for betatron amplitude large than 2 mm.

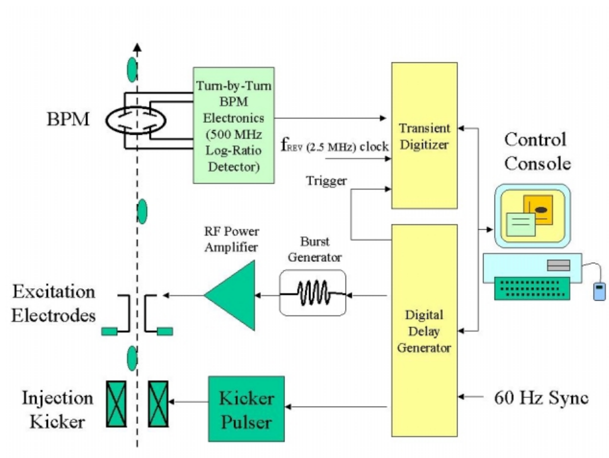

Figure 1. Block diagram of turn-by-turn beam position acquisition system and beam excitation.

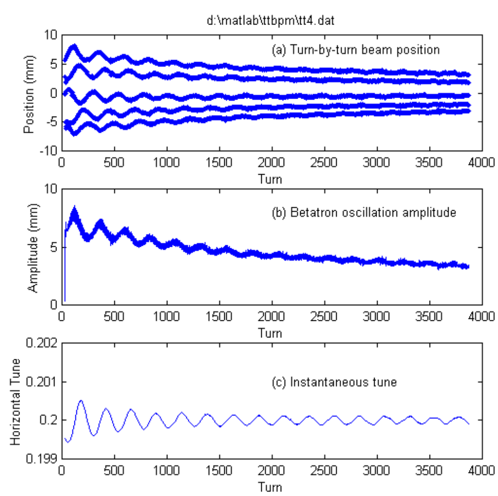

Figure 2. Tune extraction algorithm example for the turn-by-turn data at fifth order resonance. (a) Turn-by-turn beam position; (b) Amplitude of the betatron oscillation; (c) Instantaneous tune extracted by NAFF method.

4 AMPLITUDE DEPENDENT TUNE SHIFT

Amplitude dependent tune shift so call detuning is important in nonlinear lattice study. On the experiments, beam was excited in horizontal plane by injection kicker. All data was take at same trigger phase respective to power line to eliminate the effect of power supply ripples. Acquired turn-by-turn beam betatron oscillation is analysis by NAFF algorithm as shown in Figure 3. The amplitude is extract by take the absolute value of the sum of in-phase and quadrature component. Quadrature component of the beam position is done by Hilbert transform of the raw data. The tune value is increase as betatron amplitude decrease. There is different slope in the detuning curve for larger and small amplitude whether it is due to experimental reason or not need further study. Investigate the effect of the detuning on various conditions are needed to understand its nature.

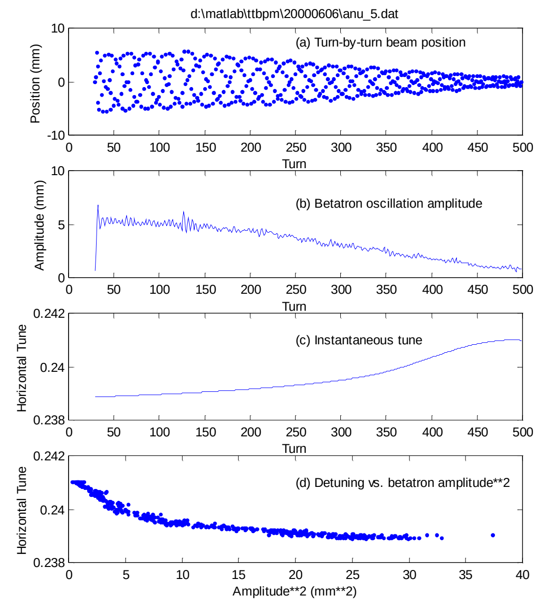

Figure 3: Tune as function of betatron oscillation amplitude. (a) turn-by-turn beam position; (b) Amplitude of the betatron oscillation decay; (c) Tune as function of turn numbers; (d) Tune as function of square of the betatron oscillation amplitude.

5 TUNE VARIATION DUE TO POWER SUPPLY RIPPLE

Transverse turn-by-turn beam position was processed by NAFF analysis to extract instantaneous tune, the stored beam was excited by phase locked with power line with phase as varied by delay generator. Figure 4 shown the tune variation as function of delay time for 300 measurements. The data was performed 5 points running averaged to remove noise. It is clear shown that the tune variation due to ripple is about 0.0002 peak-to-peak. There are two peaks on the spectrum of tune, one is the 60 Hz the other is 10 Hz. The data was taken during booster is running which work with resonance excitation at 10 Hz., it may be due to interference from booster operation, the variation is about 0.0002 peak-to-peak. However, the data acquisition delay range is only slightly large than 100 msec, the confidence of this peak may pausable. Further study is needed to clarify the source of this peak.

In Figure 5 shown the vertical tune variation as function of delay time. It is clear shown that the tune variation due to ripple is about 0.0003 peak-to-peak. It is strange why the peak of 60 Hz is not prominent, it should study more detail.

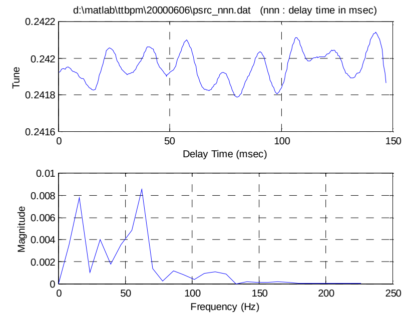

Figure 4: Horizontal tune as function of delay time (upper figure); spectral analysis of the tune modulation (lower figure).

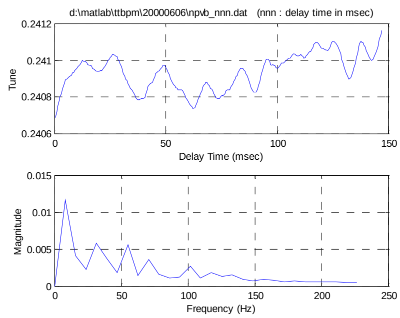

Figure 5: Vertical tune as function of delay time (upper figure); spectral analysis of the tune modulation (lower figure).

6 NON-PERIODIC TUNE VARIATION

About 300 kicks were applied during a 10 min test period with constant relative phase respect to power line to ensure tune variation not related to the power supply ripple. Instantaneous tune versus amplitude square was computed for each kick and the extrapolation of the tune to zero amplitude was performed. Two of the consecutive kicks are shown in Figure 6. The difference in horizontal tune between these two kicks is about 5 x 10e-4 which is an order of magnitude great than combined error of the tune extraction method and measurement error. There it should be interpreted as physical tune variation. Figure 7 and Figure 8 shown the tune variation in horizontal and vertical plane form 300 kicks data has tune variation near 0.0005 peak-to-peak.

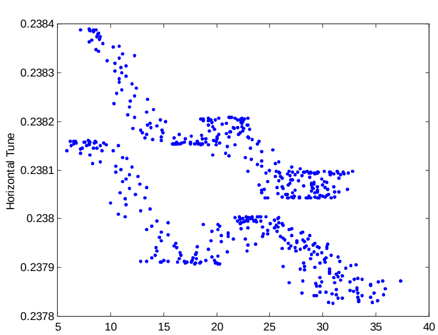

Figure 6. Tune as function of amplitude square for two consecutive kicks

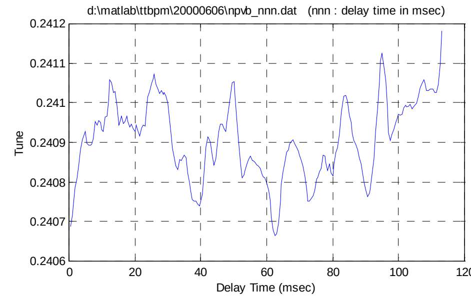

Figure 7: Non periodic horizontal tune variation.

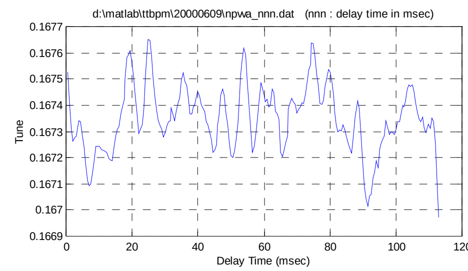

Figure 8: Non periodic vertical tune variation.

7 SUMMARY

We describe a study on the tune variation at the storage ring of SRRC in this report by using technique that developed by SPEAR group. Turn-by-turn beam position measurement combine with precision tune extraction algorithm is the tool of these experiments. Preliminary study focus to test the functionality of the hardware and software, so the study is qualitative in nature. More accuracy investigate is under planning to provide quantitative results.

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