Study of the Power Supply Ripple Effect on teh Dynamics at SPEAR

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Abstract

For long term stability analysis time variation of tunes is important. We have proposed and tested a technique for measuring the magnitude of this variation. This was made possible by using tune extraction algorithms that require small number of turns thus giving an instantaneous tune of the machine. In this paper we demonstrate the measured effect of the tune modulation with 60 Hz power supplies ripple, power line interference from SLAC linac operating at 30 Hz repetition rate, and non-periodic variation.

1 MOTIVATION

The effect of time dependence of the Hamiltonian on the short and long term stability has been studied before analytically and numerically [1][2][3]. For practical application of the results of these studies one needs to know the magnitude of such variation. If the primary source is the ripple in the power supplies and consequently in the magnetic field, a straightforward measurement of its magnitude would require either precise Hall probe measurements and/or careful calculations of the filtering effect of the magnet iron cores and vacuum chamber at the harmonics of 60 Hz [4]. Alternatively one could use turn-by-turn BPM measurements that have become standard for non-linear dynamics studies in the past few years in combination with recent tune extraction techniques from the turn-by-turn data [5],[6].

2 MEASUREMENT AND INSTANTANEOUS TUNE EXTRACTION TECHNIQUE

For measurement we used the turn-by-turn transverse phase space monitor described in [7] and its upgrade [8]. Transverse betatron oscillations of a single bunch are excited by a pair (horizontal and vertical) of fast kickers. Following the kick the transverse position of the bunch at two BPM locations is recorded every turn. We have modified the fast kicker triggering circuitry to initiate data acquisition at a controlled phase with

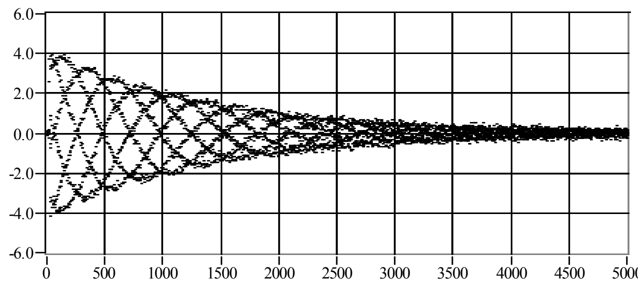

Fig.1 Horizontal centroid position (mm) vs. turn number

respect to AC. A typical response of the bunch centroid to a kick as detected at one BPM is shown on Fig.1.
We compute the instantaneous tune $\nu_{m,N}$ associated with N consequent turns starting at turn m by maximizing the absolute value of the correlator

$$I(\nu_{m,N}) = \sum_{n=m}^{m+N-1} f_n \cdot \exp\left(-i2\pi\nu_{m,N}\, n\right)\chi_n \qquad (1)$$

where f_n bunch position at the n - th turn and
χ_n weight function, we use $\sin(\pi \cdot n / N)$

Having computed $\nu_{m,N}$ this way we chi-square fit the amplitude $a_{m,N}$ in the fitting function

$$g_n = a_{m,N} \cos\left(2\pi \cdot \nu_{m,N} n + \psi\right) \qquad (2)$$

The accuracy of instantaneous tune extraction algorithm in application to realistic data was numerically tested [8]. For N = 256 that we use for the measurements described in this paper and betatron amplitudes > 1.5 mm, the frequency error is < 0.00005. The modulation of the transverse tune due to the coherent longitudinal oscillations having a period of ~50 turns is averaged out. This accuracy should allow reliable detection of the tune variation of magnitude $\sim 1\times 10^{-3}$ which may result from ripple in the guiding and focusing fields, modulation of

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the RF parameters at harmonics of AC, or the non-harmonic ground motion and power supplies drift.

If the machine is tuned sufficiently far from low order resonances the non linear tune shift with amplitude to the first order is

$$\nu_x = \nu_x^{(0)} + h_{xx} J_x + h_{xy} J_y + \ldots,$$
$$\nu_y = \nu_y^{(0)} + h_{yy} J_y + h_{yx} J_x + \ldots \qquad (3)$$

We extrapolate measured $\nu_{m,N}$ vs. $a^2_{m,N}$ to zero amplitude by fitting a second order polynomial.

3 RESULTS AND INTERPRETATION

3.1 Non periodic variation

In the first test ~200 kicks were applied during a 5 min period maintaining constant relative phase with respect to AC to separate the tune variation not related to the power supply ripple. The $\nu_{m,N}$ vs. $a^2_{m,N}$ was computed for each kick and the extrapolation of the tune to zero amplitude was performed. Few of these plots are shown for kicks approximately 1 s apart in Fig. 2.

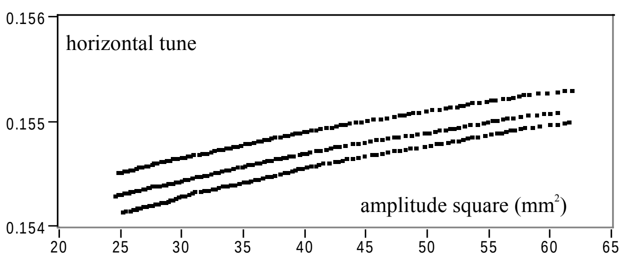

Fig.2 Horizontal tune vs. amplitude square for 3 consequent kicks.

The difference in ν_x between these graphs is ~5×10e^{-4} which is an order of magnitude greater then combined error of the tune extraction method and measurement error. Therefore it should be interpreted as physical tune variation.

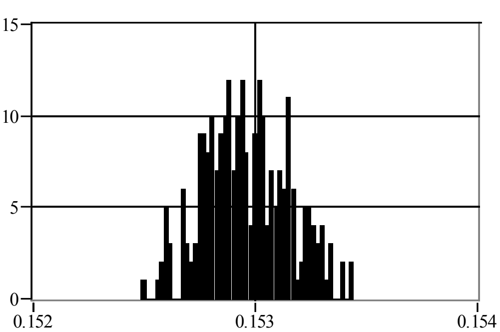

Fig.3 Distribution of horizontal tunes at 0 amplitude measured over 5 min. period at fixed phase relative to AC.

The distribution of horizontal tunes extracted from 200 kicks (Fig.3.) has FWHM of 4×10e^{-4}.

3.2 Periodic tune modulation

For the second test relative phase with respect to the AC was varied. The horizontal and vertical tune modulation is shown on Fig. 4, 5 and 6.

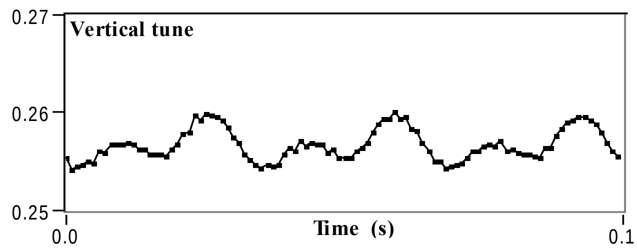

Fig.4 Modulation of vertical tune

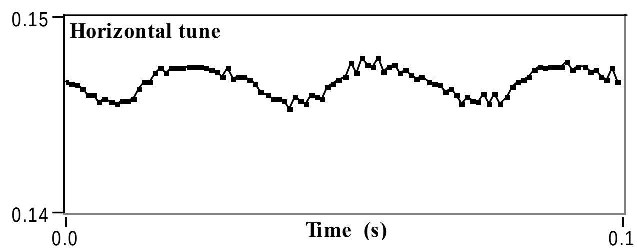

Fig.5. Modulation of horizontal tune

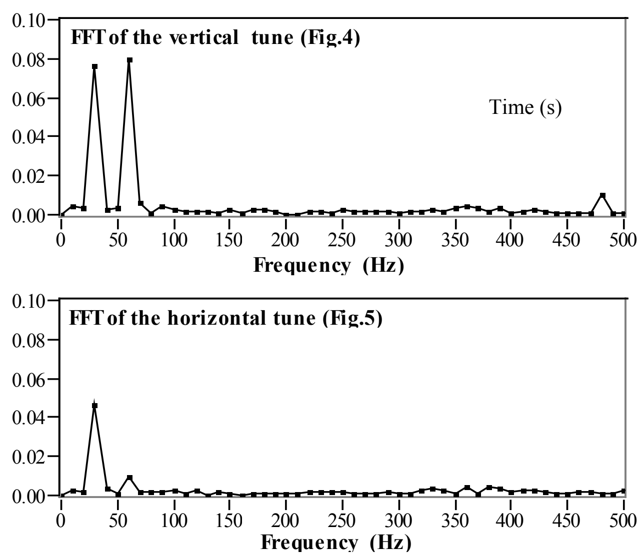

Fig. 6. Spectral analysis of the tune modulation

Figures 4 and 5 show strong 30 Hz power line interference from SLAC linac operating at this repetition rate. The peak to peak magnitude of the tune modulation is 0.002 and 0.006 for horizontal and vertical tunes, respectively. It is factor of 4 greater than non-periodic tune variations seen when the measurements are done phase locked to the ripple.

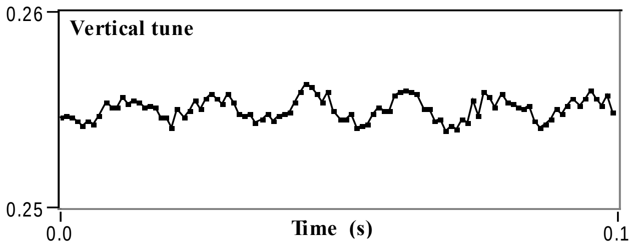

Fig.7 Modulation of vertical tune , no 30Hz power line interference

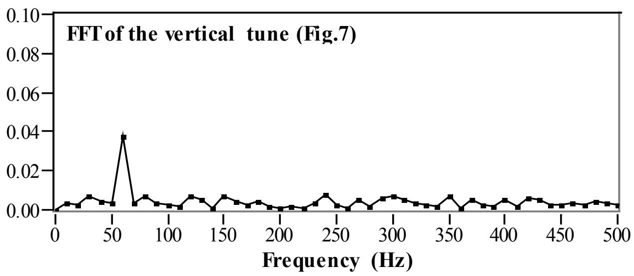

Fig. 8 Spectral analysis of the tune modulation

The data on fig.7 is taken on the day when SLAC linac was operating at 120 Hz. The strongest component in the tune modulation is 60 Hz. The measured peak-to- peak vertical tune modulation is 0.002. The horizontal one is smaller then non-periodic part Fig.3.

4 CONCLUSIONS

We demonstrated a technique for measuring the time variation of the tunes. The following experimental results were obtained:

Non-periodic variation of the tunes	horizontal vertical	$4\times10e^{-4}$ not measured
Peak-to-peak , SLAC linac operating at 30 Hz	horizontal vertical	$2\times10e^{-3}$ $6\times10e^{-3}$
Peak-to-peak, SLAC Linac operating at120 Hz	horizontal vertical	$<4\times10e^{-4}$ $2\times10e^{-3}$

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