APPLICATION OF WAVELET ALGORITHM IN TUNE MEASURE-MENT

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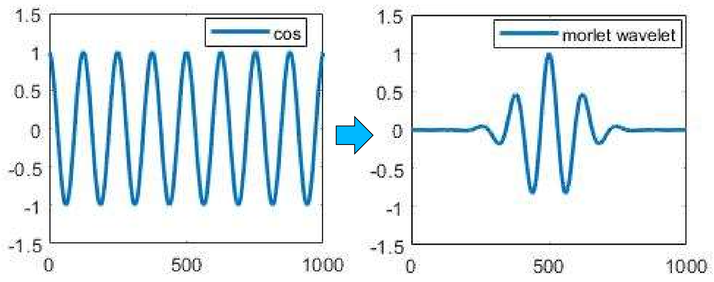
Abstract

Tune is a very important parameter for storage ring of advanced synchrotron radiation facilities. At present, fast Fourier transform (FFT) is the core algorithm of the beam spectrum analysis used in tune measurement. Taking into account the nonlinear effect in the accelerator, tune changes during the process of storage ring injection and booster energy upgrading. However, the Fourier method is used to analyse the global sampling point, and the ability to distinguish the local variation of the tune in the sampling time is poor. This paper leads wavelet analysis method as the core algorithm into beam spectrum analysis method, further analyses the change of the tune with beam amplitude in sampling time, and compares this new algorithm with the traditional Fourier method. New experimental results and corresponding analysis for the data from SSRF will be introduced here.

Introduction

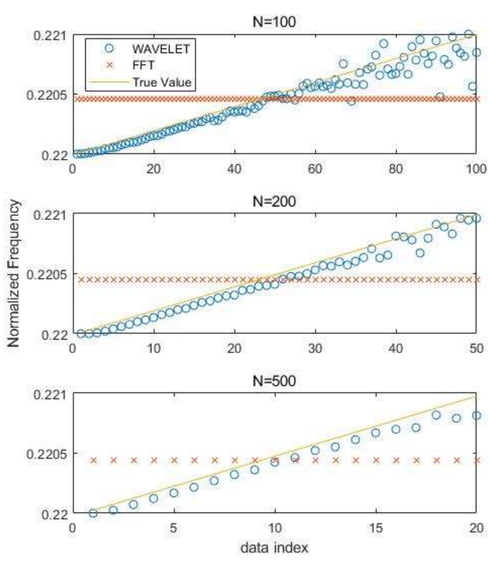
Fast Fourier transform (FFT) is the most commonly used algorithm in the tune calculation, which frequency resolution is determined by the number of sampling points N, that is 1/N. The tune accuracy and tune drift measurement in the injection process is limited by the short oscillation damping time (about 10,000 turns).



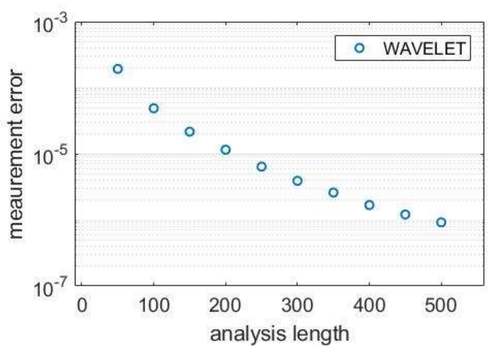
$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-i\omega t} \quad \Rightarrow \quad WT(a,\tau) = \frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} f(t) * \psi\left(\frac{t-\tau}{a}\right)dt$$

Wavelet transform is a commonly used time-varying frequency analysis algorithm. There already have some related researches on beam analysing using Wavelet. The signal is analysed by selecting an appropriate base function with limited energy on the time axis.

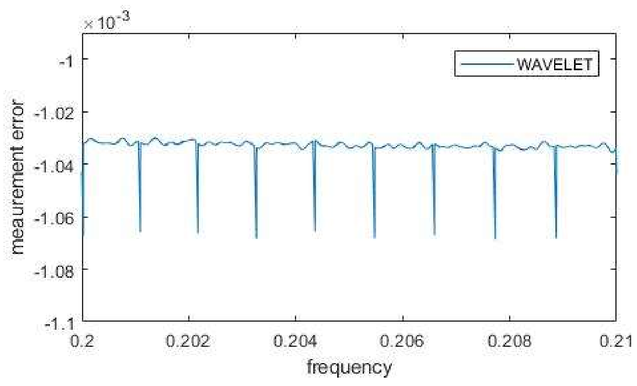
Algorithm Evaluation



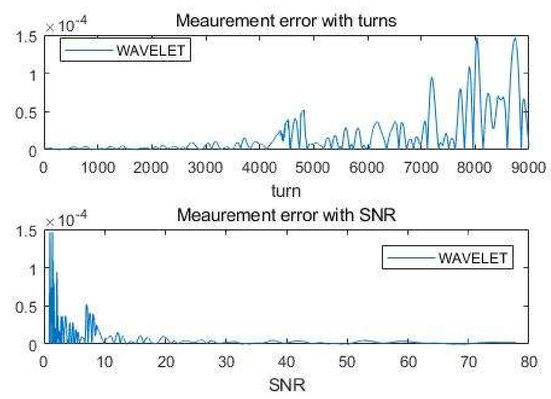
The relationship between test results and the number of sampling points



The relationship between test results and analysis length (morlet wave)

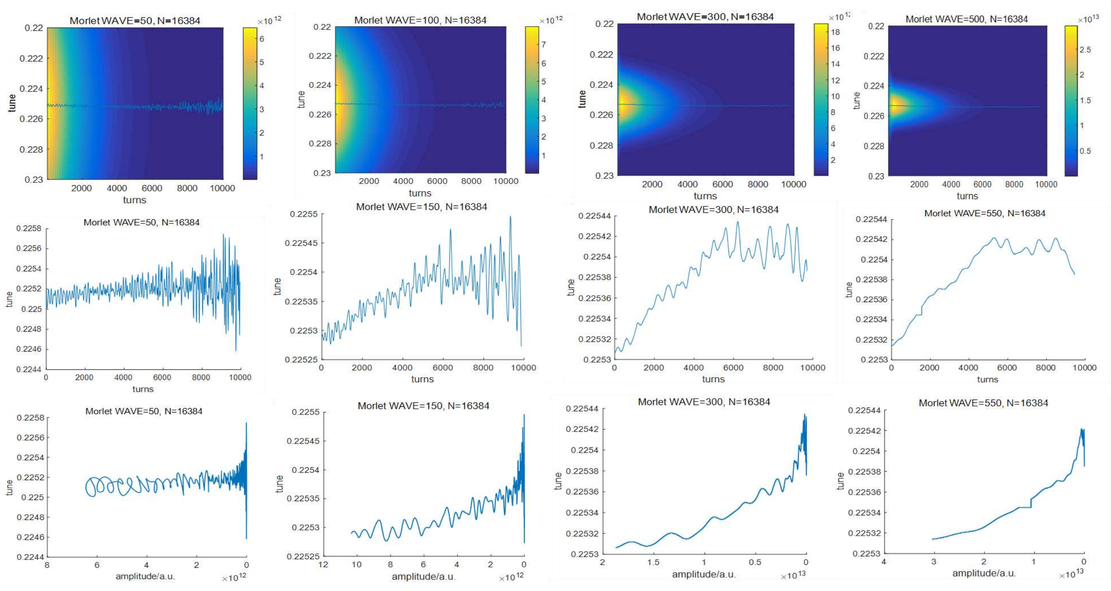


Test results and frequency dependence



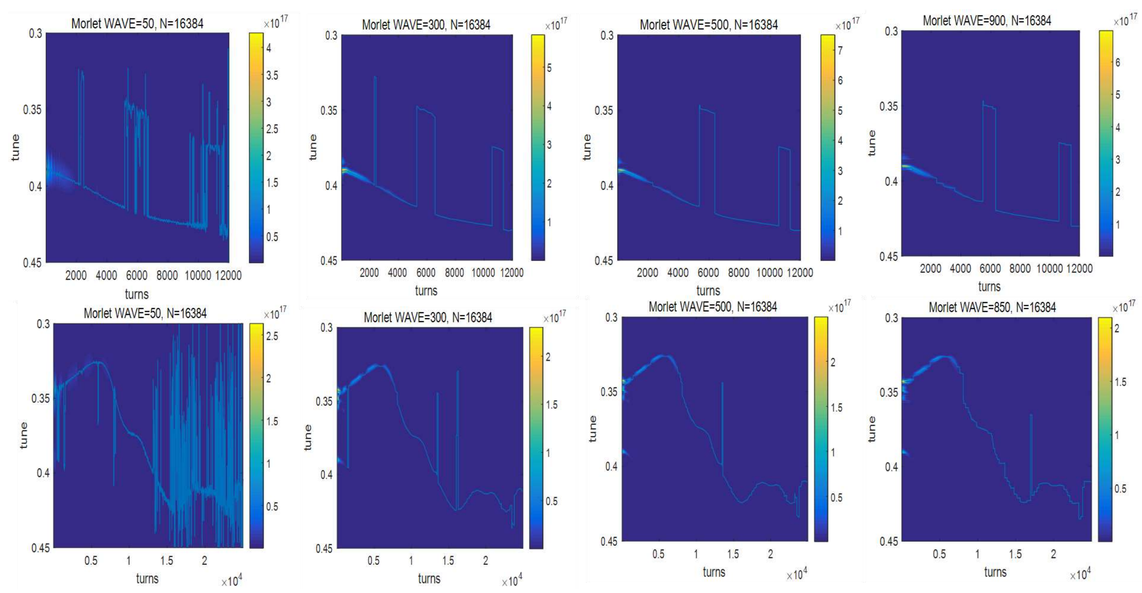
The relationship between test results and SNR

Application in SSRF Storage Ring



Tune during the injection increased from 0.22530 to 0.22543. After replaced the horizontal axis with the bunch amplitude, it can be seen that as the amplitude decreases, tune increases approximately linearly. When the amplitude is 0, tune is corrected to 0.22542. Compared with the original correction of 0.0001, this is very meaningful.

Application in SSRF Booster



It can be seen that the changing trajectories of tune in the horizontal and vertical directions are clear. Among them, the transverse tune increases unidirectionally, and the vertical tune decreases first and then increases.

Conclusion

- The simulation proves that the morlet wavelet algorithm can measure the time-varying tune. When the data analysis window is selected as 100 cycles, tune change as small as 0.00001 can be detected.
- During the period of storage ring injection and booster's energy upgrade, tune has obvious change. By applying the morlet wavelet algorithm, the complete trajectory of the tune drift during the booster's energy upgrade process can be tracked.
- This new algorithm can be used to perform undisturbed tune measurement during the top-up injection period for SSRF, which provides an effective tool for the beam instability research and performance optimization of the accelerator.

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