IMPROVEMENTS TO THE TUNE MEASUREMENT

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An upgrade to the tune measurement has been developed and is in the process of being integrated into the routine operation of the SLS. The main features of this upgrade are the inclusion of a new method for evaluating the tune (using the NAFF method) and its implementation into the CORBA framework of the Beam Dynamics applications. This new method will provide a greater accuracy in the evaluation of the fractional part of the transversal tunes and provides a centralized evaluation. These features together with the introduction of the pinger magnets will be very useful in the understanding of the machine.

INTRODUCTION

Presently, the fractional part of the transverse tunes (Q_x and Q_y) is evaluated using a java application running in one of the bays of the control room. The Tune Measurement application retrieves the single turn data from the Tune Pickup BPM and proceeds to perform a Fast Fourier Transform on the horizontal and the vertical data. The tunes are obtained from the peaks in the amplitude spectra. This method however has some limitations:

- The precision of the tune is limited to 1/N, where N is the number of points used.
- The number of points to be used (N) is required to be a power of 2.
- No centralized calculation.
- 1 Hz is the maximum frequency of the calculation.

We can improve the precision by performing data windowing and peak interpolation [1]. Using a sinusoidal window and the non linear interpolation described in [1] we can push the resolution to a value of $1/N^2$. Consequently we can have a good approach to the tunes even when we have only a small number of turns available for data, as is the case when accumulating beam. This, together with the high sensitvity of the BPMs, allows us to measure the tune even when we have only .3 mA of current for a few (32) turns. In regular operation, the tunes are evaluated using 1024 points. The effect of the electron beam decoherence does not allow for more precision when going to 2028 points. Fig. 1 shows the tunes and the amplitude spectra obtained using 1024 points.

This approach (using a high level java application with a FFT analysis and peak interpolation) has proved to work well for routine operation and commissioning.

However the installation of two pinger magnets (fast kickers that provide a single turn excitation of the beam) in the first quarter of 2004 provides us with the motivation to introduce an improved method to evaluate the tune, using some of the new techniques developed in recent years, such as the NAFF approach and Frequency Maps. Since this new methods require fast CPU, it would be a burden on resources if each console that required to display the tune were to duplicate the calculation. A software architecture based on a server/client model will allow us to centralize the tune evaluation (solving the problem of two instances of the program running in different machines simultaneously writhen different values to the control system) and to increase the rate of evaluation if required. It will also make it easier to synchronize the data acquisition with the excitation signal, allowing us to use the injection trigger in the top-up mode.

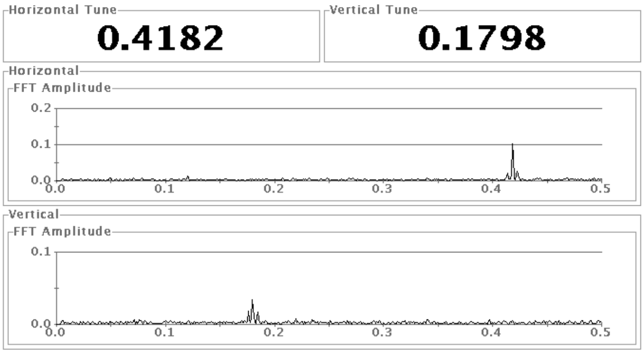

Fig. 1: Horizontal (top) and vertical (botton) amplitude spectra and tunes. The excitation is provided by the injection bump.

SOFTWARE ARCHITECTURE

We have adopted the new framework for the CORBA based beam dynamics application [2]. Fig. 2 shows a diagram of the application. The tool is composed of four major components:

1. GUI Client:
2. Tune Server
3. Tune EPA (Event Processing Agent)
4. Tune CORBA/CDEV Gateway.

The GUI client is a Java front-end for the application and does not perform any calculations. The two main tasks are the display of the tunes, the spectra and the peaks; and to set the various fit parameters such as number of points to use, limits in the peak search. One important parameter is the method used to evaluate the tunes. It communicates with the Tune Server using the CORBA protocol. The GUI tool can also perform some small operations, in particular the identification of the resonance lines. The TuneServer writes the parameters into shared memory, reads back the calculated tunes and spectra from it and pushes this data to the GUI and the Gateway. The Tune EPA is the main component of the system. It receives the BPM data through a CDEV monitor, reads the input parameters for the calculation from shared memory, and performs the calculations. To ensure greater flexibility both the previous method and the new method (based in NAFF) have been included. Once the tunes and the spectra are evaluated, the Tune EPA writes them to shared memory and waits for the callback from CDEV. The last component is the Tune CORBA/CDEV Gateway. It receives the tunes and the spectra from the TuneServer and starts writing the data into EPICS, allowing it to be archived and accessed by other applications of the control system such as the StripTool.

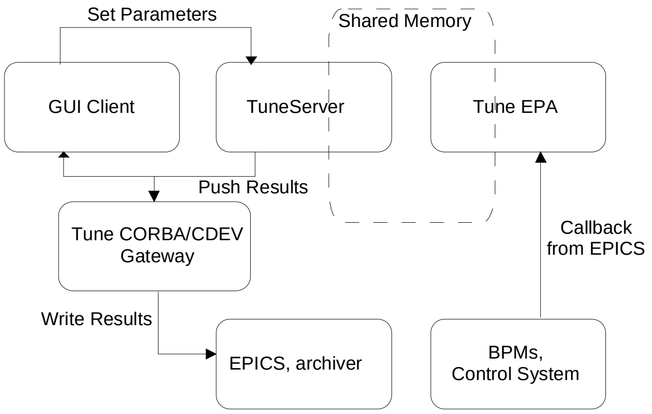

Fig. 2: Diagram of the software architecture.

The GUI can run on several consoles in the control room, and is being written in Java. The other three components are written in C/C++ for optimal performance and only one instance of each one runs on the Beam Dynamics servers.

NAFF ALGORITHM

The method chosen is the one based in the Numerical Analysis of Fundamental Frequency (NAFF) developed by J. Laskar to use in Frequency Map Analysis (FMA) [3, 4] of planetary orbits, and later applied to accelerator physics.

It is a numerical method based on refined Fourier techniques. The basic algorithm consists of the determination of the main frequency ν_0 of a signal using a FFT analysis, which is taken as the starting point for a numerical reconstruction of the overlap of the original signal and $e^{i\nu t}$, allowing ν_0 to determined with a greater precision. The overlap of ν_0 is then removed from the original signal, and the procedure is repeated for the next frequency, until the remaining signal consists only of the noise. The signal is then reconstructed as a series of frequencies and amplitudes.

The NAFF presents several advantages over the simpler FFT analysis with peak interpolation, including greater flexibility in the number of points used (it need only to be a multiple of 6) and greater precision, of the order of $1/N^4$. This method however has some drawbacks: a more difficult implementation than the FFT, and a much higher CPU load.

Due to the complexity of the mathematics behind this method, the implementation has to be well tested. We have used the implementation from the SOLEIL Project for the Tracy library, allowing us to test it with our usual tools. This implementation already offers tools for identifying the number of frequencies presents on the signal, their identification and determination of the amplitudes.

CONCLUSIONS AND OUTLOOK

The method in development allows for an increase in resolution at the evaluation of the transversal tunes. This increase in precision is not required in regular operation, but will prove useful for machine development, in particular when used with the pinger magnets. The inclusion of additional single turn BPM data in the future will allow a better identification of the resonance lines and to observe the phase space.

The new software model allows for a centralized evaluation and distributes the resulting tunes, spectra, resonance peaks and raw data to the client.

The next step is the introduction of a feedback in the values of the tunes. With the present status of the machine, with very small drift in tune, this feedback is not required. However, the introduction of new insertion devices could change the situation. This will require a stable and precise measurement of the tune. An intensive test of the new system should be performed before the feedback is implemented.

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