THE TUNE MEASUREMENTS IN THE BEPC STORAGE RING

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Abstract

The betatron and synchrotron tunes are measured frequently during the period of the machine operation and machine studies. The tune measurement system of the BEPC storage ring includes a spectrum analyzer, two sets of striplines, power amplifiers and a beam oscillation detector. As the upgrade scheme, LabVIEW is ready to be used in the tune measurement system. This paper gives the tune measurements in the BEPC storage ring as well as the detailed description of the system hardware and software.

1 INTRODUCTION

The Beijing Electron Positron Collider (BEPC) is a machine with a designing energy up to 2.8 GeV, but it has routinely operated at the energy below 2.2 GeV. The collider provides beams for high energy physics experiments as well as the synchrotron radiation research in the parasitic and dedicated modes. The betatron and synchrotron tunes are measured frequently during the period of the machine operation and machine studies. Table 1 lists some tune measurement related parameters of the BEPC storage ring for the colliding mode and the synchrotron radiation mode respectively.

Table 1: Tune measurement related parameters

Parameters		Colli. mode	SR mode
Number of bunches per beam		1	1 - 4
Averaged beam current (mA)		20 - 30	60 - 80
Beam energy (GeV)		1.5 - 2.0	2.2
Revolution frequency (MHz)		1.247	
RF frequency (MHz)		199.526	
Fractional tune freq. (kHz)	x	274	474
	y	212	175
	z	25	15

The betatron tune measurement is performed by exciting the beam externally in the horizontal and vertical planes simultaneously through a stripline and sending a processed signal, picked up by another stripline, to the spectrum analyzer. The software running on a personal computer (PC) controls the measurement procedure and receives data from the spectrum analyzer via a GPIB link. A block diagram of the betatron tune measurement setup is shown in Figure 1. For the synchrotron tune measurement, the only difference is that the output signal from the tracking generator of the spectrum analyzer is sent, without amplification, to the ring accelerating system for the amplitude modulation of the RF vol tage.

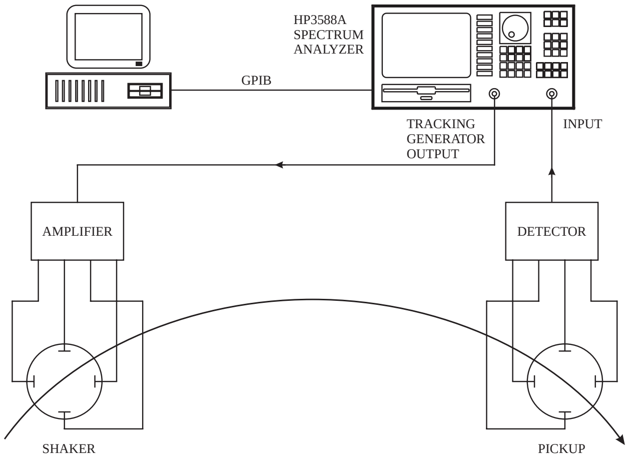

Figure 1: Block diagram of the tune measurement sy stem

2 HARDWARE DESCRIPTION

The main components of the tune measurement system are the spectrum analyzer, the striplines for the shaker and the pickup, the low frequency voltage amplifiers, the beam oscillation detector and the associated computer interface.

2.1 Spectrum Analyzer

A new spectrum analyzer HP3588A was chosen to replace the original spectrum analyzer TEK 7L5. The HP3588A is a swept-tuned spectrum analyzer with a frequency range of 10 Hz - 150 MHz. It offers swept spectrum and narrow band room measurements. The swept spectrum mode uses digital IF filters that allow increased measurement speed with no additional amplitude error or resolution loss. The narrow band zoom uses an implementation of the FFT to provide even faster measurements with even greater resolving power. The programmability of the HP3588A makes the instrument easy to be integrated into the BEPC control system.

2.2 Striplines

To simplify the design and minimize the development effort and cost, two striplines with the same mechanical structure and dimensions are used. One stripline is used as the shaker and another is used as the pickup. The stripline has four strips, one pair in each plane. The strip has N-type vacuum feedthroughs at both ends and has a length of 277 mm, a width of 27 mm, a thickness of 2 mm and is approximately held 4 mm away from the wall of the circular vacuum chamber with a 51.5 mm inner radius. The external signal is applied at one port of each strip on the shaker stripline unit and the strip is open circuited to the vacuum chamber at the other port, so the voltage excitation is realized. RF signals from the up- and down-stream ports of the pickup stripline are used for the electron and positron beams respectively and are brought to the detector in the center control room with 1/2 inch broad-band cables.

2.3 Amplifier

As shown in Figure 2, the swept frequency (0 - 600 kHz) output signal from the tracking generator of the spectrum analyzer is preamplified before it is split into two and amplified by two commercial operational amplifiers Model AM501 of Tektronix. The output of each amplifier is further split into two for both planes. The AM501 can be configured in a 0 degree or 180 degree phase inversion operation mode. So excitation signals for opposite electrodes are out of phase. The peak output voltage of the amplifier is 80 V.

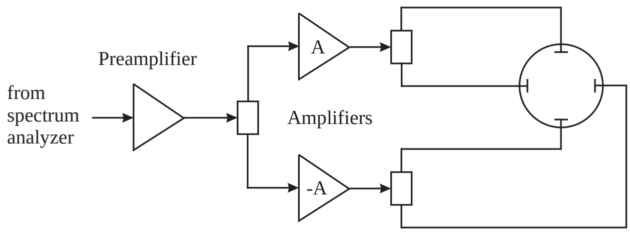

Figure 2: The drive circuit for the shaker stripline

2.4 Detector

The detector is actually a band pass amplifier. The lower cut off frequency of the amplifier is less than 10 kHz while the upper cut off frequency is 600 kHz, which is near 1/2 the revolution frequency f_0. With this detector, the x and y coherent oscillation signals of the beam are amplified. The gain of the detector is about 60 dB and the signal to noise ratio is high enough to detect the tune frequencies with the spectrum analyzer. The detector itself has the function of subtracting two input signals (see Figure 3), so no additional hybrids are needed for obtaining the difference signal (Δ-signal). Coaxial relays are used at the input of the detector to switch signals for all three tunes.

2.5 Computer Interface

A PC with the GPIB interface card Model HP82341 was used to control the spectrum analyzer and the tune measurement procedure. This PC is one of the front end computers in the BEPC beam diagnostic instrumentation system and serves as the GPIB system controller. The HP82341 is a Hewlett Packard's high-speed 16-bit PC interface card for controlling GPIB devices with the most popular Microsoft Windows-based programming languages. The interface card fits into one ISA/EISA expansion slot in the backplane of the PC. The configuration switch on the HP82341 interface card sets the interface's I/O port base address. The build-in buffering of the card provides I/O and system performance that is superior to direct memory access (DMA) up to 750 Kbytes/s.

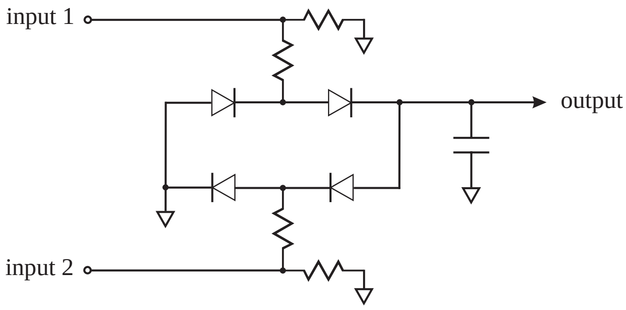

Figure 3: The Δ-signal detection part in the detector

3 TUNE MEASUREMENTS

At present, the tune measurement is usually performed by the operator manually. For everyday measurements, the spectrum analyzer HP3588A is set in the swept frequency mode. The frequency range is from 150 - 550 kHz. Both horizontal and vertical fractional tune frequencies are displayed on the screen of the HP3588A. With extended marker function of the HP3588A, it is easy to obtain the peak frequencies of the betatron tunes.

For the automatic measurement, the tune frequencies can be measured and stored into the database by a C program which reduces the frequency span range and centers alternatively on each of the horizontal and vertical tune frequencies. The program makes use of the HP3588A's peak-search capability to find the tune frequency. Therefore the operator must restrict the frequency span range and the center frequency of the spectrum analyzer so that the correct peak is displayed.

A new measurement application program developed using LabVIEW for Windows has been finished and will be put into operation in the next BEPC run. This program will be described in Section 4.

In order to provide continuos tune monitoring, the excitation voltage on the shaker stripline electrodes is kept as small as possible so that the tune measurement process does not disturb the physics and synchrotron radiation experiments.

4 NEW SOFTWARE APPLICATION

4.1 Software Architecture

The client/server model which is the most commonly used paradigm in constructing distributed applications has been chosen. Figure 4 is the client/server structure of the BEPC beam diagnostic instrumentation sy stem.

Client applications are executed on the front end PCs or on the BEPC real time control computer running under VMS. They obtain data from hardware devices through device drivers. The on-line analysis and the dynamic display can be realized with those data. The client applications communicate with the server application via the standard TCP/IP communication protocol.

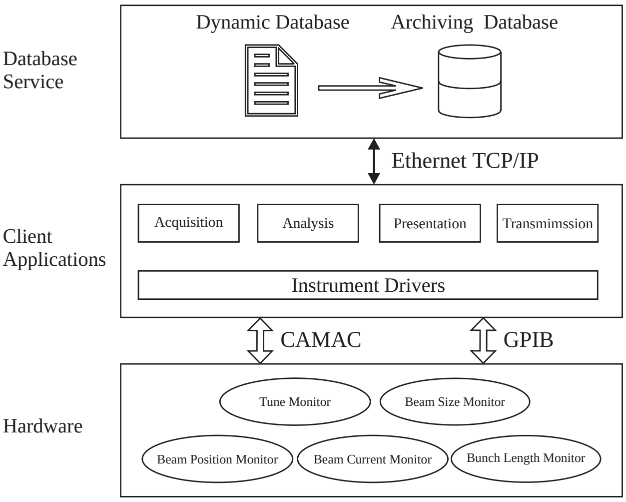

Figure 4: The soft structure of the BEPC beam diagnostic system

The database services are provided by two database servers, one is the dynamical database server and the other is the archiving database server. The dynamical database server responds to the requests from client applications on any computer platform. The data stored in the database are refreshed with different rates from 1 to 1/60 Hz. The archiving database server is made of Microsoft SQL Server 6.5. Almost all important parameters of various BEPC subsystem are stored in the database at the time interval of 1 minute. These historical machine parameters can be accessed at anytime.

4.2 Tune Measurement Application

The new tune measurement application developed with LabVIEW works as a client. Compared with other software development tools, LebVIEW was chosen because of its graphic user interface, instrument control interface and its data acquisition, data analysis and data communication capabilities.

Figure 5 gives the front panel of the tune measurement virtual instrument (VI). There are three waveforms in Figure 5. The upper left one is the spectrum waveform from the HP3588A. The right two waveforms are the horizontal and vertical fractional tunes as a function of time or sampling number (tune history). The digital display just above each of the two tune history waveforms is the latest sampled data.

The digital controls at the bottom left are used to configure the HP3588A via GPIB. SpanX, CenterX and SpanY, CenterY set the range of the frequency sweep for horizontal and vertical tunes respectively. As same as described in the previous section, the frequency span and the center frequency must be strictly specified so that the correct frequency peak can be found. For one complete measurement, the HP3588A scans twice, one for each plane. SweepTim sets the sweep time of the HP3588A and TrackGen sets the output power of the tracking generator. The On/Off button is used to start and stop the program. The user can operate the HP3588A manually when the button is off.

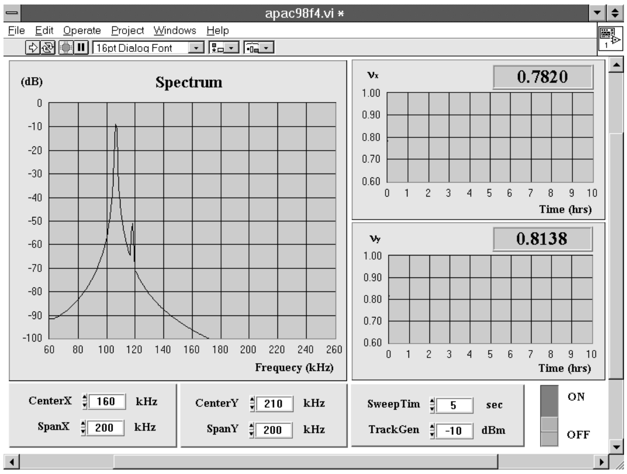

Figure 5: The tune measurement virtual instrument

The measured data are sent to the dynamic database by the same VI.

5 CONCLUSIONS

The BEPC tune measurement system has been upgraded by replacing the original TEK 7L5 spectrum analyzer with the HP3588A spectrum analyzer and by using a PC in the system. This upgrade has lead to a increase in the measurement speed and resolution. The resolution of the system can reach the order of 10^{-4} in tune and the dynamic rang is 0.4 - 40 mA. The system has been found to perform well. The measured tunes can be stored in the database for the off-line analysis. A new LabVIEW VI has been created and is going to be put into operation in the next BEPC run. Some more modifications, such as improving the dynamic range of the system and exciting the beam alternatively in the two planes, are under consideration.

6 ACKNOWLEDGMENTS

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