AN AUTOMATIC DIGITAL MEASUREMENT OF BETATRON FREQUENCIES

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Abstract

This paper describes an automatic system for measurements of the betatron frequency[1] in the ISR. The system includes pulsed beam deflectors, electrostatic pick-up electrodes[2], band pass filters, zero-crossing detectors, and a digital device for calculating the non-integral part of the Q-value.

1. Beam Deflectors

For the excitation of coherent betatron oscillations[3], a system of pulsed beam deflectors has been installed in the ISR. For a uniform horizontal deflection across the useful ISR aperture, a special kicker-tank has been designed. A 1.5 μs pulse provides a magnetic deflection of about 0.6 mm for 28 GeV. The vertical deflection is obtained by an electrostatic field of 20 kV across two pairs of normal clearing electrodes as used in the ISR. The pulse lasts for 3 μs, (one revolution), and gives a deflection of about 0.3 mm for 28 GeV.

Delay-lines charged to 20 kV, are used as pulse-forming networks. The discharging elements are hydrogen thyratrons. Maximum repetition rate is 10 pulses per second.

2. Signal Amplifiers and Filters

The signals used for the measurement are taken from electrostatic pick-up electrodes. Differential amplifiers measure the signal difference between the inner and outer plates for the horizontal measurement, and the upper and lower plates for the vertical measurement. These amplifiers are set to balance out the bunch-induced signal at the injection orbit. This is important for the measurement of a bunched beam since the bunches only fill 2/3 of the circumference, and hence produce a strong revolution frequency component.

The difference signal is split and amplified by identical, bandwidth-limited low noise amplifiers. The outputs from these amplifiers go to three bandpass filters. One filter passes the frequencies between 0.05 and 0.48 times the revolution frequency (15 - 150 kHz). Another filter passes the frequencies between 0.51 and 0.98 times the revolution frequency (162 to 311 kHz). A third filter passes the revolution frequency itself (∿ 316 to 318 kHz).

The first filter covers the 9 - Q mode, and the second filter, the Q - 8 mode.

The signals from the filters go into high gain limiting amplifiers. These amplifiers have a gain of about $5 \cdot 10^3$, and are used in a saturated mode. A zero-crossing detector at the output transforms the signals to TTL level.

3. The Dividing and Display Unit

The signals from the revolution frequency filter, and from either of the two other filters, are gated into a counting unit. A preselected number of periods from 1 - 100, is counted by a 50 MHz clock. The start of the counters can be delayed by 1 to 99 incoming periods. This is incorporated in order to reduce phase errors produced by filter transients[4]. The numbers of clock pulses counted, are stored in two 16 bit registers. One register contains the information on the betatron frequency. The other register contains the information on the revolution frequency. A dividing system, driven by a 10 MHz clock, divides the two stored numbers. The result is displayed, it is the non-integral part of the Q-value.

The number of digits displayed is linked to the number of periods counted, as the precision of the measurement depends on the number of clock pulses counted. For a precision of $\pm 1 \cdot 10^{-3}$, 10^3 clock pulses must be counted, corresponding to 18 periods of the revolution frequency.

4. Operational Aspects and Performance

The measurement is initiated by a trigger pulse. A system of push buttons permits selection of external trigger pulses, or manual push-button operation. The measurement takes less than 1 ms for an accuracy of $\pm 1 \cdot 10^{-3}$.

With a fraction of a millimetre beam deflection per measurement, many measurements can be performed on the same injected beam. Measurements have been performed on a D.C. beam of 10^{11} protons at 26 GeV without losing accuracy.

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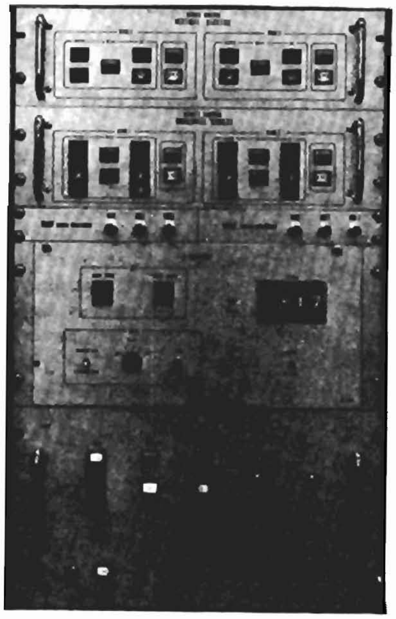

Figure 1

Control and display panels of the Q-measurement system

References

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