Acceleration voltage calibration by synchrotron frequency measurement

Takashi OHSHIMA, Takeshi NAKAMURA, Mitsuhiro MASAKI and Shiro TAKANO

SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

1. Introduction

The nominal acceleration voltage of the SPring-8 storage ring can be calculated from the RF power picked up from the cavities, assuming the shunt impedance of the cavities. To check this evaluation, we measured the synchrotron frequency of the stored electron beam of the ring.

The synchrotron frequency ω_{sy} follows the equation

$$\omega_{sy}^2 = \frac{2\pi h\alpha}{E_0 T_0^2}\sqrt{\left(eV\right)^2 - U_0^2}.$$

where α is the momentum compaction factor of the ring, h the harmonic number 2436, E_0 the beam energy, T_0 the revolution time, U_0 the energy loss of the electron in one turn, V the RF acceleration voltage. Assuming the values of α, E_0, and U_0 to be design values, and the total acceleration voltage V is calculated from the synchrotron frequency ω_{sy}.

2. Measurement of synchrotron frequency

The signal from a button pickup electrode has a harmonic spectrum corresponding to the time interval of the electron bunches. When the phase of the acceleration voltage is modulated by an electrical phase shifter in the reference RF signal, the beam starts the energy oscillation and if the frequency of the phase modulation coincides with the synchrotron frequency, a side band peak appears at the synchrotron frequency in a button spectrum. The button signal is converted by a double balanced mixer with the reference RF signal and is measured by a spectrum analyzer. Figure 1 shows the schematic diagram of the measurement set-up.

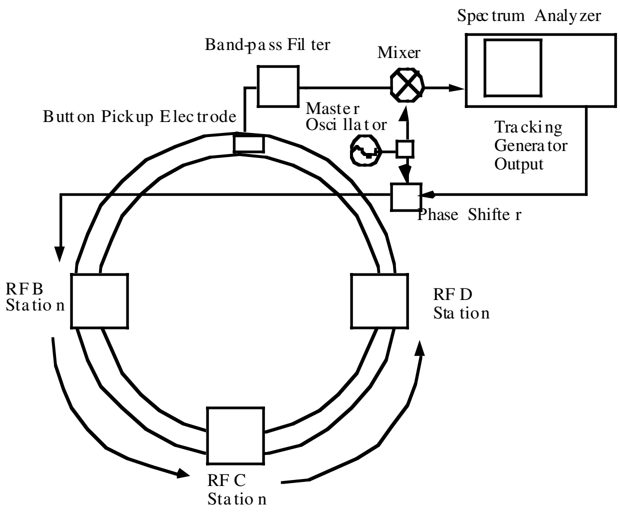

Figure 1. Experimental set-up to measure the synchrotron frequency.

2.1 Adjustment of relative phase between three RF stations

There are three RF acceleration stations in the ring. Each station has eight acceleration cavities. Before the beam operation, the phase adjustment of each components were carried out as follows. The phase between the klystron output and each cavity pickup was measured using a vector network analyzer, and was adjusted to the value determined by the longitudinal position of the cavity using a waveguid-type phase shifter. The reference RF signal from a master oscillator is delivered to each station with a phase-stabilized optical fiber [1]. The phase of this reference signal was adjusted using a reflected light from a half mirror inserted at the end of the optical fiber [2]. The phase between the reference RF signal and the pickup signal from the number one cavity was adjusted to be zero degree using a trombone-type phase shifter.

As the first step to measure the acceleration voltage by the synchrotron frequency, we checked the relative phase of the RF stations. The total acceleration voltage is the vector sum of the acceleration voltage of each RF station. If the relative phase is not optimized, the total effective acceleration voltage is reduced. The synchrotron frequency is measured as a function of the phases of each station. When the optimum phase to maximize the synchrotron frequency is obtained at one station, the same procedure is done at another station. Repeating this procedure, we can obtain the maximum total acceleration voltage. Figure 2 shows a result obtained on July 30, 1997. The phase deviation between the previous set value and timum phase was within 30 degrees.

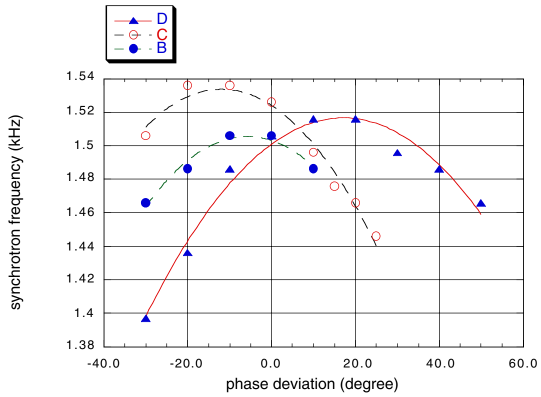

Figure 2. An example of synchrotron frequency measurement as a function of station phases.

2.2 Calibration of acceleration voltage

With the optimized station phases, the synchrotron frequency is measured as a function of the nominal acceleration voltage of a station, which is given by the following equation

$$V = \sqrt{R_{sh} \cdot P},$$

where P is the power picked up from the cavities and R_{sh} is the shunt impedance of the cavity and is assumed to be 5 MOhm. Figure 3 shows a result obtained on July 10, 1997. The result is fitted by the least square method using the equation

$$\omega_{sy}^2 = \frac{2\pi h\alpha}{E_0 T_0^2}\sqrt{\left(e(C_B V_B + C_C V_C + C_D V_D)\right)^2 - U_0^2},$$

where C_B, C_C, and C_D are voltage correction coefficients for B, C, and D stations, respectively. The result shows that the coefficients of the stations' voltages are 1.054, 1.022, and 0.895 for C_B, C_C, and C_D, respectively. From this result, the calibration coefficient for the D station, which had deviated by -10.5%, is corrected.

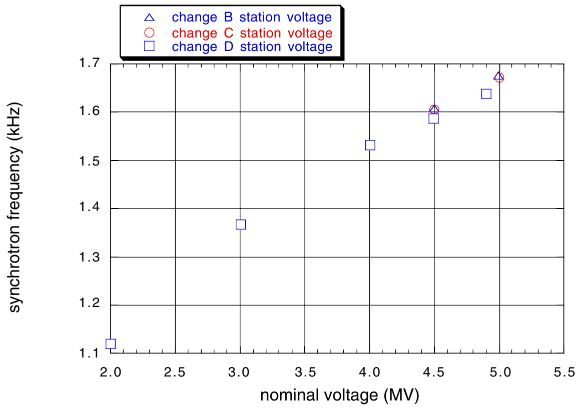

Figure 3. Synchrotron frequency and nominal acceleration voltage.

3. Conclusion

Using the voltage calculated from the synchrotron frequency measurement, the coefficients of the acceleration voltage were obtained. The coefficient for the B station was +5.4%, and that for C was +2.2%. The coefficient for the D station was -10.5%, which was a rather large deviation. So we changed the coefficient of the nominal voltage of the D station using this result.

There is the possibility of obtaining information on the momentum compaction factor from the synchrotron frequency measurement. Accordingly, we plan to carry out more precise measurements on the synchrotron frequency with various conditions in the near future. In addition measurement of the quantum life time should provide further information for acceleration voltage calibration.

References

[1] H. SUZUKI et al., 9th Symp. on Accel. and tech., 252 (1993)

[2] T. OHSHIMA et al., 11th Symp. on Accel. and tech., 95 (1997)