THE STANDING WAVE TYPE KICKER FOR A LONGITUDINAL FEEDBACK SYSTEM.

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Abstract

In this paper the kicker for longitudinal bunch by bunch feedback system is described. The kicker is a coaxial transmission line design using standing wave type regime. The description of the kicker construction, the calculation and measurement results of the shunt impedance and operating frequency bandwidth are presented.

1 INTRODUCTION

Here the results of the R&D on a kicker oriented on longitudinal feedback system for KEKB ring are described. We follow here the concept building the bunch-by-bunch feedback system presented in [1]. For bunch spacing 2 nsec the feedback frequency bandwidth is determined by the frequency of the coupled oscillation mode when the neighboring bunches oscillate in opposite phases. This frequency is 250 MHz. The kicker frequency bandwidth at the KEKB is chosen to be 1.0÷1.25 GHz.

Two types of the longitudinal kicker operating in the similar frequency band are used now in feedback systems to cure longitudinal coupled bunch instability. First one, the travelling wave type kicker [2] is two full coverage 25 Ohm striplines connected in series by $\lambda/2$ lines to increase the shunt impedance. In the band 1.0÷1.25 GHz the shunt impedance measured is 200÷300 Ohm. Second one, the DAΦNE type kicker [3,4] is the waveguide-overloaded cavity. The shunt impedance measured is 620 Ohm, with a half power bandwidth of 250 MHz, centered at 1.2GHz.

Below another variant of the longitudinal kicker is described. The kicker is a coaxial transmission line design utilizing a standing wave type regime. The shunt impedance of ~1000 Ohm for the bandwidth of 250 MHz at the operating central frequency 1 GHz is obtained.

2 THE KICKER MODEL

The longitudinal kicker presents the half-wave length drift tube (at the operating frequency) forming with the inner surface of the vacuum chamber coaxial transmission line. The transmission line is excited through two 50 Ohm feedthroughs and then through the connection stripline of the special form at the middle of the drift tube (Fig.1).

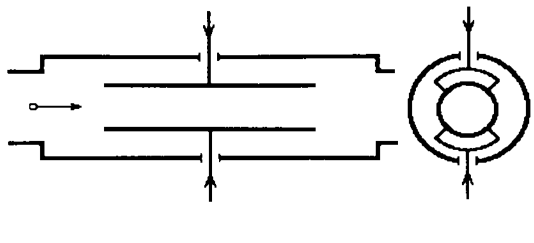

Fig. 1. The kicker design.

Both the upstream and the downstream ends of the drift tube transmission line are open. In such a structure the RF power propagates as TEM wave from the middle point of the drift tube line to the ends, reflects from the open ends, comes back by the same way through the feedthroughs and then dissipates in the terminating load of a power amplifier circulator.

3 THE SHUNT IMPEDANCE CALCULATION

For the calculation of the kicker shunt impedance is conveniently to use the kicker model presented as a combination of a transmission lines of equal length with the appropriate wave impedances (Fig.2). Z_1 and Z_2 are the wave impedances of the

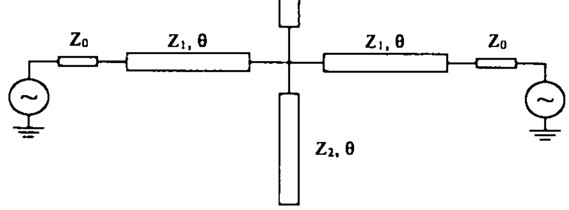

Fig. 2. The equivalent kicker scheme as a combination of a transmission lines.

connection striplines and the drift tube transmission lines correspondingly; θ=kl where k is the wavenumber, l is the lines length; Z_0 is the terminating impedance (50 Ohm). At the central operation frequency $\theta=\pi/2$.

Because of the kicker inputs excitation is in-phase the equivalent kicker scheme can be simplified (Fig.3).

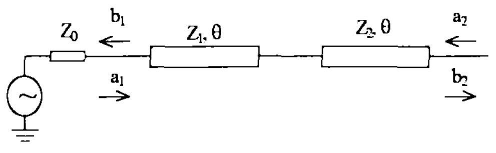

Fig. 3. The calculated kicker scheme.
Here a_1, a_2 and b_1, b_2 - the voltages of the forward and reflected waves divided by $\sqrt{Z_0}$ correspondingly

The scheme involving the connection stripline and the drift tube transmission line is completely described by the normalized scattering matrix:

$$St = \begin{bmatrix} S1_{11} + \dfrac{S1_{12}^2 \cdot S2_{11}}{1 - S1_{11} \cdot S2_{11}} & \dfrac{S1_{12} \cdot S2_{12}}{1 - S1_{11} \cdot S2_{11}} \\ \dfrac{S1_{12} \cdot S2_{12}}{1 - S1_{11} \cdot S2_{11}} & S2_{11} + \dfrac{S2_{12}^2 \cdot S1_{11}}{1 - S1_{11} \cdot S2_{11}} \end{bmatrix}$$

where S1, S2 are the scattering matrixes of the connection line and the drift tube line correspondingly. The S-matrix elements are determined by expressions:

$$S_{11}(z,\theta) = S_{22}(z,\theta) = \frac{\mathrm{Sin}(\theta) \cdot (z^2 - 1)}{\mathrm{Sin}(\theta) \cdot (z^2 + 1) - i \cdot 2 \cdot z \cdot \mathrm{Cos}(\theta)},$$

$$S_{12}(z,\theta) = S_{21}(z,\theta) = \frac{2 \cdot z}{i \cdot \mathrm{Sin}(\theta) \cdot (z^2 + 1) + 2 \cdot z \cdot \mathrm{Cos}(\theta)}.$$

Here $z=Z/Z_0$ is a normalized wave impedance of the lines.

The voltage at the open end of the drift tube transmission line, U_{gap}, can be described via the St-matrix elements:

$$\begin{cases} b_1 = St_{11} \cdot a_1 + St_{12} \cdot a_2 \\ b_2 = St_{21} \cdot a_1 + St_{22} \cdot a_2 \end{cases},$$

$$\begin{cases} U_{gap} = (a_2 + b_2) \cdot \sqrt{Z_0} \\ U_{input} = a_1 \cdot \sqrt{Z_0} \\ a_2 = b_2 \end{cases}.$$

where a_1, b_1, a_2, b_2 are the normalized components of the forward and reflected waves. U_{input} is a forward wave voltage. Taking into account the presence of two kicker gaps the kicker accelerating voltage is

$$U_{acc} = U_{gap} \cdot 2 \cdot \mathrm{Sin}(\theta) \cdot e^{i \cdot \left(\frac{\pi}{2} - \theta\right)}$$

or

$$U_{acc} = U_{input} \cdot \frac{4 \cdot St_{21}}{1 - St_{22}} \cdot \mathrm{Sin}(\theta) \cdot e^{i \cdot \left(\frac{\pi}{2} - \theta\right)}$$

The shunt impedance is founded from the input power expression:

$$\frac{U_{acc}^2}{2 \cdot Z_{shunt}} = P_{input} = 2 \cdot \frac{U_{input}^2}{2 \cdot Z_0}$$

So, we have

$$Z_{shunt} = \frac{8 \cdot Z_0 \cdot St_{21}^2}{(1 - St_{22})^2} \cdot \mathrm{Sin}^2(\theta) \cdot e^{i \cdot (\pi - 2 \cdot \theta)}$$

This expression is simplified if the wave impedances of the connection stripline and the drift tube transmission line are 50 Ohm.

$$R_{shunt} = |Z_{shunt}| = 8 \cdot Z_0 \cdot \mathrm{Sin}^2(\theta)$$

4 THE KICKER CONSTRUCTION AND TESTING

The main trouble with kicker as the 50 Ohm transmission line is the large gap between the drift tube and the inner surface of the vacuum chamber (it is compared with quarter-wave length at the operating frequency). As a result there are difficulties to match the transmission line in the operating band 1.0÷1.25 GHz. We have chosen the transmission line impedance 35 Ohm in real construction to simplify the problem. Moreover, we have complicated drift tube form near the vacuum feedthrough to decrease the gap additionally, as it is illustrated by Fig.4.

Fig. 4. The drift tube and the connection lines.

The measurements were performed by exciting the testing line, formed by a wire on the kicker axis and vacuum chamber, and detecting sum signal of kicker outputs (Fig.5.). The characteristic impedance of the testing line, R_{wire}, is of 100 Ohm in the volume where the drift tube is placed. The conical connectors provide

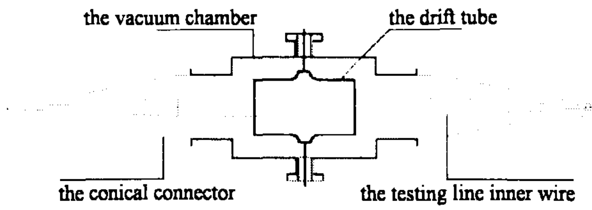

Fig. 5. The kicker with testing accessories.

the transformation of the terminals impedance R_0=50 Ohm to 100 Ohm. The longitudinal transfer (pickup) impedance is determined as [4]

$$|Z_{transfer}| = \sqrt{R_0 \cdot R_{wire}} \cdot \left| \frac{S_{21}^{pickup}}{S_{21}^{thru}} \right|,$$

where S_{21}^{pickup} transmission measured from the testing line to the combined signals from the kicker outputs and S_{21}^{thru} is transmission measured through the testing line. The shunt impedance is then defined from

$$R_{shunt} = \frac{4 \cdot |Z_{transfer}|^2}{R_0}.$$

5 THE RESULTS

The results of the shunt impedance calculation and experimental measurements for the different wave impedances of the connection stripline are presented at Fig.6. The simulation result of the model of the DAΦNI type kicker [5] and the measured shunt impedance of ALS type kicker [2] are shown at the same figure. All characteristics are represented with frequency normalization for more convenient comparison.

The efficiency of a kicker can be characterized by the value $R_{shunt} \times \Delta f_{op}$ (Δf_{op} - operating frequency bandwidth). From this point of view, it seems for us, INP type kicker is more preferable than ALS and DAΦNI types.

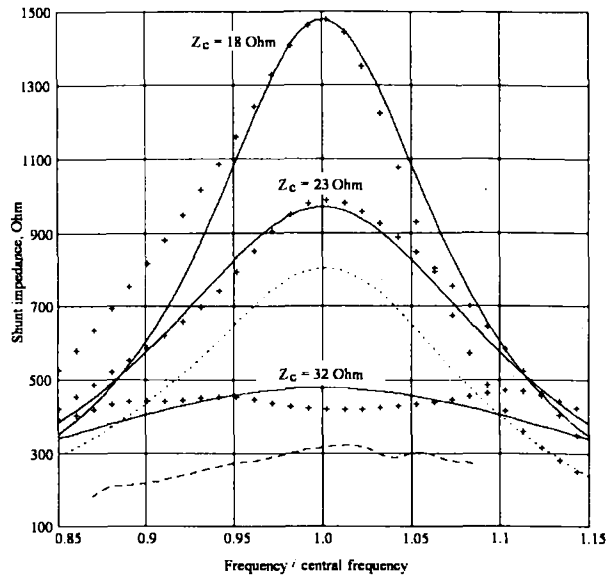

Fig. 6. The kicker shunt impedance vs. frequency. Z_C is wave impedance of the connection striplines.
INP Kicker: ——calculation, +++ measurement
DAΦNI Kicker - - - ALS Kicker — —

6 REFERENCES

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