DESIGN OF THE STRIPLINE AND KICKERS FOR ALBA

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Abstract

The design of stripline kickers shall be adapted to match the line impedance, maximize the effective beam kick, reduce the heat load and minimize the transverse coupling impedance. These kickers are used for either tune measurements or transverse feedback. We describe the ALBA design of these kickers for the Storage Ring.

INTRODUCTION

The term "striplines" refers to a configuration of longitudinal electrodes that may be used either as beam pickup (to extract information about the beam motion), or beam kickers (to change its motion). Their design should be taken with due care. The electrodes must be adapted to match the line impedance, reduce heat load, and minimize the transverse coupling impedance. Moreover, when used as active devices, we shall maximize the beam kick efficiency.

ALBA has designed different stripline kickers. In the following we use the word "striplines" to the combination that allows the dual purpose of beam pickup and beam excitation, and "kicker" to the one used only to excite the beam. The two designs are:

- Storage Ring Stripline: only one unit is installed in the machine. Its purpose is to provide the beam excitation for tune measurements. In early phases of the commissioning, this unit will be also used for tune measurements. Thus, its length is $\lambda/4$, being λ the bucket length (λ =2 ns in our case). See Fig. 1, left.

- Feedback Kickers: in order to cure the fast transverse instabilities, we will install two of these kickers (horizontal and vertical). See Fig. 1, right. Since their purpose is only beam excitation, their length is $\lambda/2$.

In this report we describe the steps followed for the design of these devices.

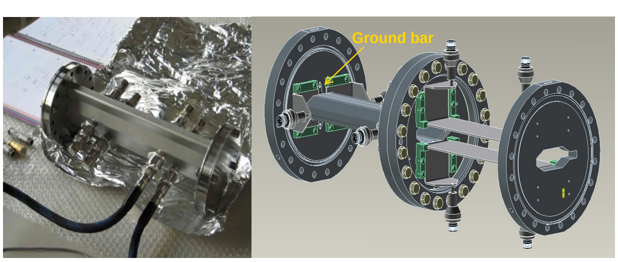

Figure 1: Stripline (left) and hor and ver kicker (right).

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STORAGE RING STRIPLINE

In this case, we design a four-electrodes striplines for either beam measurement or beam excitation. We describe the line impedance matching, the effective kick produced by the stripline, and its coupling impedance.

Line Impedance Matching

First, the electrodes shall be matched to the line impedance. A four-electrode stripline supports 4 independent TEM eigenmodes: sum, dipole horizontal, dipole vertical, and quadrupole modes (see Fig. 2. left). Typically, when the purpose of a stripline is the beam position measurement, these devices are designed using the traditional sum-mode matching with wide electrodes to maximize the beam signals [1]. For the dual purpose case, we have adopted the compromise relation [1]:

$$Z_L = Z_{\text{dipole}} = \sqrt{Z_{\text{sum}} Z_{\text{quad}}} \,. \tag{1}$$

where $Z_L = 50\Omega$, and we have assumed that the hor and ver dipole modes are identical (which, as seen "a posteriori", is a good approximation).

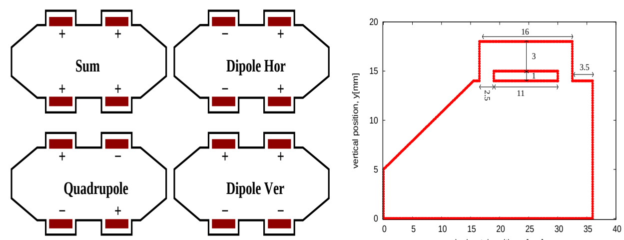

Figure 2: Independent modes in a four-electrode stripline (left), and geometry of one forth of it (right).

For symmetry reasons and because of the low coupling between the strips, the differences between the 4 aforementioned modes can be neglected and it is common to focus the study on one forth of the vacuum chamber [2]. As the results will show (see Table 1), this is not a bad approximation. Each of these eigenmodes has a characteristic impedance that can be easily computed with simple transverse 2-d electrostatic codes (in this case, we use SUPERFISH). The final geometry for one forth of the vacuum chamber is shown in Fig. 2, right.

The results for the 4 modes are shown in Table 1. Note that $\sqrt{Z_{\text{sum}} Z_{\text{quad}}} = 51.16\Omega$, and so the last condition in Eq. 1 is fulfilled with $\sim 2\%$ of discrepancy.

Table 1: Impedance of the SR Stripline for Each Eigenmode

	Sum	Dipole Hor	Dipole Ver	Quad
Z(Ω)	52.78	50.89	50.05	49.59

Effective Kick

The shunt impedance Z_{sh} of a kicker made out of two electrodes of length l and spaced with a distance d is [4]

$$Z_{sh} = 2Z_0 \left(\frac{2g\beta c}{d\omega}\right)^2 \sin^2\left(\frac{\omega l}{c}\right), \qquad (2)$$

where Z_0 is the vacuum impedance, ω refers to the kick angular frequency, c is the speed of light, and g is the geometrical factor [4]. Figure 3 shows the shunt impedance for the stripline and the vertical feedback kicker (which will be seen in the next Section). Note the difference between the nodes position (corresponding to $\lambda/4$ and $\lambda/2$, respectively) and the significant difference between shunt impedances at $\omega = 0$ GHz (1.3 kΩ vs 45 kΩ). Since the purpose of the stripline is just the beam excitation for tune measurements, this shunt impedance is sufficient.

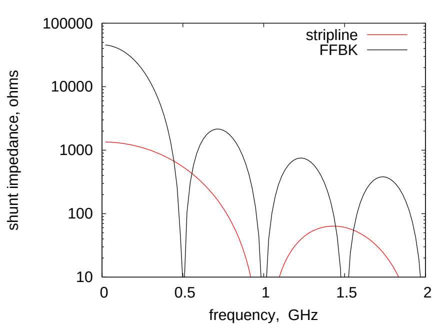

Figure 3: Shunt impedance of the stripline and vertical feedback kicker.

Coupling Impedance

Since the loss of a stripline is inversely proportional to the bunch length of only 4.6mm, the losses are quite high, namely 23W. Under the assumption that above the cutoff-frequency most wake fields propagate away from the stripline, the remaining losses at the device are slightly above 15W. But it can be even a bit more if the modes trapped at the feedthroughs do not couple well to propagating modes. Figure 4 shows the stripline impedance spectrum, where on distinguishes two separate parts: the characteristics of a stripline (below $\sim$ 6 GHz) and of a BPM button (around 10 GHz).

On the other hand the vertical and horizontal transverse impedance of 180Ω/m and 263mΩ/m are small compared to the storage ring transverse impedance budget.

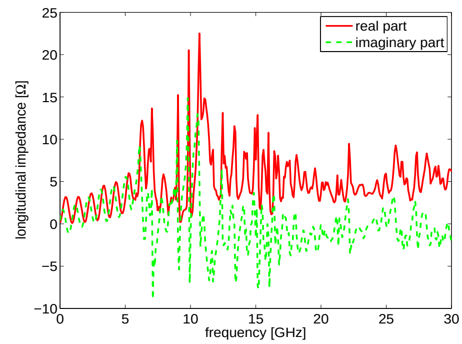

Figure 4: Spectra of the longitudinal impedance.

STORAGE RING FEEDBACK KICKERS

As in the ALBA storage ring resistive wall coupled instabilities are expected already at moderate currents a dedicated feedback kicker is needed for each transverse plane. Our design is based on the one of SLS/Elettra[3]. Since its purpose is to damp the coupled bunch instabilities, the electrodes length is $\lambda/2$. The drawback of this solution is the significant geometrical impedance these devices produce.

Line Impedance Matching

In this case we will only use the dipole configuration (+ -), and the line impedance matching is straightforward. Figure 5 shows both vertical and horizontal kickers dimensions. The ver kicker consists of two parallel plates placed inside a cylindrical chamber, where the distance between them is equal to the vertical dimension of the SR beam pipe. The hor kicker follows the general SR chamber geometry, where we have introduced a ground plate between the two electrodes to reduce the transverse beam impedance (see below).

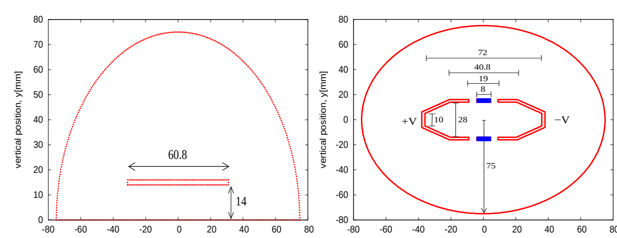

Figure 5: Transverse geometry of the vertical (right, half-geometry) and horizontal kickers (right).

Effective Kick

In this case, the goal is that the effective kick can cure the CBI, i.e. feedback damping time τ_F should be faster than CBI growth time.

The maximum kick $\Delta\theta_k$ produced by the feedback system shall correspond to the maximum beam transient x_{max}. With the proper phase advance between the kicker and the pickup, the feedback damping time τ_F is [4]:

$$1/\tau_F = \frac{\Delta\theta_k}{2x_{max}} f_0 \sqrt{\beta_p \beta_k} \qquad (3)$$

where f_0 is the revolution frequency, β_p and β_k are the beta function at the pick-up and kicker.

The kick produced to a elementary particle crossing between two electrodes is:

$$\Delta\theta_k = e\sqrt{2PZ_{\rm sh}}/E \ , \qquad (4)$$

where Z_{sh} for the hor and ver kickers are shown in Fig. 3 and Table 2, P=100 W is the amplifier power and E=3 GeV is the beam energy.

On the other hand, the (fastest) resistive wall (RW) instability growth time τ as a function of the beam intensity I is:

$$1/\tau = \frac{I}{2E/e}\frac{f_0(\langle\beta\rangle R_\perp)}{\sqrt{(1-Q_0)f_0}} \ , \qquad (5)$$

where $\langle\beta\rangle$ is the beta function, Q_0 is the fractional betatron tune, and $R_\perp$ is the transverse rw impedance for f=1 GHz.

Figure 6 shows the instability growth time as a function of the beam intensity using the parameters in Table 2, compared to the feedback damping time assuming a maximum transient of $x_{\rm max} = 1$ mm.

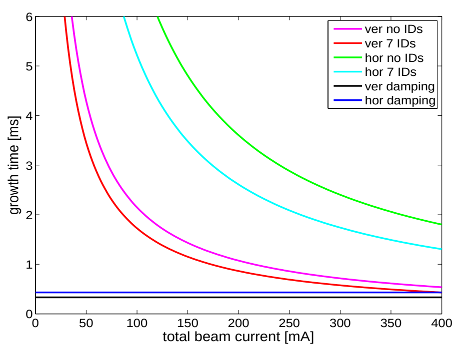

Figure 6: Damping rate needed for both planes for different machine configurations at zero chromaticity.

Table 2: Parameters Determining Feedback Damping and rw Instability Growth Times

Parameter	unit	Hor	Ver
β_p, β_k	m	8.9, 8.6	5.6, 5.1
Z_{sh}	kΩ	45.7	10.1
$\langle\beta\rangle R_\perp$ (w.o. IDs)	$\mathrm{k}\Omega\sqrt{\mathrm{GHz}}$	210	600
$\langle\beta\rangle R_\perp$ (with IDs)	$\mathrm{k}\Omega\sqrt{\mathrm{GHz}}$	290	750

Coupling Impedance

The geometrical coupling impedance of the hor and ver feedback kickers are calculated with GdfidL and shown in Table 3. The ceramical supports in the electrodes provide mechanical stability, and a slight improvement in the impedance in both cases. The power loss of the hor kicker could be reduced by almost a factor 4 with the introduction of the ground plate and now is only 56 W.

As for the vertical kicker, a countermeasure to reduce this power loss is currently being investigated. First analysis show that the power loss in the ver kicker can be reduced by about a factor of 2-3 by reducing the gap between the edge flanges and the electrodes (from 5mm to 1mm).

Table 3: Geometrical Coupling Impedance of the Kickers

	$Z_V[\frac{k\Omega}{m}]$	$Z_H[\frac{k\Omega}{m}]$	$\kappa_\parallel[\frac{V}{pC}]$	P[W]
ver kicker	1.67	0.78	0.57	179
hor kicker	0.43	0.55	0.18	56

The longitudinal impedance spectra contain many resonances. The analysis of the eigenmode vertical kicker spectrum shows that the shunt impedances of the resonances remain below the threshold of LCBIs. Around 4 GHz, the shunts reach values of already half of the threshold.

Whereas the values of transverse impedance are acceptable within the storage ring impedance budget, the power loss is of larger concern. By summing up the individual loss factors of the resonances below the cutoff frequency of the beam chamber ($\lesssim$ 6 GHz), a better appreciation of the power dissipation was achieved. A power loss of around 100 W for the vertical kicker is calculated, the horizontal one is only 33 W. The endplates, the feedthroughs and occasionally the ground plate were identified as parts of highest heat load. We plan to perform a finite element analysis to evaluate the temperature rise along the vertical kicker.

SUMMARY

Striplines and kickers at ALBA are presented. The analysis of their designs show that they are properly adapted to the line impedance, and their design fulfills the goals of tune excitation (for the stripline) and feedback damping (for the kickers). A potential concern can be the power loss in the vertical kicker, for which a first countermeasure is being investigated.

ACKNOWLEDGMENTS

We are very grateful for the engineering support from M. Cornelis, suggestions from our Cinel colleagues, and useful comments from M. Dehler and V. Schlott (SLS).

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