A WIDEBAND SLOTTED KICKER DESIGN FOR SPS TRANSVERSE INTRA-BUNCH FEEDBACK

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Abstract

Control and mitigation of transverse beam instabilities caused by electron cloud and TMCI will be essential for the SPS to meet the beam intensity demands for the HL-LHC upgrade. A wideband intra-bunch feedback method is in development, based on a 4 GS/s data acquisition and processing, and with a back end frequency structure extending to 1 GHz. A slotted type kicker, similar to those used for stochastic cooling, has been considered as the terminal element of the feedback chain. It offers the most promising deflecting structure characteristics to meet the system requirements in terms of bandwidth, shunt impedance, and beam coupling impedance. Different types of slotted structures have been explored and simulated, including a ridged waveguide and coaxial type waveguides. In this paper we present our findings and the conceptual design of a vertical SPS wideband kicker consistent with the stay clean, vacuum, frequency band coverage, and peak shunt impedance requirements.

INTRODUCTION

1. Intensity dependent effects like electron cloud (Eclou) and transverse mode coupling instabilities (TMCI) cause intra-bunch motion that can lead to emittance blowup and ultimately loss of beam in the SPS.
2. For the HL-LHC phase of the LHC, the SPS must be able to provide beams with a 1 GHz frequency band coverage, and peak shunt impedance requirements.
3. First measurements with the new feed-back system have been successfully performed this past year at the SPS with a limited bandwidth 200 MHz stripline kicker.
4. A wideband kicker critical An effort to evaluate the most suitable type of kicker technology available has been on going, investigating striplines, cavities, and slotted structures.
5. The slotted-coaxial kicker exhibits desirable characteristics in bandwidth and shunt impedance.
6. The transverse kicker must be able to provide kick deflections of the order of 10⁻²° over a bandwidth up to 1 GHz to mitigate such beam intensity effects.

SLOTTED STRUCTURES

1. The slotted-type kicker geometries, evaluated in HFSS, are similar to that used for stochastic cooling.
2. The slotted-coaxial kicker consists of a waveguide coupled to a beam pipe via slots.
3. The slotted-waveguide is an extension of the slotted-waveguide kicker, the ridge concentrates the field.
4. The slotted-coaxial kicker has a coaxial transmission line within the waveguide.

SLOTTED-COAXIAL KICKER INITIAL PARAMETERS

1. The dimensions of the entire coaxial model were parameterized for optimization, maximizing the shunt impedance of the kicker.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Dimension (mm)</th>
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<tbody>
<tr>
<td>w</td>
<td>Waveguide width</td>
<td>150</td>
</tr>
<tr>
<td>h</td>
<td>Waveguide height</td>
<td>50</td>
</tr>
<tr>
<td>ss</td>
<td>Slot spacing</td>
<td>20</td>
</tr>
<tr>
<td>th</td>
<td>Slot interface thickness</td>
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<tr>
<td>bh</td>
<td>Beam pipe height</td>
<td>52.3</td>
</tr>
<tr>
<td>al</td>
<td>Overall length of slotted section</td>
<td>1000</td>
</tr>
</tbody>
</table>

Figure 2: Quarter model geometries of the three slotted-type kickers evaluated in this study.

PHASE OF TRANSVERSE VOLTAGE

1. The slotted-coaxial kicker has linear phase response in operating band.

Figure 4: Transverse shunt impedance calculations for the three variations of the slotted type kicker. The slotted-coaxial kicker shunt impedance is plotted for different slot lengths (SL).

Figure 5: Phase of the transverse voltage. Color and symbol coding reference is the same as above.

TRANSVERSE SHUNT IMPEDANCE

Transverse voltage $V_i = \int_{-L/2}^{L/2} [E_z(x) - dB_y(x)] e^{ikx} dx$

$Z_y = \left(\frac{\mu_0}{2\pi}\right) \left(\frac{w}{h}\right) R_y$ (1)

- Beam propagates in the $z$-direction
- $E_z(x)$ and $B_y(x)$, complex fields in the vertical and horizontal directions
- $\mu_0$ accounts for the beam transit-time
- $L$, the length of the structure
- $P$, the input power to the structure
- $T$, the reduced energy gain from the beam’s finite transit-time through the kicker

Figure 3: Quarter model geometries of the three slotted-type kickers evaluated in this study.

Figure 6: Real and imaginary parts of the transverse beam coupling impedance for the coaxial slotted kicker with a slot length of 80 mm for a simulated beam transverse offset of 4 mm.

- The broadband kicker impedance is a small fraction of the total SPS impedance.
- Estimated transverse broadband impedance is less than 150 MΩ/m, as compared with 8 – 9 MD/m, from all other installed SPS kickers.
- Wake fields decay very fast.
- Longitudinal wakes $\omega_z$ disappear before the arrival of successive bunches.

Figure 7: The longitudinal wake potential of a 2 cm long bunch. The blue line marks the 25 ns bunch separation.

- Optimal slot width to slot spacing (along the beam axis) aspect ratio of 1 to 1.
- For fixed length of 1 m, doubling slots increased the shunt impedance by 25%.
- Shunt impedance 20 mm horizontally off axis reduced by 40%.
- Future studies include power coupler design and matching.

OPTIMIZATION

1. Numerical simulations with G4Sim, to evaluate beam coupling impedance.
2. Both longitudinal and transverse impedances broadband until > 5 GHz.

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