A BROADBAND RF STRIPLINE KICKER FOR DAMPING TRANSVERSAL MULTIBUNCH INSTABILITIES*

Manuel Schedler†, André Roth, Wolfgang C.A. Hillert, Dominik Heiliger,
ELSA, University of Bonn, Nussallee 12, D-53115 Bonn, Germany

Abstract

When operating an RF feedback system, being able to reliably act upon every single bunch is a necessity. By employing a broadband RF stripline kicker, any bunch displacement can be corrected for.

In a 500 MHz accelerator, the decay time of the electromagnetic field inside the kicker has to be less than 2 ns in order to avoid the following bunch being affected. By designing the kicker as an RF coax device matched to the line impedance of the power cables, perturbing reflected signals are avoided. Additionally, the kicking strength and thus the shunt impedance should be maximized over the full spectrum from DC to 250 MHz. The kicker design has been optimized to meet the above requirements by relying on CST Microwave Studio™ simulations. Their results and first measurements are presented.

BUNCH BY BUNCH FEEDBACK SYSTEM

The stripline kicker is part of a multibunch feedback system to damp coherent transverse beam instabilities [1]. The oscillation of every bunch is measured by a beam position monitor (BPM) and the amplitude is used to calculate a correction signal, which has to be amplified by a broadband 100 W RF amplifier in order to achieve enough damping power for damping instabilities at high beam currents. In addition a higher shunt impedance is obtained by driving the kicker antisymmetrically using a 180° splitter to divide the RF signal, each component driving one of the opposing striplines. After the signal has passed the kicker structure, it is absorbed by a water cooled 100 W load of 50 Ω impedance, to avoid reflections which would affect the beam. The complete driving scheme is shown in Figure 1.

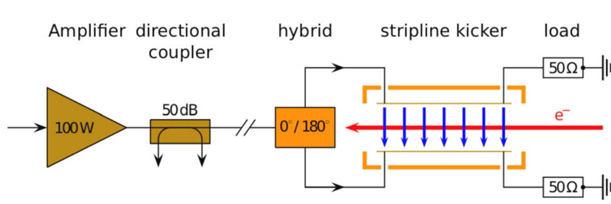

Figure 1: Driving scheme of the stripline kicker (vertical plane) using a broadband RF amplifier and a 0°/180° hybrid

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† schedler@physik.uni-bonn.de

REQUIREMENTS

When operating a bunch by bunch feedback system in an accelerator with a 500 MHz rf system, the kicker must be able to kick every single bunch with a correction signal with individual polarity and strength. This leads to a maximum driving RF frequency of 250 MHz and correspondingly to a required bandwidth from DC to 250 MHz.

To properly kick every single bunch with its respective correction signal, the line impedance of the kicker structure has to be matched to the impedance of the power cables, which typically is 50 Ω. Thus, there will not be any reflections at the power connectors which could act back on the beam, even with no external correction signal being applied.

The frequency dependency of the shunt impedance R_S of an ideal cylindrical stripline kicker is basically given by the length L of the striplines and their radius r, using

$$R_S(\nu) = \frac{8 Z_L c^2}{\pi^2 r^2 \nu^2} \sin^2\left(\frac{\theta}{2}\right) \sin^2\left(\frac{2\pi\nu}{c} L\right), \quad (1)$$

where Z_L denotes the line impedance of the kicker, c the speed of light, ν the signal frequency and θ the opening angle of the striplines [3]. This behaviour is shown in Figure 2 for different lengths of the striplines.

To obtain the desired bandwidth of 250 MHz, a maximum stripline length of 60 cm can not be exceeded. In addition, the peak value of the shunt impedance also depends on the length. Thus, one has to find a compromise between bandwidth and maximum value of the shunt impedance. By setting the length to 30 cm both requirements are fulfilled. The first zero of the shunt impedance then is located at 500 MHz, so that none of the RF harmonics of the beam's spectrum will transfer energy to the kicker which could damage the driving amplifiers and heat the kicker due to resistive losses.

SIMULATION AND DESIGN

In a coaxial cable, the line impedance only depends on the ratio of the radii of the outer and inner conductor. Based on this relation, the kicker is build as a coax device with outer and inner conductor, where the inner conductor consists of four bended striplines. In order to be able to drive the striplines independently, each of them is equipped with an RF port at both ends. By driving opposing striplines with different polarity, one can obtain a horizontal or vertical dipol field, which due to its homogeneity in the center region of the inner conductor, kicks the particle beam only

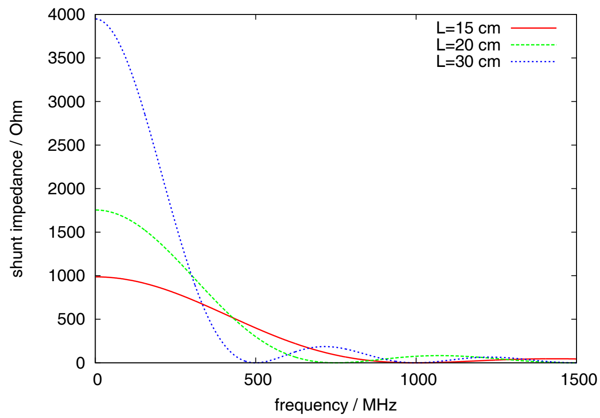

Figure 2: Shunt impedance of an ideal stripline kicker for different lengths of the striplines

in one plane. In Figure 3 electric and magnetic field distributions, calculated with CST Microwave Studio™, are shown in the case of driving the upper and lower stripline. Due to the Lorentz force, both field components act in a deflecting way in the vertical plane when the electron beam enters form the front.

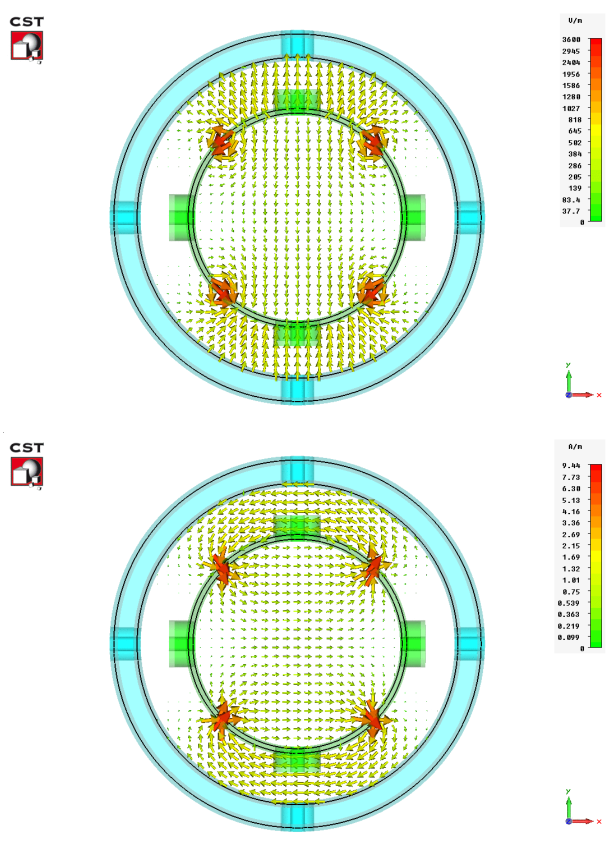

Figure 3: Electric (top) and magnetic (bottom) field distribution in the stripline kicker, when driving the upper and lower stripline

By minimizing of the reflection parameter, calculated with the Transition Solver of CST Microwave Studio™, the optimum ratio between the radii of the outer and inner conductor was found by variing the radius of the outer one. A minimum of the reflection parameter was obtained for a ratio of 1.53.

According to equation (1), the kick strength of a stripline kicker depends on the opening angle θ of the striplines. Using the Electrostatic Solver of CST Microwave Studio™, one can find the dependency between the electric field strength on the beam axis and the opening angle, shown in figure 4. To assure electric disjunction between the striplines, the opening angle is set to 85°, which reveals the maximum electric field strength as indicated in Figure 4.

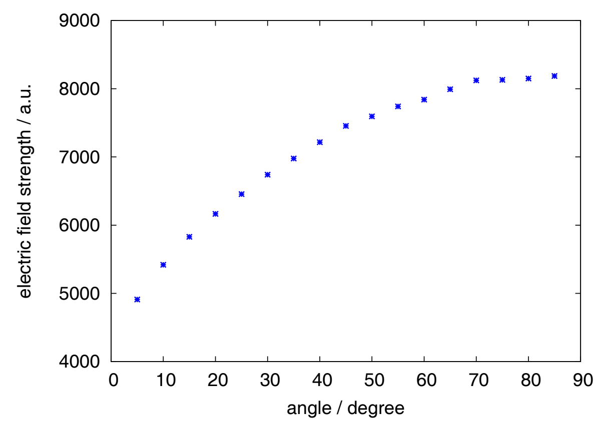

Figure 4: Calculation of the electric field strength on the beam axis of the stripline kicker in dependence of the opening angle of the striplines

Additionally, the peak value of the shunt impedance depends on the striplines' radius r. The limiting factor when optimizing this radius is the beam diameter. To assure a proper beam lifetime, the beam pipe should not go below 10 times the standard deviation of the gaussian beam shape. This leads to an optimal radius for the striplines of 22.5 mm.

Due to resistive losses and due to beam coupling the striplines are heated by the input power and the beam. To avoid damaging the kicker, the equilibrium temperature when being in operation has been calculated and is used to find the optimum material and thickness to construct the striplines. Figure 5 shows the result of a temperature simulation of the final kicker geometry with the Thermal Solver of CST Microwave Studio™. Based on these calculations, the striplines have been manufactured out of copper because of its high conductivity and their thickness has been set to 1 mm. With these parameters, the kicker's heating up can be reduced to 10° C in case of 50 W RF power per port and a beam current of 200 mA.

To couple in RF power, eight vacuum feedthroughs were built as coaxial devices, matched to the line impedance by choosing the right relation of radii. One of these feedthroughs is shown in Figure 7. The outer conductors of feedthrough and kicker as well as the inner ones are con-

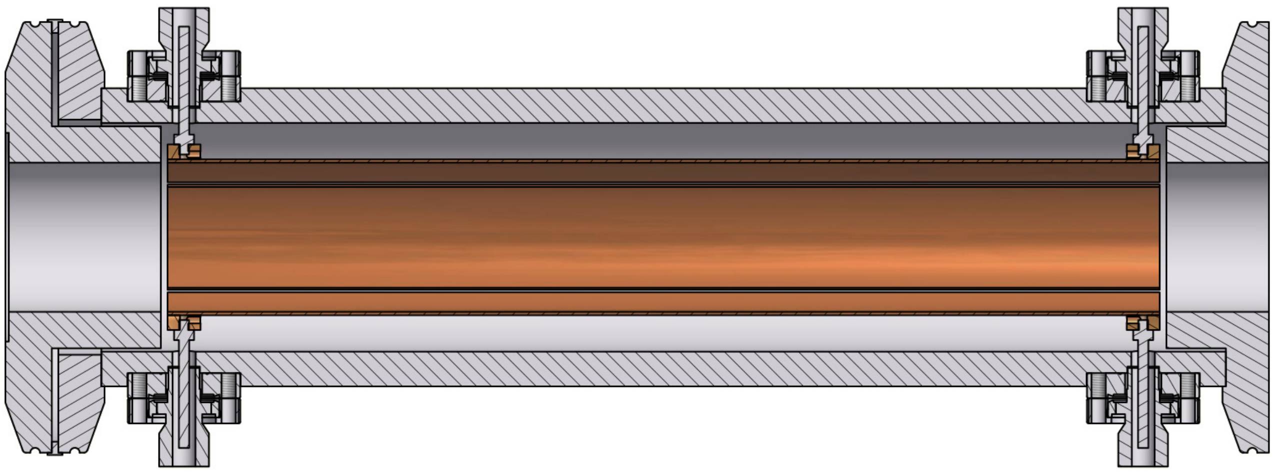

Figure 6: Cut through the final geometry of the new stripline kicker

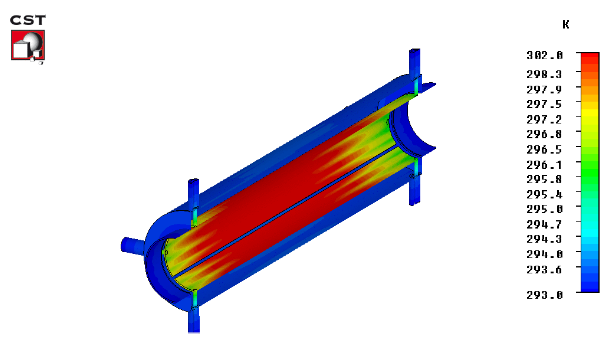

Figure 5: Heating up of the striplines due to resistive losses when driving the kicker with 200 W total power on four ports

nected to each other.

The final geometry of the kicker's design is shown as a cut in Figure 6, all relevant parameters are summarized in Table 1. There are shown the striplines made out of copper mounted to two feedthroughs and the outer conductor made out of stainless steel. To avoid additional excitation of wake fields, outside the kicking region the radius of the outer conductor is adapted to the radius of the striplines. Thus, there is no change in diameter which could produce additional wake fields.

CONCLUSION

With this new stripline kicker, it will be possible to damp coherent multibunch instabilities as part of a new bunch by bunch feedback system.

Figure 7: One of the special feedthroughs built to excite the RF field inside the kicker device, manufactured by Hositrad Vacuum Technology™

Table 1: Final Parameters of the New Stripline Kicker

Parameter	**Value**	
bandwidth	$(0-500)$	MHz
maximum shunt impedance	≈ 4	kΩ
length of striplines	300	mm
thickness of striplines	1	mm
radius of striplines	22.5	mm
radius of outer conductor	34.5	mm
line impedance	$(50-54)$	Ω
maximum heating (50 W per port)	≈ 10	°C

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