Proc. 13th International Beam Instrumentation Conference,Beijing JACoW Publishing
ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP07

STRIPLINE DESIGN FOR TUNE MEASUREMENT IN THE ILSF STORAGE RING*

S. Mohammadi.A†, N. Khosravi, A. Danaeifard, Z. Rezaei
Institute for Research in Fundamental Sciences (IPM),
Iranian Light Source Facility (ILSF), Tehran, Iran

Abstract

The Iranian Light Source Facility Storage Ring is under design with a 528 m circumference and will store the electron bunches with 3 GeV energy to produce high-flux radiation that ranges from infrared to hard X-rays. The Stripline is planned to be installed in the ILSF storage ring for beam tune measurement and transverse feedback system (TFS). This stripline can be used for exciting the beam in tune measurement system and damping the transverse instabilities in TFS. In this paper, the design of the striplines for the ILSF storage ring is investigated. Each stripline is matched with 50Ω and has 4 strips (electrodes) that are placed at 45 degrees to the beam axis, the best geometry is achieved and optimized by CST Microwave Studio simulation.

INTRODUCTION

The Iranian Light Source Facility (ILSF) Storage Ring is under design with a 528 m circumference, 176 harmonic number, 100 MHz frequency, and ($a = 26$ mm) vacuum chamber diameter. It will store the electron bunches with 3 GeV energy to produce high-flux radiation that ranges from infrared to hard X-rays. The stripline is planned to be installed in the ILSF storage ring for beam tune measurement and transfer feed-back system.

Each stripline consists of four strips (electrodes), eight coaxial feed-throughs, and water colling connectors. This system is matched to the 50 Ω impedance of the coaxial feed-through cables. The mechanical design of the stripline depends to geometric parameters such as electrode thickness (t), opening angles (φ_s) and the distance between the electrode and chamber (housing) (G) ultimately aiming for a high geometry factors.

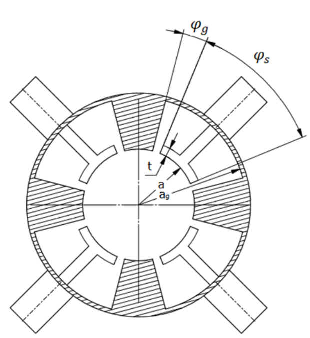

Figure 1: Overview of the ILSF stripline. The cross section of the nominal section.

† Email address samira.mohammadi@ipm.ir.

The kicker stripline plays a crucial role in manipulating the trajectory of the electron bunches by applying precise electromagnetic pulses. This ensures the stability and accuracy of the electron beam, which is essential for producing consistent and high-quality radiation. Additionally, the striplines are involved in tune measurement and beam position determination, contributing to the overall performance of the storage ring. In this paper geometric factors of several design with different geometric parameters are calculated to choose the best design. The wakefield impedance and loss factor of the optimal geometry are then determined using CST Microwave Studio.

DESIGN

Design of the Stripline Geometry

In this design 4 electrodes are placed in the 45,135,225, and 315 degrees at a distance equal to the radius of the storage ring vacuum chamber (a) (Fig. 1). The choice of these angles for the electrodes is to protect them from synchrotron radiation emitted from an upstream dipole magnet [1].

The electrode lengths are given by [2]:

$$l = \frac{c}{4f} = \frac{\lambda}{4} = 75 \text{ cm} \tag{1}$$

Where (c) is the speed of light, (f) is acceleration frequency and (λ) is the wave length. In this length, the first maximum voltage is will be obtained.

The design of the stripline depends to geometric parameters such as electrode thickness ($t = 2$ mm), opening angles (φ_s) and the distance between the electrode and chamber ($G = \varphi_g - a$).

Several designs with varying geometric parameters, were created. Their geometric factors were calculated using the geometry factor formula for comparison [1,3]:

$$g_\perp = \frac{8}{\varphi_g \pi} \sin\left(\frac{\varphi_g}{2}\right) \sin\left(\frac{\varphi_s + \varphi_g}{2}\right) \tag{2}$$

And the impedance is calculated by using CST Microwave Studio's Frequency domain solver (H and E are boundary conditions in ¼ models) by placing a port in the middle of the designs for 4 modes: vertical and horizontal dipole, quadrupole, and sum mode (Figs. 2, 3, 4, and 5). The shunt impedance is given by the following formula [4-6]:

$$Z_{ch} = \sqrt{Z_{sum} \times Z_{quad}} = \sqrt{Z_{V-dipole} \times Z_{H-dipole}} \tag{3}$$

ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP07

The best design features a high geometric factor (see Table 1) and excellent matching for characteristic impedance, close to 50 Ω (Table 2).

Table 1: Geometric Factor Comparison

No. Design	φ_s (°)	φ_g (°)	$g_\perp$
1	60	5	0.6839
2	60	8	0.7114
3	45	6	0.5479
4	45	8	0.5677
5	45	10	0.5872
6	40	10	0.5374
7	40	12	0.5571
8	30	12	0.4555
9	30	15	0.4859

The CST software does not provide an acceptable result for the sum mode, so it was disregarded. Design number 4 was selected as the appropriate design for the ILSF storage ring.

CST Simulation

The chamber material is considered to be 316LN, and the electrode material is steel 316L (similar to MAXIV).

- WAKE Impedance

Wakefield simulations are performed by CST microwave studio with wakefield solver. The bunch length (σ)is set to 2 mm, and the mesh consist of 88 million cells (Figs. 6, 7 and 8):

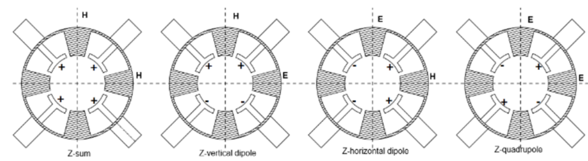

Figure 2: Different operation modes of stripline.

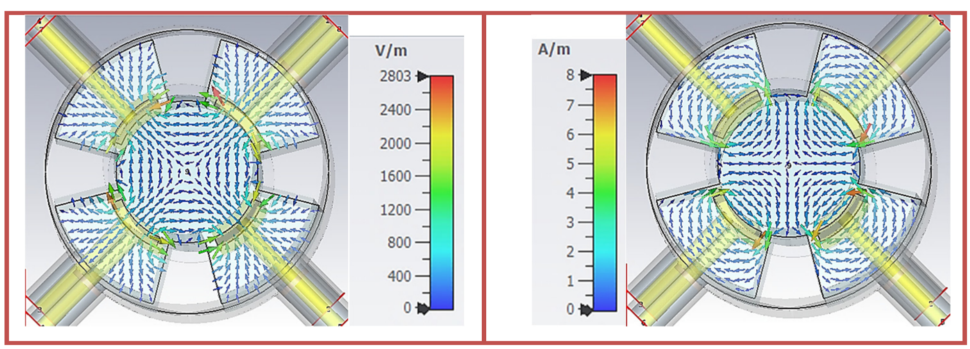

Figure 3: E-field (left) H-field (right) in quadrupole mode results in the stripline kicker in the x-y plan.

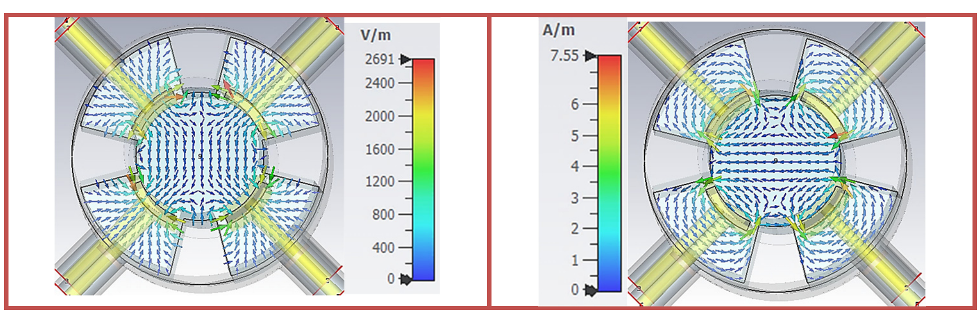

Figure 4: E-field (left) H-field (right) in V-dipole mode results in the stripline kicker in the x-y plan.

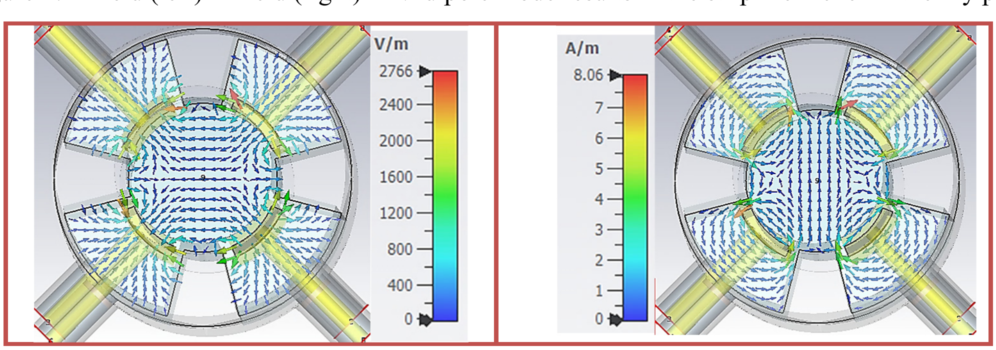

Figure 5: E-field (left) H-field (right) in H-dipole mode results in the stripline kicker in the x-y plan.

ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP07

Table 2: Impedance in Different Modes

No. Design	G	$Z_{H-Dipole}$ (Ω)	$Z_{V-Dipole}$ (Ω)	Z_{Quad} (Ω)	Z_{ch} (Ω)
2	7	43.690	43.686	41.829	43.687
	10	46.300	46.293	44.177	46.296
4	7	48.706	48.706	47.576	47.706
	10	50725	50.732	49.522	50.727
5	5	49.373	49.370	48.108	49.371
	7	53.233	53.165	51.648	53.198
7	5	55.039	55.037	53.669	55.037

The CST simulation was performed for 3 frequency 100, 250, and 500 MHz, so 3 strip length 75, 30 and 15 cm (see Table 3).
The time of between two signals is:

$$t = \frac{2l}{c} \tag{4}$$

$$l = 75\text{ cm } (t = 5\text{ ns}), l = 30\text{ cm } (t = 2\text{ ns})\ and\ l = 15\text{ cm}(t = 1\text{ ns})$$

Table 3: Geometric Factor Comparison.

Length of strip	$g_{\perp d}$	$Z_{H-Dipole}$ (Ω)	$Z_{V-Dipole}$ (Ω)	Z_{Quad} (Ω)	Z_{ch} (Ω)
75	0.5677	50.730	50.730	49.514	50.730
30	0.5677	50.731	50.734	49.470	50.732
15	0.5677	50.664	50.725	49.507	50.684

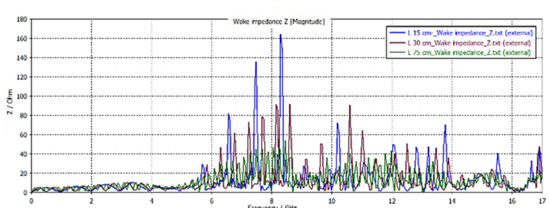

Figure 6: Longitudinal wake Impedance for 3 strip length.

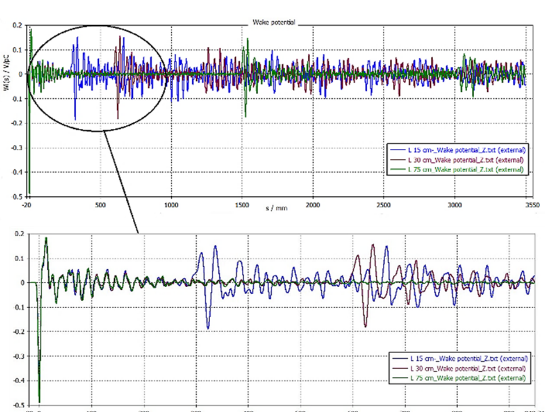

Figure 7: Wake potential for 3 strip length.

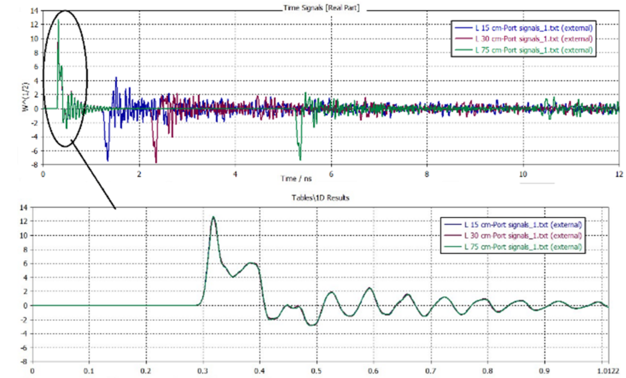

Figure 8: Port signal for 3 strip length.

- *S Parameter*

S parameter simulations are performed by time domain CST solver (see Fig. 9, Fig.10, Fig.11).

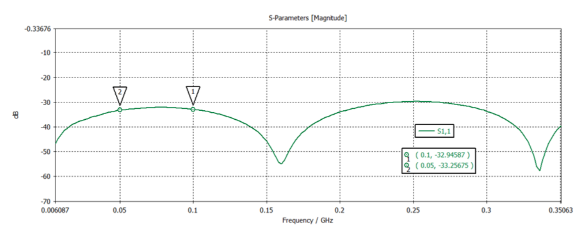

Figure 9: S parameter for strip length 75 cm.

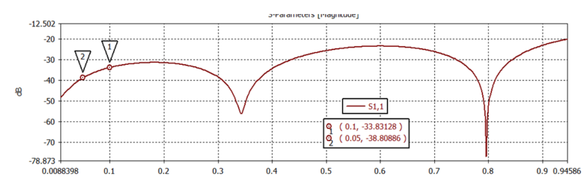

Figure 10: S parameter for strip length 30 cm.

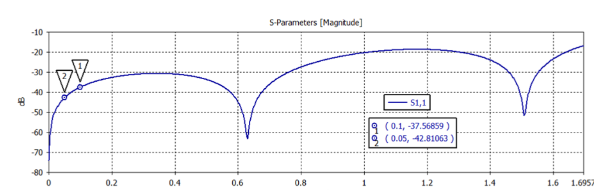

Figure 11: S parameter for strip length 15 cm.

- *Power Loss*

The wake loss factor (k_{loss}) for the bunch length $\sigma = 2$ mm and $\sigma = 7.9$ mm is given by [7]:

$$k_{loss} = -\int_{-\infty}^{\infty} \lambda(s) W\|(s) ds \tag{5}$$

Where $\lambda(s)$ is charge distribution and $W\|(s)$ is wake potential.

The power loss (P_{loss}) is calculated by:

$$P_{loss} = T_0 \frac{I_{av}^2}{M} k_{loss} \tag{6}$$

ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-TUP07

Where $I_{av} = 400$ mA is the total average current, $T_0 = 1.7623$ µs is the revolution periode, and M=140 is the number of bunches (see Table 4). The overview of the stripline CST simulation can be seen in Fig. 12.

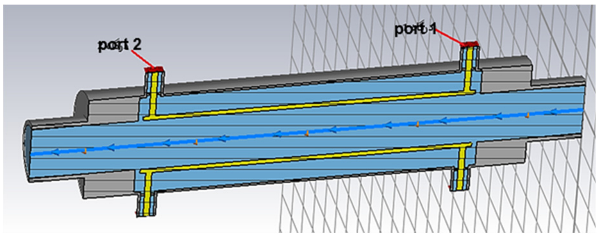

Figure 12: overview of the CST stripline simulation.

Table 4: Loss Factor and Power Loss for Bunch Length ($\sigma = 2$ mm) and Real ILSF Bunch $\sigma = 7.9$ mm

Bunch length	$k_{loss}(^{V}/_{pC})$	P_{loss}**(Watt)**
$\sigma = 2$(mm)	3.675×10^{-1}	$73.97 \times 10^{+1}$
$= 7.9$(mm)	5.798×10^{-2}	20.121
L=75 cm		
$\sigma = 2$(mm)	3.090×10^{-1}	$62.19 \times 10^{+1}$
$\sigma = 7.9$(mm)	4.660×10^{-2}	20.128
L=30 cm		
$\sigma = 2$(mm)	2.949×10^{-1}	$59.35 \times 10^{+1}$
$\sigma = 7.9$(mm)	4.436×10^{-2}	20.127
L=15 cm		

CONCLUTION

The length of 15 cm results in lower Wakefield potential, leading to less energy loss and greater stability. Additionally, it has lower Wakefield potential and fewer peaks. The Wakefield impedance peaks are also shorter. At all three lengths, the impedance matching at the ports is good, with values less than -30 dB.

The optimal length for our ring is 75 cm, but based on the results, if an appropriate electronic system like the Libera Signal Pass is used for signal reading, the length can be reduced to 15 cm. This would also solve the space issue for placing the strip lines.

REFERENCE

[1] D. Olsson, "Design of stripline kicker for tune measurements in the MAX IV 3GeV ring", presented at the Electromagnetics Research Symposium, Stockholm, Sweden, Aug. 12-15, 2013, unpublished.

[2] P. Forck, "Lecture Notes on Beam Instrumentation and Diagnostics", presented at JUAS 2017, ESI, Grenoble, France, unpublished.

[3] K. Tian *et al.*, "Design of a Multi-Bunch Kicker in SPEAR3", in *Proc. IPAC'21*, Campinas, SP, Brazil, May. 2021, pp. 327-330. doi:10.18429/JACoW-IPAC2021-MOPAB087

[4] CST, https://www.cst.com/products/cstps

[5] M. El Ajjouri *et al.*, "Design of the Transverse Feedback Kicker for ThomX", in *Proc. IBIC'16*, Barcelona, Spain, Sep. 2016, paper TUPG08, pp. 329-332. doi:10.18429/JACoW-IBIC2016-TUPG08

[6] W. X. Chemg, A. Blednykh, A. Loulergue, and O. Singh, "Stripline Kicker Design for NSLS2 Storage Ring", in *Proc. IPAC'11*, New York, NY, USA, Mar.-Apr. 2011, paper MOP266, pp. 603-695. https://jacow.org/PAC2011/papers/MOP266.pdf

[7] S. Naeosuphap, P. Sudmuang., "Design and Optimisation of Button Beam Position Monitor for SPS-II Storage Ring", in *Proc. IBIC'21*, Pohang, Korea, Sep. 2021, pp. 118-122. doi:10.18429/JACoW-IBIC2021-MOPP29