RF-KICK CAUSED BY THE COUPLERS IN THE ILC ACCELERATION STRUCTURE

A. Lunin, I. Gonin, A. Latina, N. Solyak, and V. Yakovlev, Fermilab, IL 60510, U.S.A.

Abstract

In this paper new results of calculation of the RF kick from the power and HOM couplers of the ILC acceleration structure are presented. The RF kick is calculated by HFSS and CST codes. Special measures allowing the calculation of the effect are described.

INTRODUCTION

The standard 1.3 GHz SC RF cavity of the ILC linac contains 9 cells, an input coupler, and two HOM couplers, upstream and downstream, see Fig. 1.

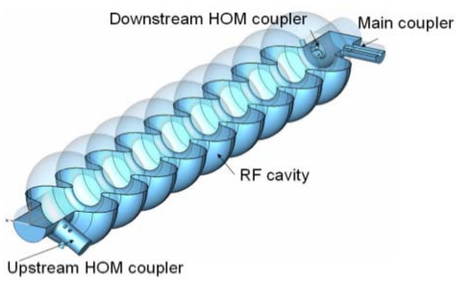


Figure 1: The ILC RF cavity with the main and HOM couplers.

The couplers break the cavity axial symmetry that causes a) main RF field distortion and b) transverse wake field. These effects may cause beam emittance dilution. RF-kick and coupler wake increase with the bunch length [1]. Calculations of the RF kick for the ILC cavity have been performed by different groups, with mismatching results, see Tab. 1.

Table 1: Results of RF-kick calculations.

	FNAL [1] $Q=3.5\times10^6$ HFSS	DESY [2] $Q=2.5\times10^6$ MAFIA	SLAC [3] $Q=3.5\times10^6$ OMEGA3P
$\frac{10^6 V_x}{V_z}$	-105.3+69.8i	-82.1+58.1i	-86.0+60.7i
$\frac{10^6 V_y}{V_z}$	-7.3+11.1i	-9.2+1.8i	-4.6+5.6i

The main reasons of the disagreement are the following: transverse fields caused by the couplers are extremely small (about 5-6 orders of magnitude smaller than the longitudinal fields); cancellation takes place between upstream and downstream coupler. Such characteristics demand for very high precision simulations of the field, better than 10^{-6}. This is a severe challenge for all numerical methods and codes.

GENERAL

In order to achieve reliable estimation for the RF kick, we used the following approaches: (i) different mesh geometry, (ii) different mesh size, (iii) different order of finite elements, (iv) different methods of the kick calculations (direct and Panofsky – Wenzel theorem), (v) different number of cells (from ½ cell to entire 9-cell geometry), and (vi) different codes (HFSS and CST).

HFSS code allows the use of a non-uniform mesh. A special three-zone mesh (see Fig. 1) was used in order to improve the field approximation near the axis. Intermediate mesh is necessary to match the fine mesh near the axis and regular mesh in the rest of the cavity.

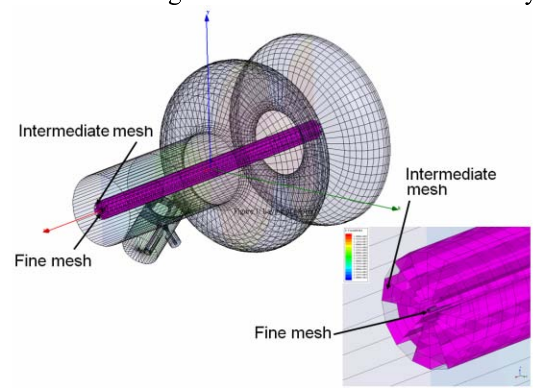


Figure 2: The three-zone mesh for HFSS used in order to improve the field approximation near the axis. Fine mesh repeats the pattern of the intermediate one.

A special symmetric mesh pattern was used in order to reduce the mesh noise. Different techniques of mesh symmetrization were used near the axis. The number of mesh nodes was up to 0.8×10^6. Cross-check of the direct RF kick were performed applying the Panofsky – Wenzel theorem. Fig. 3 shows the field pattern near the coupler.

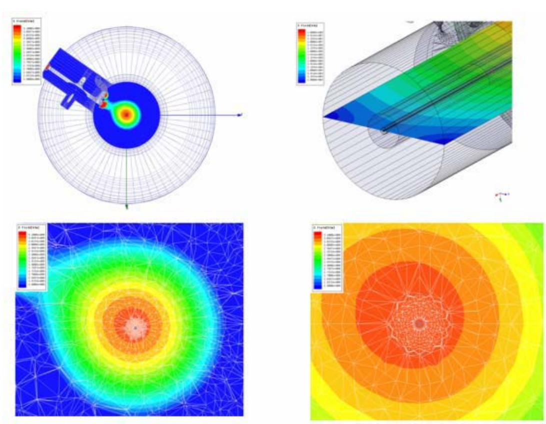


Figure 3: The field pattern near the coupler. The field asymmetry causes RF-kick.

Fig. 4 shows the results of the RF-kick HFSS simulations for upstream and downstream couplers for three cases: different finite element orders, different mesh numbers and direct calculation and Panofsky – Wenzel (PW) theorem. One can see that convergence takes place for large number of mesh nodes, and that both 1st and 2nd order elements and direct and PW method give the same results.

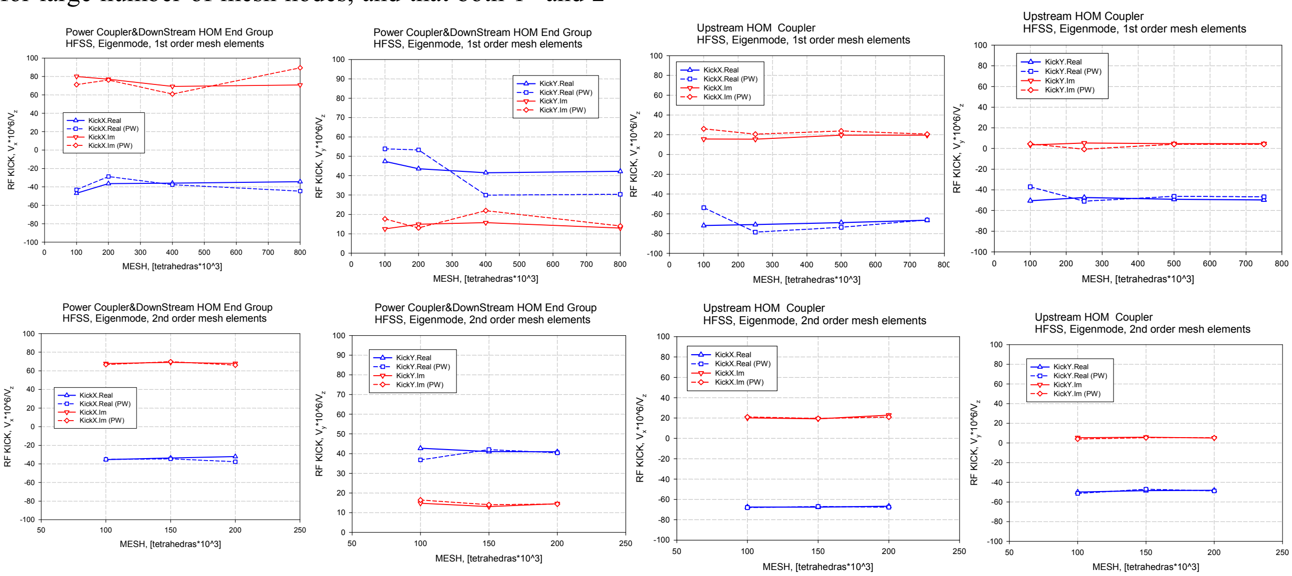


Figure 4: The results of the RF-kick simulations for upstream and downstream couplers for different finite element order, different mesh number and for direct calculation and Panofsky – Wenzel (PW) theorem. One and half cells were calculated.

In the Fig. 5 the results for the RF-kick for upstream coupler are presented for different number of the cells. Calculations were made by both HFSS and CST codes. In the CST case the mesh position was adjusted to the cavity axis in order to achieve symmetry in this region. One can see that the results are very close for all the cases and that the only difference is in the first cell, where the transverse field's components are not completely dumped.

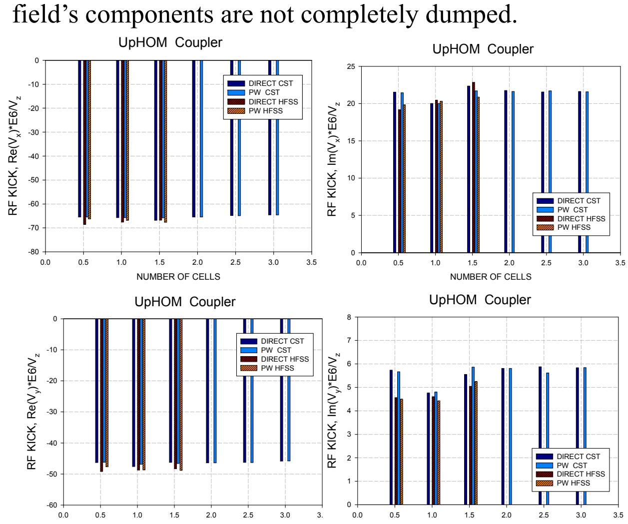
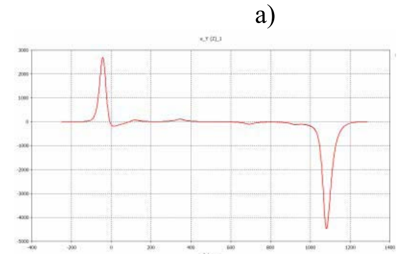


Figure 5: RF-kick for upstream coupler for different number of the cells calculated by both HFSS and CST codes.

In order to cross check the results, the entire structure with the couplers were simulated, see Figure 1. The total RF-kick is close to what was calculated separately, see Tab. 2. Thus, all the results show the same values of the transverse kick that however differ from the previous results for the vertical kick, that is the most critical for ILC.

a)



b)

Figure 6: Transverse magnetic field (a) and electric field (b) of the 9-cell ILC structure axis.

The vertical kick ratio to the energy gain per cavity is $(-6.8+18.4i)\times10^{-6}$ versus $(-7.4+11.1i)\times10^{-6}$ in our old calculations. However the beam vertical dilution is still small for the main linac. For the bunch compressor the girder optimization technique [4] still allows to compensate the emittance dilution

Table 2. RF-kick calculated separately for Upstream Coupler (a), Downstream End (b) and Total RF-kick (c) of ILC structure .

a)

	NEW FNAL* (HFSS & CST MWS)		**OLD FNAL (HFSS)**		**SLAC (Omega3P)**	**DESY (Mafia)**
	Direct	PW	Direct	PW	Direct	Direct
KickX $\frac{10^6 \cdot V_x}{V_z}$	-62.8+21.1i (CST) -62.7+21.4i (HFSS)	-61.7+20.4i (CST) -63.5+19.6i (HFSS)	-68.8+3.7i	-65.6+7.6i	-57.8+7.0i	-57.1+6.6i
KickY $\frac{10^6 \cdot V_y}{V_z}$	-43.5+5.2i (CST) -45.3+4.7i (HFSS)	-43.8+5.5i (CST) -45.9+4.9i (HFSS)	-48.3-3.4i	-53.1-2.1i	-40.9-3.5i	-41.4-3.5i

b)

	NEW FNAL* (HFSS)		**OLD FNAL (HFSS)**		**SLAC (Omega3P)**	**DESY (Mafia)**
	Direct	PW	Direct	PW	Direct	Direct
KickX $\frac{10^6 \cdot V_x}{V_z}$	-34.8+70.1i	-35.6+69.6i	-36.5+66.1i	-27.3+67.2i	-25.1+51.4i	-25.0+51.5i
KickY $\frac{10^6 \cdot V_y}{V_z}$	41.1+14.1i	42.1+13.1i	41.0+14.5i	40.9+12.8i	36.5+8.9i	32.2+5.2i

c)

	NEW FNAL* (HFSS & CST MWS)		**OLD FNAL (HFSS)**	**SLAC (Omega3P)**	**DESY (Mafia)**
	Direct	PW	Direct	Direct	Direct
KickX $\frac{10^6 \cdot V_x}{V_z}$	-97.5+91.5i (HFSS)	-99.1+89.2i (HFSS)	-105.3+69.8i	-86.0+60.7i	-82.1+58.1
KickY $\frac{10^6 \cdot V_y}{V_z}$	-4.2+18.8i (HFSS) Full ILC Cavity 0.4+20.6i (CST)	-3.8+18.0i (HFSS) Full ILC Cavity 0.1+21.2i (CST)	-7.3+11.1i	-4.6+5.6i	-9.2+1.8

* The End Group effect is taken into account during V_z calculation

REFERENCES

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[2] I. Zagorodnov, and M. Dohlus, LCWS/ILC 2007
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