3D NUMERICAL ANALYSIS OF MAGNETS AND THE EFFECT OF EDDY CURRENT ON FAST STEERING

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I. INTRODUCTION

Using the computer code of MAGNA, a product of Century Research Center in Japan, we made numerical analyses of magnets for a high-brilliant VUV and soft X-ray synchrotron radiation ring being designed at ISSP and Photon Factory ring of KEK. It is possible for MAGNA to calculate 2D and 3D magnetic fields and include the effects of eddy currents in the calculations.

II. 3D ANALYSIS OF PF BENDING MAGNET

First, in order to check the applicability of MAGNA to magnet design, we made the 3D analysis of the bending magnet used at Photon Factory of KEK. the calculated result fairly agreed with the measured one (Fig. 1). the s in the figure is the distance from the center of the magnet along the longitudinal direction. It has thus been demonstrated that MAGNA can calculate a 3D magnetic field with a sufficient accuracy.

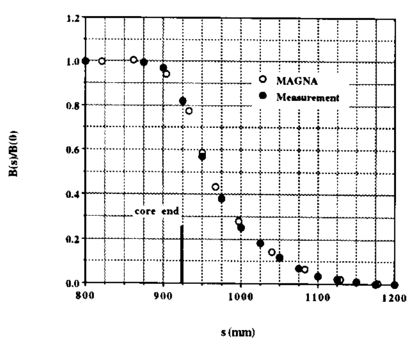

Figure 1: The field of PF bending magnet.

III. 3D ANALYSIS OF DC STEERING MAGNET

We then made the 3D analysis of DC steering magnet for the high-brilliant ring. Table 1 gives its parameters and Figure 2 shows a quadrant of its cross section. Figure 3 shows the horizontal field strength integrated by s. Figure 4 also shows the integrated vertical field strength. As shown in these figures, both fields have sufficient uniformity. Since the edges of the horizontal steering coils are closer to the iron core than those of the vertical steering coils, the vertical field is more like 2D and flatter than the horizontal field. We also made the same analysis for a fast steering. Because its shape is similar to the DC steering (see Fig. 5), the results are also similar to the above ones.

Table 1: Parameters of DC steering magnet.

	Vertical steering (2 coils)	Horizontal steering (2 coils)
Number of turns	1260/coil	720/coil
Current (A)	5	5
Magnetic field (G)	400	350
Effective length	0.15	0.115
Bend angle (mrad)	0.89	0.6
Inductance (H)	0.1	0.1

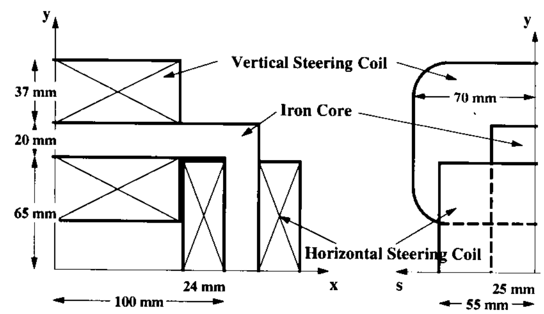

Figure 2: A quadrant of DC steering magnet.

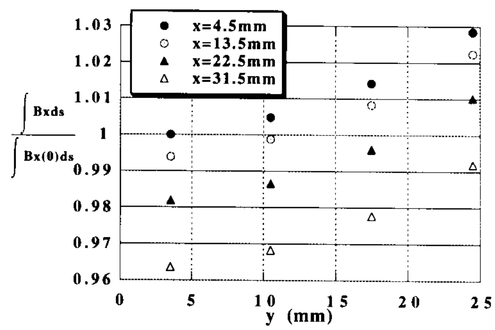

Figure 3: Integrated strength of horizontal field.

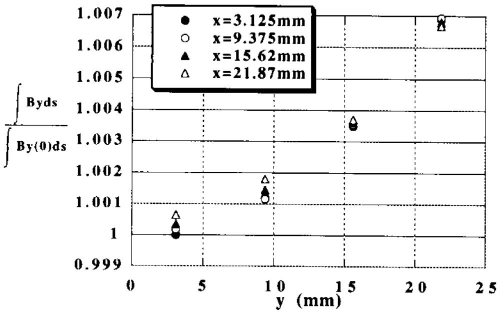

Figure 4: Integrated strength of vertical field.

IV. 2D ANALYSIS OF THE EFFECT OF EDDY CURRRENT ON FAST STEERING

As the fast steerings are expected to operate in a frequency range up to 100 Hz, we have examined the effect of eddy current induced on the vacuum chamber. The analysis is two dimensional in this section. Table 2 gives its parameters and Figure 5 shows a quadrant of its cross section together with the chamber. The shape of the chamber was simplified to reduce the number of meshes. Figures 6 and 7 show the fields at the center of the magnet in the cases of aluminum and stainless steel chambers, respectively. As seen in Fig. 6, the vertical magnetic field is strongly attenuated for the aluminum chamber. Therefore, it may be difficult to control the horizontal closed orbit by fast feedback, though the effect of eddy current almost does not influence the field uniformity.

Table 2: Parameters of fast steering magnet.

	Vertical steering (2 coils)	Horizontal steering (2 coils)
Number of turns	140/coil	120/coil
Max. current (A)	5	5
Magnetic field (G)	55	110
Effective length (m)	0.11	0.065
Bend angle (mrad)	0.09	0.1
Inductance (mH)	1.2	2.7

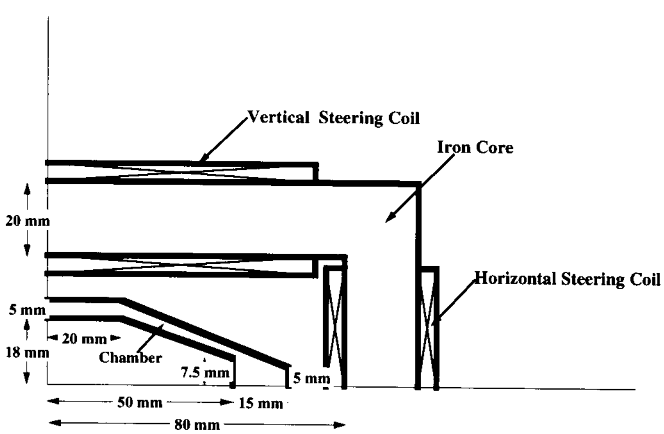

Figure 5: Fast steering and its chamber.

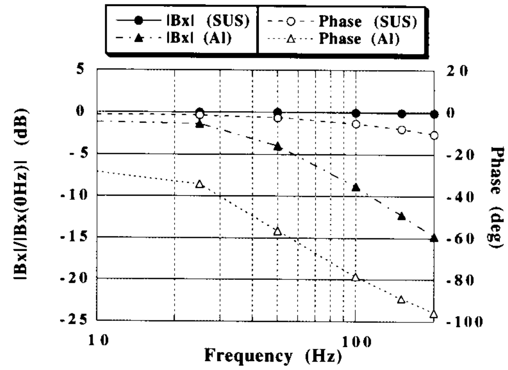

Figure 6: Bode diagram for vertical steering.

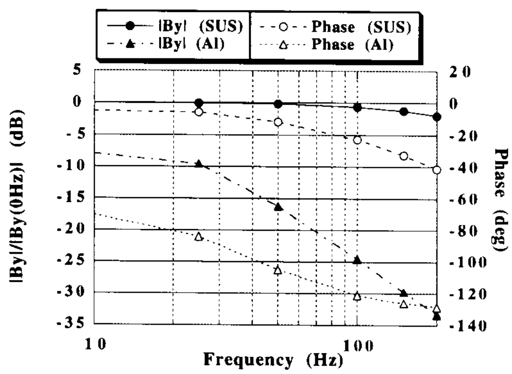

Figure 7: Bode diagram for horizontal steering.

In order to check the calculation, we measured the magnetic fields of a PF vertical steering with an aluminum chamber for quadrupole magnet and compared the result with the calculated one. Figure 8 is a quadrant of its cross section together with the chamber. to make a vertical field, we added horizontal steering coils to the PF steering. The chamber used was about 1 m long. figures 9 and 10 show the results. A close agreement between the measured and the calculated values was obtained for the horizontal magnetic field (Fig. 9). but they are somewhat different for the vertical field (Fig. 10). The reason why such differences occur is as follows. In spite of the short magnet length, the eddy current generated by horizontal field on the chamber behaves like 2D at least more than for vertical field since the height of the chamber is smaller than its width. As a result, both 2D calculation and measurement may agree each other for the frequency dependence of horizontal field, whereas it is not the case for vertical field.

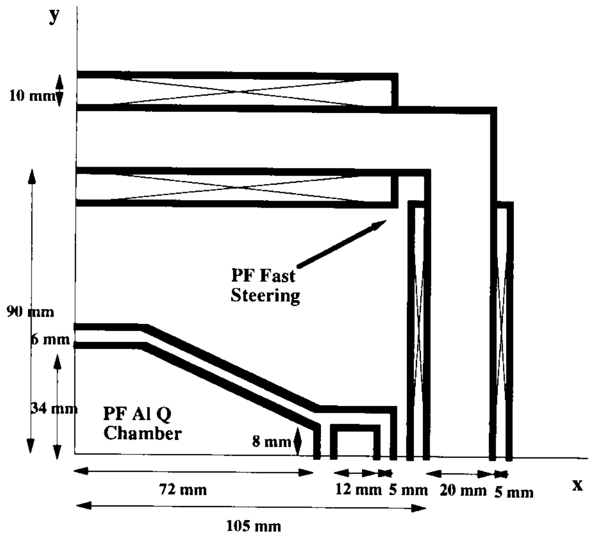

Figure 8: the PF steering magnet and AI Q chamber.

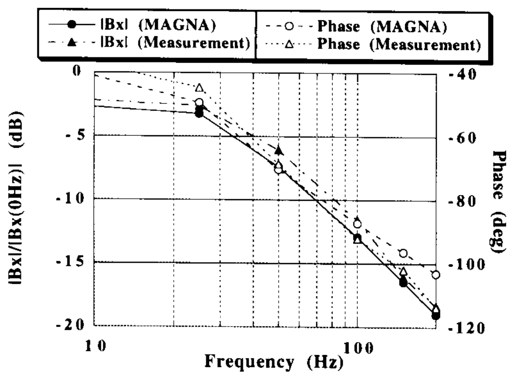

Figure 9: Bode diagram for PF vertical steering.

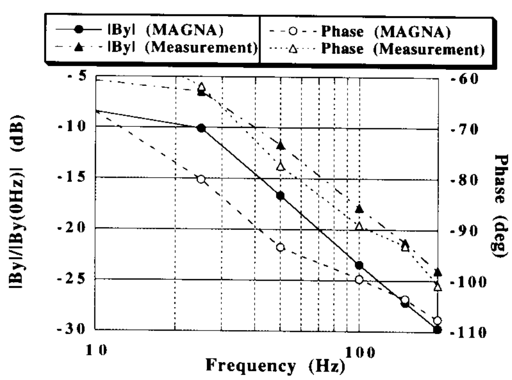

Figure 10: Bode diagram for PF horizontal steering.

V. 3D ANALYSIS OF THE EFFECT OF EDDY CURRENT ON FAST STEERING

Using 3D analysis we tried to study the effect of eddy current for the above PF steering with its chamber. Because we had to deal with a finite length of the chamber and our WS had not enough memory for 3D calculation, we covered the chamber with aluminum plates at its end to simulate a long chamber (Fig. 11). It was showed that 10 to 20 % of the central DC field strength remained at the plate. Nevertheless, the 3D calculation showed that the normalized vertical fields in both cases of calculation and measurement well agrees with each other for the horizontal steering, as shown Fig. 12.

For the integrated field strength and for horizontal field, 3D calculation did not give satisfactory results, because we were short of computer power and probably took inaccurate data for a long search coil to measure the integrated field. In near future, we will improve the WS power and the field measurement of frequency dependence.

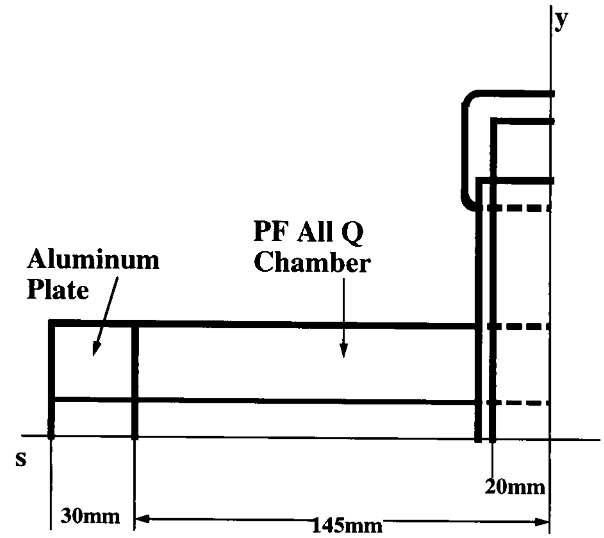

Figure 11: The steering magnet and covered chamber.

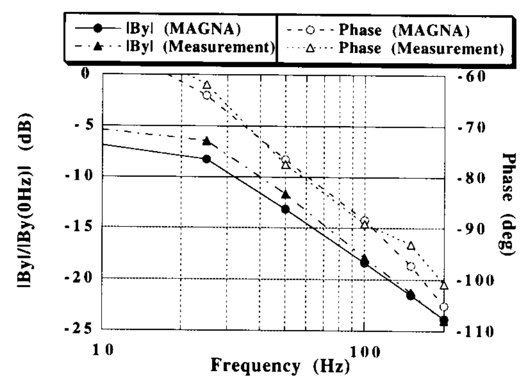

Figure 12: Bode diagram of PF horizontal steering.