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ERROR FIELD ACROSS THE APERTURE OF THE ISABELLE DIPOLE

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ABSTRACT

Error field multipoles due to systematic errors in the current distribution are computed and compared with the error field multipoles due to random errors in the current distribution. The systematic field error multipoles are found to vary rapidly across the aperture, and in some cases may be the dominant error multipoles.

It was pointed out by Kycia and Month,¹ and Month and Parzen² that random errors in the positions of the current blocks can produce error field multipoles that may vary rapidly across the aperture, becoming largest near the coils. This note investigates a similar effect due to systematic errors in the current distribution. The systematic error that is studied here is due to the procedure of approximating the ideal cosine current distribution by current blocks which are wound with a superconducting ribbon conductor.

In the case of the ISABELLE dipole, six current blocks are used to approximate the cosine current distribution. The position of the blocks is adjusted to cancel out the lowest five undesired multipoles, $b_2, b_4, b_6, b_8, b_{10}$. The deviation from a uniform field is then given primarily by the b_{12} term. The multipoles b_n are defined by writing the median plane magnetic field as:

$$B = B_0 (1 + b_2 r^2 + b_4 r^4 + b_6 r^6 + \dots)$$

For the ISABELLE dipoles, one finds that $b_{12} = 2.8 \times 10^{-12}/\text{cm}^{12}$. At the inner radius of the coil $r_c = 6 \text{ cm}$, the fraction of the field which is due to the b_{12} term is $r_c^{12} b_{12} = 0.0061$. Thus, one might expect that the change in the field across the aperture due to this systematic error to be small. This is shown in Fig. 1 which shows the variation of the deviation from a uniform field, $\Delta B = (B - B_0)/B_0$ across the aperture of the ISABELLE dipole. One sees that the systematic error is much smaller than the random error.

For the higher multipoles, the systematic error gradually becomes more important relative to the random error. Figures 2-4 show how the multipoles $\Delta b_n(x)$ vary across the aperture. The $\Delta b_n(x)$ are defined by expanding the field in the median plane around the point $r = x$ on the median plane as:

$$B = B_0 [1 + \Delta b_0(x) + \Delta b_1(x)(r-x) + \Delta b_2(x)(r-x)^2 + \dots]$$

1. T. Kycia and M. Month, BNL Report ISA 76-6 (1976).

2. M. Month and G. Parzen, Nucl. Instrum. Methods (to be published).

Fig. 1. Error field across aperture in ISABELLE dipole.

Fig. 2.

Fig. 3.

Fig. 4.

Both the systematic Δb_n and the random Δb_n are shown for $n = 0, 1, 2, 3, 4, 5$. For $n = 5$, the systematic Δb_5 starts to dominate at $r = 2$ cm.

One may conclude that for the higher order resonances which are generated by the higher order multipoles, and if one desires to use a large proportion of the aperture, then the error multipoles due to systematic errors may become important. Like the random error multipoles, the systematic error multipoles vary rapidly across the aperture. One may even keep in mind that systematic error multipoles can be more effective in driving some resonances than the random error multipoles, whose effect is reduced by the factor $\sqrt{M}$, M being the number of magnets.

I would like to thank Dr. M. Month for bringing this effect to my attention and for helpful discussions. I would also like to thank Dr. P. F. Dahl for making available to me results for the field distribution obtained with the MAGFLD program written by G. Morgan, and K. Jellett for help with the computations.