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Magnetic Measuements of the Elliptical Multipole Wiggler Prototype

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1. Introduction

A prototype of the elliptical multipole wiggler (EMW) [1] has been assembled, tested, and magnetically tuned at the APS. This prototype has a period of 160 mm with seven poles for the hybrid structure (antisymmetric configuration) and ten poles for the electromagnetic part of the EMW (symmetric configuration). The hybrid structure of the EMW produces a vertical magnetic field of 0.83 T (K_y = 12) for a gap of 27 mm, and the electromagnet structure provides a maximum horizontal field of 0.12 T (K_x = 1.6) with AC frequency up to 100 Hz. The alternation time is about 3 ms.

The requirements for electromagnetic field quality are very tight because the EMW introduces orbit perturbations in the vertical plane, where the emittance is smallest. Also, the storage ring correction system cannot respond to perturbations of more than 10 Hz frequency. Thus the main effort during the magnetic tuning of the EMW was directed toward establishing time independence of the magnetic field integrals to better than 2 G-cm while the current was alternating through the electromagnet. This time independence has been achieved by implementing a special field integral compensation system and novel fast magnetic measurement techniques.

Magnetic measurements of the EMW prototype have been performed at the APS insertion device magnetic measurement facility [2]. A new fast acquisition system with a maximum sampling rate of 1 MHz has been developed and used for these measurements. Also, a novel “twisted coil” technique has been used in order to make fast measurements of the second field integral. The field integral compensation on the order of 1 G-cm and 1000 G-cm^2 for the first and second integrals, respectively, has been achieved at electromagnet AC frequencies up to 100 Hz.

2. Magnetic Measurement Technique

The EMW with an electromagnet operated at up to 100 Hz represents a challenge for precision magnetic measurements, especially for the measurements of the second field integrals. Conventional methods of second field integral measurements are based on the step-by-step translation of magnetic sensors, such as Hall probes or small coils, along the main axis of the EMW, and with measurements taken at every step. These measurements take too long for there to be any possibility of measuring the time dependence of the field. Therefore, a novel technique was introduced and ;used fo the fast and precise magnetic measurements of second field integrals.

The stretched coil conventional configuration with parallel wires [3] has been used to measure the first field integrals. In order to conduct fast measurements, however, two boards, a CTM05 board and a FastADC board, have bee installed on the PC bus. The first generates pulses to define the frequency of the power supply, i.e., the AC frequency, and to trigger the FastADC board to synchronize magnetic measurements. Figure 1 presents a layout of this configuration. A typical sampling time of 0.1 ms has been ;used for the AC frequency of 100 Hz.

In order to measure the second field integral, a novel long coil configuration was proposed by one of us (N.V.) and then developed and implemented for the EMW measurements. The long coil has been twisted by 180°, as shown in Fig. 2.

The magnetic flux in that case is defined from the following expression:

$$\phi = \int_{-L}^{L} \theta \; z \;\; B(z)dz = \theta \;\; z \int_{-L}^{z} B(z')dz' \Big|_{-L}^{L} - \int_{-L}^{L} \theta \;\; I_1(z')dz' =$$

$$= \theta [L \;\; I_1(L) - I_2(L)],$$

where:

$$\theta = \frac{d}{L}; \;\; I_1(z) = \int_{-L}^{z} B(z')dz'; \;\; I_2(z) = \int_{-L}^{z} I_1(z')dz'.$$

Unlike for the conventional long coil configuration, the magnetic flux now depends on both the first and second field integrals.

From the expression for the magnetic flux, one can obtain:

$$I_2(L) = -\frac{\phi}{\theta} + L \;\; I_1(L).$$

This expression becomes especially simple when the first field integral is equal or close to zero, and that is exactly what we have in our case.

3. Measurement Results for the First and Second Field Integrals

Two types of correction systems have been used to compensate for the AC dependence of the horizontal field integrals. The first one, a passive (i.e., nondynamic) correction system includes a manually adjustable magnetic gap for the two last poles at each end of the electromagnetic structure. The first field integral can be adjusted by decreasing the magnetic gap for the last pole at the end of the wiggler and increasing the gap for the last pole at the other end. This adjustment also affects the second field integral. The second field integral is adjusted by increasing (or decreasing) the magnetic gap equally at both ends of the wiggler. Since there is an even number of poles in the electromagnetic structure, this adjustment has no effect on the first field integral. Finally, the gap for the next-to-last poles at both ends were chosen to make the trajectory of the beam as close to the axis of the device as possible.

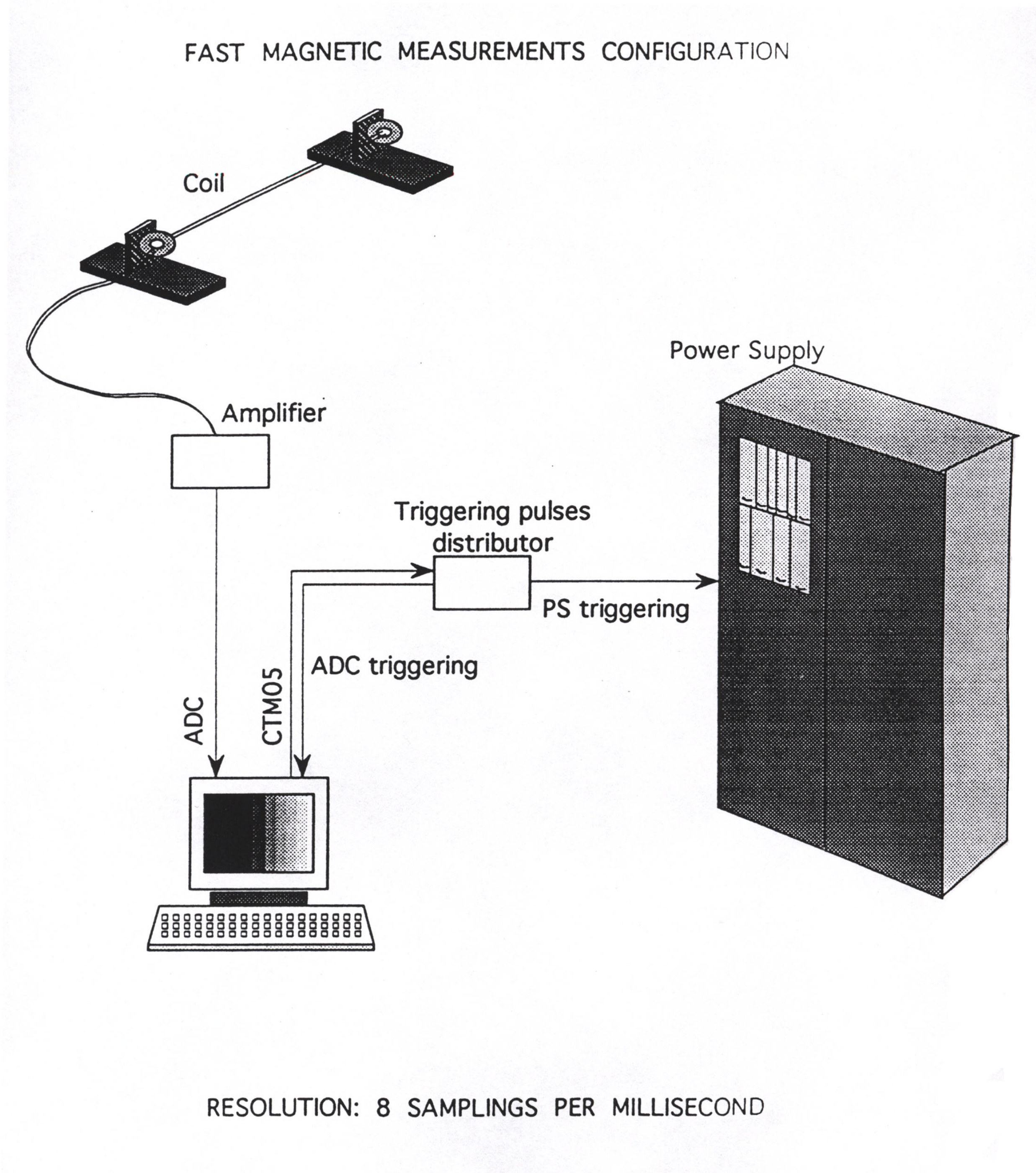
FAST MAGNETIC MEASUREMENTS CONFIGURATION
Coil
Power Supply
Amplifier
Triggering pulses distributor
PS triggering
ADC triggering
ADC
CTM05
RESOLUTION: 8 SAMPLINGS PER MILLISECOND

Fig. 1

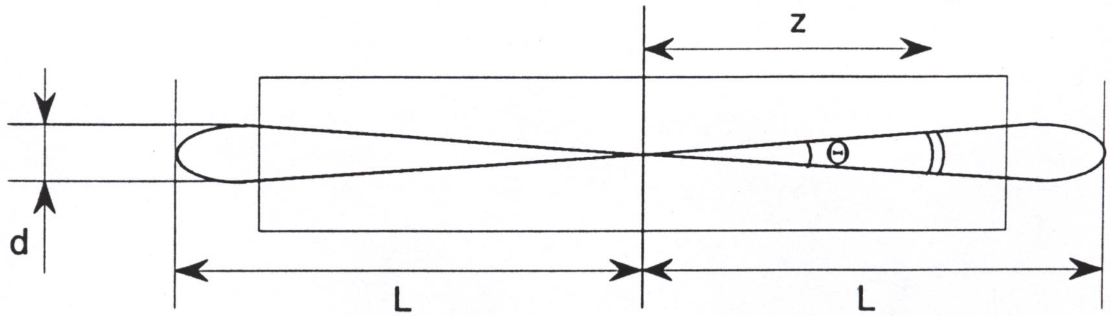

Fig. 2. Long Coil Configuration for Second Field Integral Measurements

The active or dynamic correction system is based on the use of a set of two correction coils mounted on each end of the electromagnetic structure. These coils are fed by the power supply with an arbitrary function generator [4].

The results of the compensation of the first and second horizontal field integrals for an AC frequency of 100 Hz are shown in Fig. 3. The peak-to-peak variation of the first field integral during a 10 ms period is about 10 G-cm with the dynamic compensation off and less than 1 G-cm with the dynamic compensation on. The results for the second horizontal field integral are 4000 G-cm^2 and 1000 G-cm^2, correspondingly.

Similar results for the first and second vertical field integrals are shown in Fig. 4. There was no active correction system for the vertical field integral at the time of the measurements. This system is under construction now and will be incorporated into the EMW later.

4. Conclusions

The magnetic measurements and magnetic tuning of the EMW were started in the middle of October 1994. New magnetic measurement techniques have been developed and used that allowed completion of all measurements and tuning within a period of one month. The EMW was installed at the NSLS x-ray ring in December 1994, and the first tests of the device in February 1995 have shown the predicted performance.

References

1. E. Gluskin et al. “A Status of the Elliptical Multipole Wiggler Project,” SRI 94, International Conference, Abstracts, July 1994.

2. L. Burkel, R. Dejus, J. Maines, J. O’Brien, J. Pflüger, and I. Vasserman, ANL/APS/TB-12, March 1993.

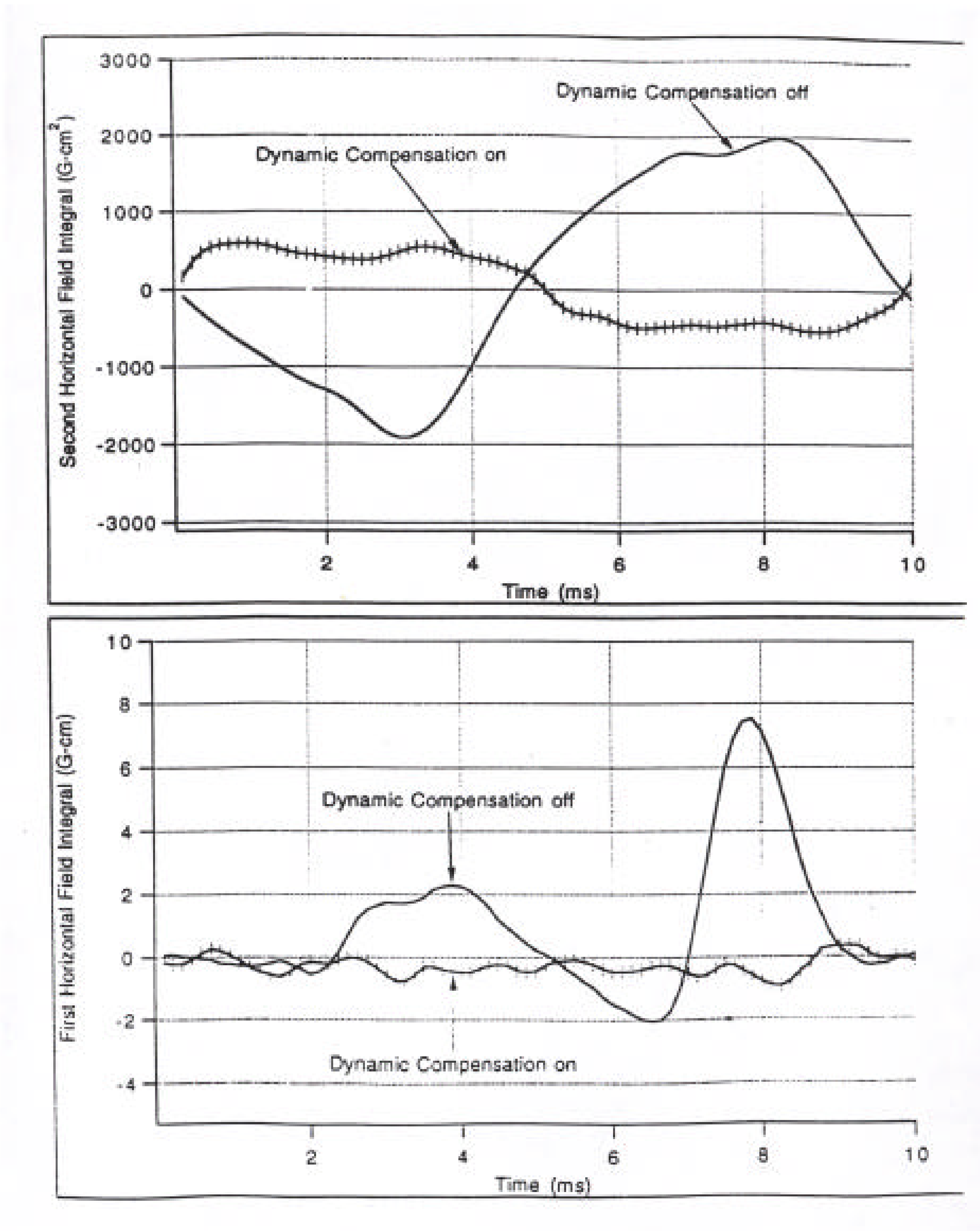

Fig. 3. Time Dependence of First and Second Horizontal Field Integrals for 100 Hz Frequency

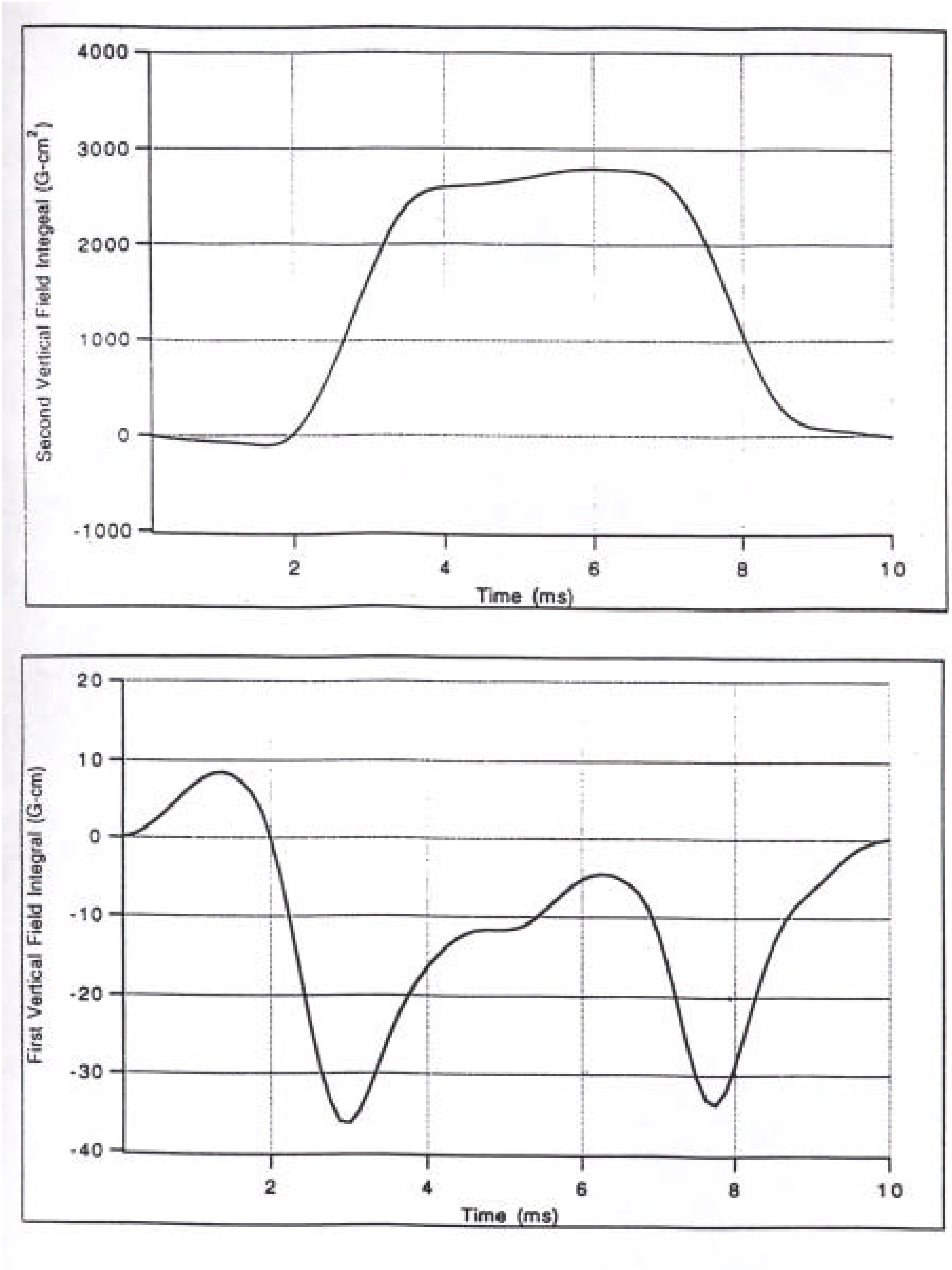

Fig. 4. Time Dependence of First and Second Vertical Field Integrals for 100 Hz Frequency

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4. O.D. Despe, “Arbitrary Function Generator for APS Injector Synchrotron Correction Magnets,” ANL Light-Source Note LS-158, November 1990.