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THE IASA MAGNETIC FIELD MAPPING (MFM) PROJECT

E. P. Pournaras, A. Karabarbounis, C. N. Papanicolas and E. Stiliaris,
Institute of Accelerating Systems & Applications, P.O. Box 17214, GR-10024 Athens, GREECE
and Physics Department, National & Kapodistrian University of Athens, GR-15771 GREECE

Abstract

The design and development of an automatic magnetic field mapping device as supporting equipment for the 10 MeV CW-Linac and its transport system at the Institute of Accelerating Systems & Applications (IASA) is presented. The MFM project aims to totally automate the operation of mapping room temperature magnetic field sources, reconstruct the 3D-field shape and reveal nonlinearities in the fridge field regions. The positioning system covers an area of 50x50 cm^2 with an accuracy of better than 32 μm in both axes; magnetic field measurements, mainly based on a Hall Probe, can reach in precision the 10^{-5} value. Several software tools for the visualization of the measured fields and for a direct comparison with theoretical estimates are also presented.

INTRODUCTION

The construction of the 10 MeV CW-Linac which is currently being developed and hosted in the IASA basement [1] has led to several other parallel running projects. One of them is the Magnetic Field Mapping (MFM) project, which focuses on the static field measurement, test and analysis of all magnetic elements belonging to the CW-Linac [2] and its transport system [3]. Specifically, it provides us with an accurate knowledge of the non time changing magnetic field distribution in space, through a totally automated procedure. The demanded accuracy turns the whole activity into a tiring and long time process. The control software has been designed in such a way that after the pre-mapping software adjustments no further external user input is needed. The mapping procedure divides space into slices and produces 2D output ASCII type portable files.

THE MAPPING DEVICE

The MFM mapping device is composed by a Group3 MPT-141-75 Hall Probe together with its controller, placed on the movable base of an Arrick Robotics XY-9 positioning table. The whole implementation is steadily placed on a special granite table and steel base, which reduces environmental disturbances. Each arm is driven by its individual controller and both of them by the main CPU, consisted of a simple Pentium PC and application specific developed software. The main parts of the mapper are shown in Fig. 1 and Fig. 2.

Specifications

The device has the ability to measure static fields in the ranges of 0.3, 0.6 and 3 Tesla. The absolute error in measuring is 5, 10 and 50 MicroTesla respectively, which results to a specific error $\Delta B/B \approx 10^{-5}$ for all ranges. Consequently, the relevant error for dipole fields suitable for the 10 MeV electron beam is $3.4\text{x}10^{-5}$. The field sensor (probe) takes 10 measurements per second.

The positioning system with two high precision stepping motors covers an area of 50x50 cm^2 with an accuracy of better than 32 μm. The resolution in both axes is 1 twip, which translates to 0.125 mm. The twip unit has been introduced in order to refer to one "full step" of the stepping motors that are used to place the probe's sensor head in a specific point of the 2D mapped area. Provided that the full step can be divided into four shorter steps, which correspond to four different patterns for the motors coils' states, the resolution becomes 32 μm.

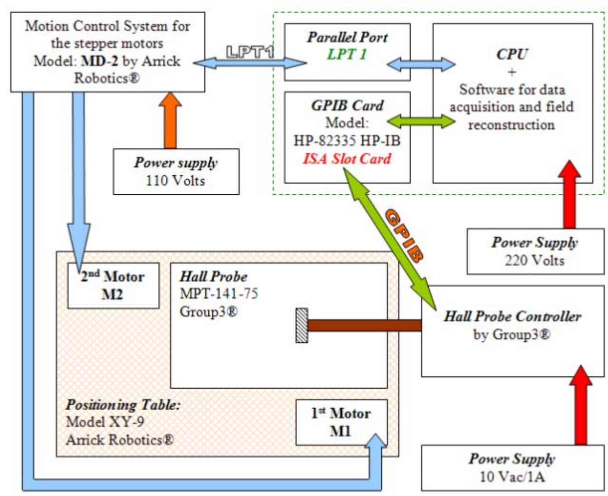

Figure 1: The mapping device block diagram.

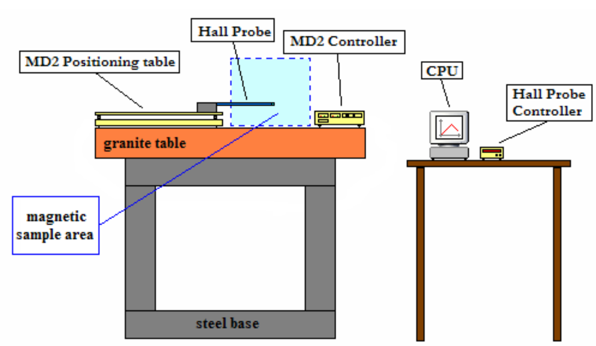

Figure 2: Diagram of the mapper's main parts.

Data Acquisition Software

The first part of the software has been written for DOS in order to make use of the almost real time response of this operating system. GPIB is the communication protocol between CPU and the controller of the Hall Probe, while the positioning table is being driven via the simpler LPT parallel port.

The mapping settings include: 1) the dimensions of the area to be mapped and the number of nodes for the given grid, 2) algorithmic digital filtering of the measured values, 3) operation range and the type of units (Gauss or Tesla), 4) automatic zeroing in order to cancel any contribution of the earth's existing magnetic field, 5) number of measurements per node and time brakes and 6) several other device dependent settings.

The application's user interface is graphical and fully informative; a snapshot is shown in Fig. 3. The probe head is temperature sensitive, thus a special data storing protocol has been introduced to include both field and temperature measurements [4]. Large temperature variations – from point to point – demand normalisation of the field values according to the B=f(T) diagram, supplied by the probe manufacturer.

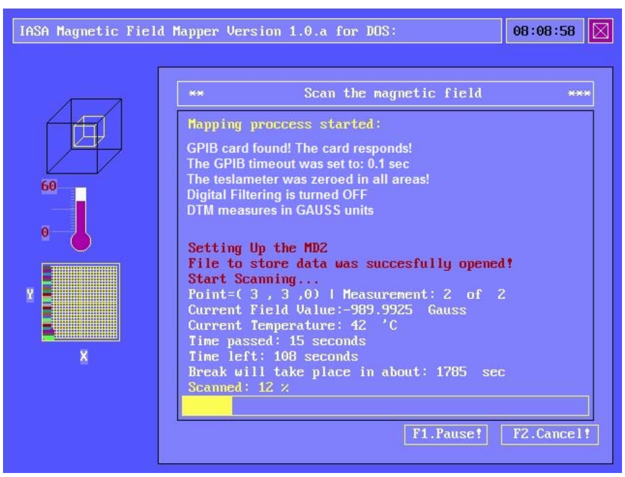

Figure 3: The data acquisition user interface.

The large amount of time needed for a complete high resolution mapping area leads to stepping motor overheating. The mapping of a 1600x1400 twips^2 with 2 measurements per node and 0.5 sec brake among both neighbouring nodes and measurements demands about 4 complete hours. In order to avoid damages, the software automatically pauses the process for a pre-specified time period, until the motors cool back again.

Field Visualisation Software

The second part of the software which deals with the visualisation of the field has been written for Windows and as a consequence demands faster CPU and higher amounts of available memory. It can run separately from the Data Acquisition Software on another platform.

A simple visualization software tool, called MFM2MFF, converts MFM protocol files (full DAQ output files) to simple field (MFF) or temperature (MFT) matrixes ready to be read by other applications such as MathCAD or MATLAB. The utility can be setup to remove any background magnetic field contribution even if this is constant or varies from point to point. For the second case, a differential mapping procedure is implemented, where the same area is twice mapped with and without current supply to the electromagnet. Furthermore, this utility normalizes field values to a specific temperature due to its interference to probe's measurements.

Another advanced visualization software tool is RaceTRACK (currently at Version 1.0.0) It has the ability to produce x-B(x) and y-B(y) 2D section plots, contour plots and 3D plots with various control possibilities over them (Fig. 4). The software package is freely available [5].

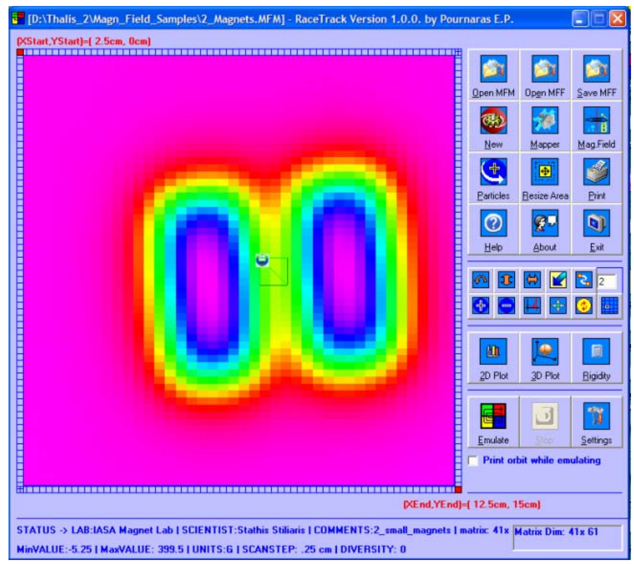

Figure 4: The RaceTRACK contour plotting the field of two linear magnets.

In order to check for magnetic field nonlinearities (fridge fields) of the measured distribution in a given magnetic element, the RaceTRACK can also simulate the motion of a charged particle in it by using integral two dimensional techniques based on Lagrangian formulation of the motion (Fig. 5).

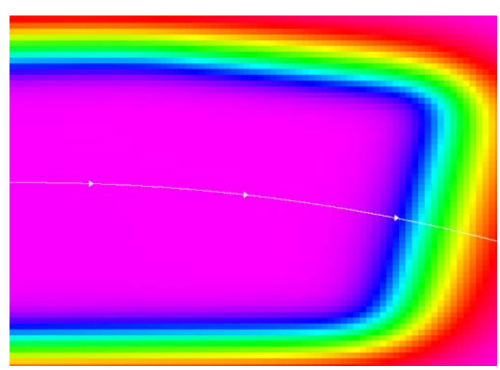

Figure 5: The orbit of an electron in the B-field of a bending magnet.

CURRENT STATUS

The 2D mapping procedure has been successfully installed and works properly. The first 30^o and 45^o dipole bending magnets of the 10 MeV CW-Linac transport line are being measured; a systematic fridge field analysis is in progress.

The Magnetic Field Mapping device can also accept modifications to extend its automated mapping ability along the z-axis by adding special Arrick Robotics supporting equipment for the positioning table. It can also be completed with an extra sensor which will activate time brakes when motors reach a temperature lintel.

Parallel to the Hall Probe a NMR device is currently implemented to the project. The model used is the BRUKER Microprocessor Controlled ER 035m, which covers the resonance range from 2 to 90 MHz. The magnetic field operation ranges are 450-2.4 KGauss and 1.45-20 KGauss. The specific error is $\Delta B/B < 5 \times 10^{-6}$ for both ranges. The NMR device will be used for the comparison of the absolute values measured by the Hall Probe with those acquired by the more accurate method based on the resonance effect.

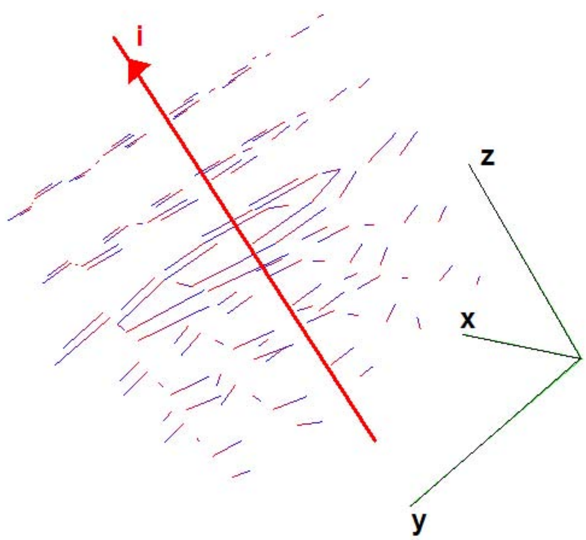

Figure 6: Linear current's reconstructed field.

Finally, new analysis software is currently under development. The THALIS software package aims to reconstruct the **B** magnetic field vectors by combining data from different slices in the three orthogonal directions of the Euclidean mapping space. A first simulated sample of data generated by a linear current has been reconstructed as shown in Fig. 6.

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