Magnet field mapping and calibration system at Grenoble High Magnetic Field Laboratory

1-First part : System currently in use

This system uses the flux variation from a thin flat pick up coil mobile along the (vertical) axis of a magnet to calibrate. Motion is realized by step motor and lead screw linear slide system. Metrolab digital integrator can receive either the signal generated by coil motion in a steady field (space integration “red lines”) or the signal generated by field variation in a fixed position of the coil (time integration “black lines”). Acquisition and control special “home made” software comes from low level C programming. Photo shows heavy mechanical structure and incremental linear encoder (5 μm resolution).

Practical space integration interval used for field mapping is 0.1 mm. Acquisition rate of 40 points/s (speed is 4 mm /s) helps reducing magnet current drift effects. Real time averaging of up and down motion cycles data is done to minimize integrator drift (offset) effects. All measured distances are referenced to encoder zero (index). This enables relative positioning and alignment of different coaxial parts of a magnet.

After coil motion and positioning in magnet center (done with software feedback) it is possible to convert flux units into field units by determining magnet field factor. This is done with power supply trapezoidal modulation cycles.

Typical curves of field gradient and field map are shown for a polyhelix (internal) part of a 20 MW magnet at 5 KA current (~ 5 Teslas). Visible (periodical waveform) noise around maximum gradient (field inflexion point) comes from very small radial motion of the coil with each turn of the lead screw. Visible noise (at much higher frequencies) around zero gradient (field maximum) comes from power supply current (50 Hz harmonics).

Same curves are shown for a magnet designed for 60 Teslas (pulsed field), powered by a small DC low noise power supply generating a small field of about 800 Gauss. Space period of noise at maximum gradient appears clearly to be 2 mm (lead screw pitch) and noise at zero gradient is very small enabling high accuracy field measurement around maximum field (magnet magnetic center).

These last examples show at the same time the possibilities of the system (high accuracy measurement) and small defects of its mechanical motion part which is now the most limiting one.

An example of field factor determination using modulation cycles is shown : To minimize the effects of power supply regulation overshoots, each flat top level value is determined by an average of measured points after a computed settling time. Integrator and magnet current drift are minimized by automatic averaging of all up and down cycles. Real time modulation control, acquisition and calculations are performed by the software.

An example illustrating the performances of the system as a tool for aligning centers of a two coil magnet is shown. The inner coil has a special “W” profile which, added to the outer coil profile is supposed to give a very homogeneous field in a range of about +/- 5 mm from the center. Real configuration individual coils measurements showed a misalignment distance of 1.4 mm between the 2 magnetic centers. Total resulting field map (globally measured map in good agreement with the sum of individual measurements) is slightly unbalanced with a sign change close to centers position. Only the sum of the 2 individual curves with one shifted of the exact misalignment (1.4 mm) give the ideal symmetric homogeneity over the foreseen range.

Since all mapping distances are relative to the encoder zero, an accessory has been developed (as a portable "tool") to reference them to the magnet housing top surface plane (useful for magnet users). A flat thin active coil placed on the magnet axis at a very well known distance from the magnet housing top plane (using a "length gauge" part) is used for that purpose. A preliminary mapping (peak shaped) of a very small field generated by this coil is used to link following magnet mappings to this new origin.

2-Second part : New prototype design

A new replacement mechanical system prototype has recently been studied and designed. It uses a non magnetic piezoelectric linear motor for direct linear motion generation (no rotation/translation conversion wanted). Most of the applications and designs associated with such type of motors are limited to low travel lengths or small loads (micro-positioning) , and a number of mechanical problems had to be solved to enable high speed vertical motion (strong influence of weight of all moving parts) over a relatively long travel length (more than 300 mm) using no magnetic parts…. Though it has a lightweight and compact non magnetic structure, the prototype has a high stiffness and dimensional stability.

It will be possible to use it also as a "simple" high resolution positioning system for other types of probes (including NMR). This prototype also has the accessory "tool" (described above) used to link field maps distances to magnet housing top origin, pre-built as an integral part of the whole mechanical structure.

First tests using open loop analog control were successful with a travel length of 326 mm and a maximum useful moved mass of 0.9 kg. Though the theoretical performances of the Nano motion motor are very high (5 nm positioning distance and 230 mm/s maximum speed) the final practical performances of the whole system will be of course strongly dependant from mechanical design, load, and (future) closed loop feedback.

Future developments include use and mounting of an incremental non contact optical linear encoder (whose indexing sensor and associated electronic devices are currently being designed in GHMFL) on the prototype. A specially designed motor controller using a programmable digital PID based micro-controller chip is also currently under study for closed loop feedback. The existing software will then be considerably modified to take into account the new mechanical prototype and all associated control hardware.