DAΦNE TECHNICAL NOTE

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DAΦNE MAGNETIC MEASUREMENT SYSTEMS

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The different magnetic measurement systems for DAΦNE magnets are presented here. The intent of this Note is to illustrate the main characteristics of the different measurement systems. More detailed specifications on performances of each device will be described in future Notes where results of specific magnet measurements will be reported.

Four different systems are now available:

1. A Hall Effect Digital Teslameter mounted on a 5-axes movement device, (4 of the 5-axes are motorized, with remote control capability via IEEE488). The system is mainly devoted to magnetic measurements of dipoles, splitters, septum magnets and correctors.

2. An automatic rotating coil Multipole Measurement System, with automatic magnetic centering. Bench and coils are designed to measure all the multipole magnets of DAΦNE Accelerator Complex (Accumulator Ring and Main Rings).

3. Two 3 meter length magnetic measurement systems (Hall effect and rotating coil) devoted to wiggler magnets.

4. A Nuclear Magnetic Resonance (NMR) Teslameter.

Several other magnetic instruments, such as gaussmeters, digital and analogic integrators are available.

1. The Hall Effect system consists of 2 independent devices: the digital movement system (from MICROCONTROLE - France), and the Hall Effect Digital Teslameter (from GROUP 3 - New Zealand).

   The digital movement system permits the probe-keeper to be moved along 3 axes and to be rotated around 2 axes (see Fig. 1). A Hewlett-Packard computer HP 98581 A 9000/300, and a granite bench on which the positioning tables are mounted complete the system.

   Four of the five axes (X, Y, Z, Φ) are motorized by means of stepping-motors. The control of the stepping-motors can be Local (manual) or Remote through serial interface RS232/RS422 or parallel interface IEEE488. The main features are:

   for the X, Y, Z axes:

- movement resolution:	10 μm
- minimum step:	10 μm
- maximum speed:	30 mm/s
- X axis max. throw:	1000 mm
- Y axis max. throw:	500 mm
- Z axis max. throw:	200 mm

   for Φ axis:

- rotation resolution:	1/100 of degree
- minimum step:	1/100 of degree
- Φ axis max. throw:	± 170 degrees

   Normally, the movements are remotely controlled by computer, so that dedicated softwares are written to perform sets of measurements, i.e. the control of sequential steps of the stepping-motors that move the Hall probe along predefined paths. We are now writing software programs to perform magnetic measurements of the Splitter and Septum prototypes and to produce different data presentation (plots and maps of the fields and gradients).

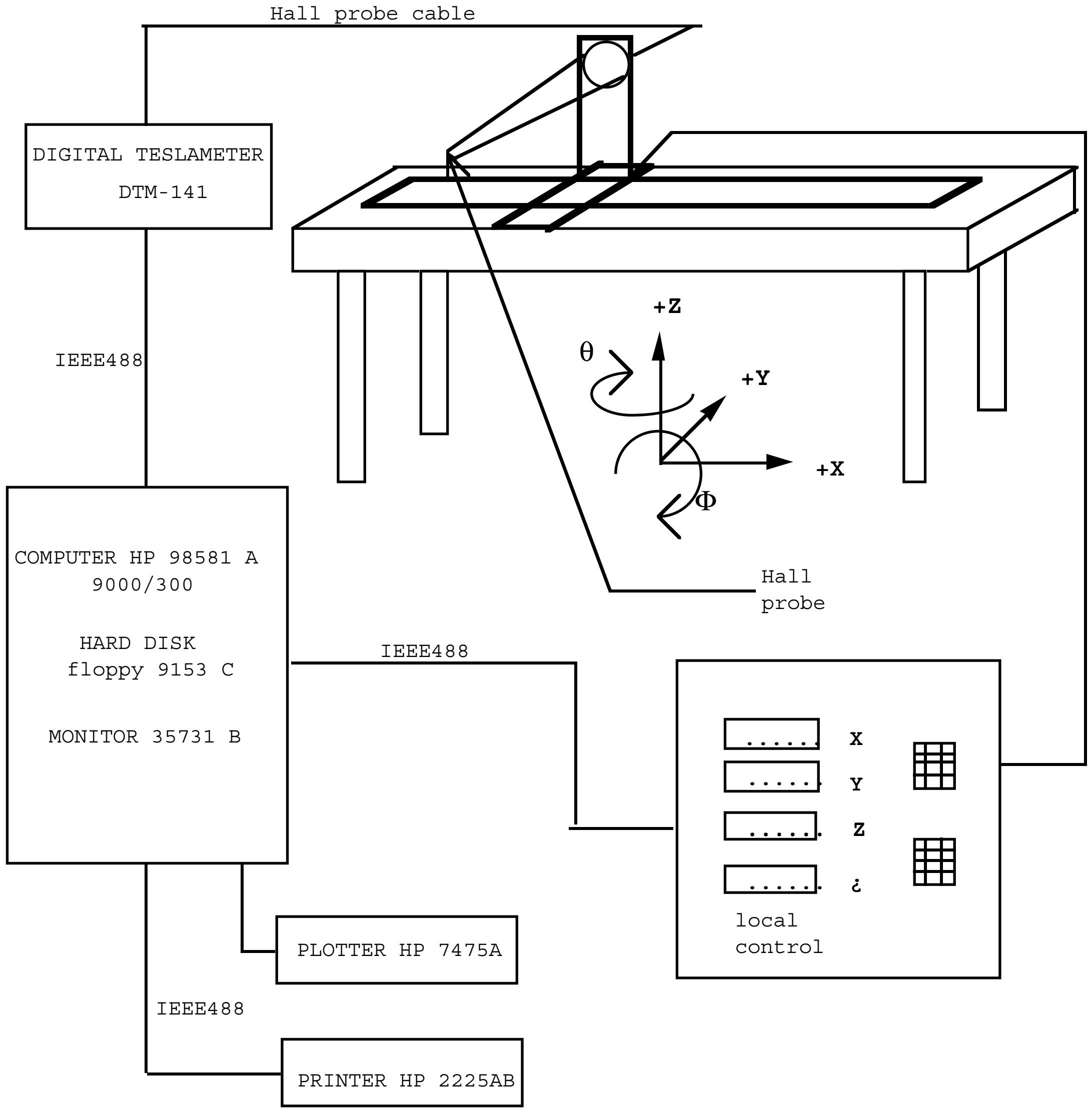

Fig. 1- Hall effect measurement system with computer controlled movements.

The Hall Effect Digital Teslameter is equipped with two Hall probes having the following measuring ranges:

- 0-3000 Gauss
- 0-6000 =
- 0-12000 =
- 0-30000 =

The system can be remotely controlled via IEEE488 parallel interface. The field reading is thermally compensated using an internal stored thermal calibration curve and it is stabilized through a signal filtering.

The principal features of the teslameters are:

- precision:	0.01% of reading ± 0.006% of full-scale max. at 25 °C
- max thermal drift:	10 ppm/°C
- Resolution:	1 part in 60000 of full scale
- measurement rate:	10 meas. per second

2. The Multipole Measurement System "Model 692" (from DANFYSIK - Denmark) uses the technique of rotating coils and it is the commercial version of the measurement system developed at CERN for the LEP multipole measurements. The measurement is based on the "Harmonic coil method" where a very stable cylinder holding the main measuring and rejection coils is rotated inside the bore of the magnet. The induced voltage across the coil terminals is electronically elaborated and integrated on angular intervals (defined by an absolute encoder). The measurements gives an accurate determination of the integrated field, the integrated multipolar components and the magnetic center position.

OVERALL SPECIFICATIONS:

- Relative accuracy of the integrated main harmonic	±3 E-4
- Angular phase absolute accuracy	±0.2 mrad
- Lateral positioning of magnetic center with respect to rot. axis	± 0.03 mm
- Positioning accuracy of alignment targets with respect to coil axis	±0.03 mm
- Accuracy of ratio between the integrated field of a multipole component and the main component at the major coil radius	± 3 E-4

The logical layout of the measurement bench is composed by 4 principal systems (see Fig. 2):

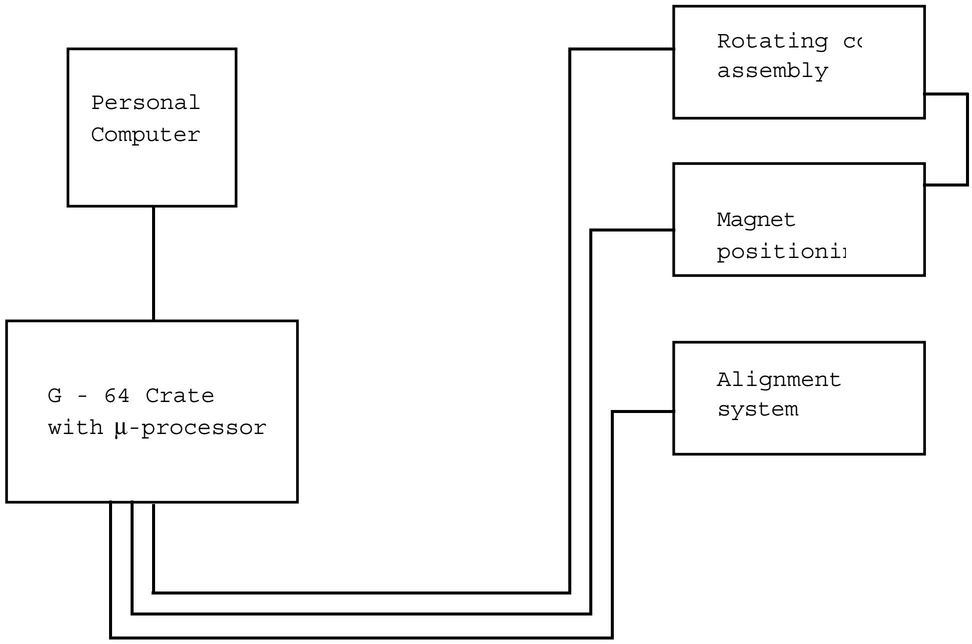

Fig. 2 - Layout of the Multipole Magnet Measurement system

<u>Rotating coil assembly</u>

It consists of a set of epoxy impregnated Kevlar cylinders holding the measuring coils. On our specific request three rotating coil assemblies were built, 2 for quadrupoles (1 is a spare part), and 1 for sextupole magnets.

The coils are designed to achieve maximum sensitivity to our specific magnetic measurements. Each coil consists of a wire bundle suspended under spring tension force on two sets of rollers at each end of the cylinder. The cylinder is supported on air-bearings and is rotated during measurements by a stepping-motor. The rotational angle is measured by a high resolution (15 Bit) absolute angular encoder.

<u>Magnet positioning system</u>

After placing the magnet on the bench, it is moved by five stepping-motors and corresponding gears and power supplies. Horizontal and vertical displacements, as well as rotations around three different axes are allowed. During the horizontal movement the magnet is supported on four air-cushions to minimize friction. Position is revealed by linear potentiometers mounted on the gears.

Alignment system

The system is composed by a laser, a position-sensitive laser detector mounted in a Taylor-Hobson ball, and by two inclinometers. The alignment system is used for the pre-alignment of the magnet (before measurement) and for the final positioning of the alignment targets (fiducial marks) on the magnet.

Control system and signal analysis

The hardware and software of the control system and signal analysis is placed in a G64 crate and it is operated by a PC (MS-DOS). The majority of the measurements operations are automatically controlled by a microprocessor located in the G64 crate. The PC controls the magnet positioning, the alignment and measurement procedures, communicates via RS232C serial interface with the microprocessor. The PC also analyzes, displays and stores measurement data.

3. The first of the 3 meter length systems for wiggler magnets consists of a device that permits the movement of a Hall Effect probe into a guide frame box along the wiggler gap. The probe carriage is suspended on air cushions to minimize the friction. The longitudinal movement reproducibility is 100 μm.

The magnetic measurement is made by a Hall Effect Digital Teslameter (from BRUKER - Germany) having the following main characteristics:

- Operating Field Range	-23000 to +23000 Gauss
- Accuracy of Center Field unit (CF): or, whichever is larger	$\lvert(B_{true} - B_{CF})/B_{CF}\rvert < 5\ 10^{-5}$ $\lvert B_{true} - B_{CF}\rvert < 1.2$ Gauss
- Repeatability setting (CF):	5 mGauss
- Resolution (CF):	50 mGauss
- Overall Field Stability:	$\frac{\Delta B}{B \Delta T} \sim 2\ 10^{-6}\ K^{-1}$

The other system is a Rotating Coil to measure the integrated field and the multipolar components. The bearings and the devices for the coil allignment are under development at labs, they will permit to match the allignment precision requests with the characteristics of the system, that was not originally dedicated to this wiggler prototype.

4. The NMR Teslameter is a general purpose instrument, which can be very useful in a magnetic measurements program for the following reasons:

   a) Precision (independent from the temperature),

   b) Functioning principle based on a very "stable" effect (the nuclear magnetic resonance of protons ^1H or deuterons ^2H, depending on the value of the magnetic field under investigation),

   c) Automatic search and "lock" of the unknown magnetic field,

   d) High reliability and compactness.

   The principal applications of the NMR Teslameter are:

   - The cross-checking of other measurement systems,
   - the calibration of Hall probes.

   The principal limitations are:

   - The requirement of a relatively "flat" field region,
   - the limit on the lower magnetic field (430 Gauss),
   - the probes' dimensions (no mini-probes are available for these kinds of instruments).

   The main characteristics of our NMR teslameter (by METROLAB - Switzerland, based on a CERN design) are:

- Field range: (with 8 different probes)	0.043 - 13.7 Tesla
- Absolute accuracy:	better than ± 5 ppm
- Relative accuracy:	better than ±0.1 ppm
- Resolution:	10^{-7} Tesla
- Thermal stability of the internal frequency counter :	± 1 ppm (-20 °C to 70 °C)
- Required homogeneity of the field:	200 to 1300 ppm/cm
- Digital interfaces:	IEEE 488 and RS 232 C

   Some of the described systems (like the Multipole Magnet Measurement system) are dedicated to DAΦNE magnets, other systems are of general purpose or, coming from previous magnetic measurement sets, they will be modified according to the needs. This part of the work is now under development.

Some power supplies are also available and others are on order for testing magnet prototypes and general use. Their main features are the following:

CURRENT RANGE	[A]	[a]2300	[b]700	[b]350	[b]150
VOLTAGE RANGE	[V]	50	100	50	120
CURRENT RIPPLE		$<\pm 1 \cdot 10^{-4}$			
CURRENT RESOLUTION		$<\pm 1 \cdot 10^{-4}$			
CURRENT REPRODUCIBILITY		$<\pm 5 \cdot 10^{-4}$			

([a] from DANFYSIK - [b] from OCEM).