About the Possibility of Measuring Pulsed Bending Magnets Using Hall Sensors

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The paper describes a method based on the use of Hall sensors for field mapping in pulsed dipole magnets. The reasons that initiated the creation of the method are analyzed and its capabilities are described. The information about the hardware developed for measurements is provided. In conclusion, the results of measurements of pulsed bending magnets of the Booster Nuclotron transport line are presented.

Introduction

Hall sensors have an **important advantage** for pulse measurements: it is an active element, which is powered by a current source. If the current source is switched off, the measured signal will then consist solely of inductive parasitic voltage on the parasitic areas of the junction and cable trace. Thus, by making two measurements at each point (with and without current), the influence of induction parasitic voltage can be eliminated. Hall sensors also have the necessary dynamic characteristics for measurements of pulsed fields with durations from hundreds of microseconds. This makes it possible to apply to pulsed magnetic fields the calibration obtained for constant fields and to **obtain absolute values of pulsed fields** in measurements. Both of these circumstances make the application of Hall sensors in measurements of pulsed magnet field maps extremely promising.

Hall Sensors in pulsed measurements

Step 1 (Fig. 1a). The Hall sensor current is switched on. The measured signal consists of the Hall voltage and the inductive parasitic voltage, which is determined by the field derivative and the parasitic areas.

Step 2 (Fig. 1b). Hall sensor current is off. The measured signal contains only the inductive parasitic voltage, the amplitude of which is the same as the induction pickup in Fig. 2a.

Step 3 (Fig. 1c). The Hall voltage is obtained by subtracting the inductive parasitic voltage (Fig. 1b) from the measured signal (Fig. 1a).

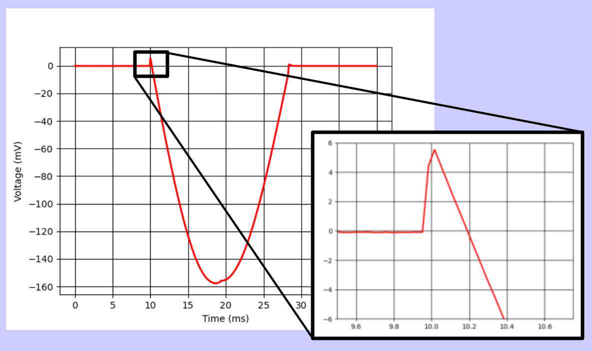

Figure 1a. Measurement with current

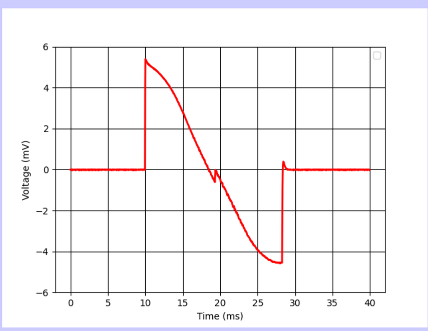

Figure 1b. Measurement without current

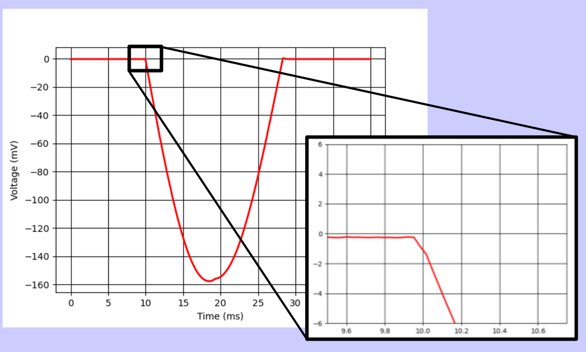

Figure 1c. Difference

Structure and parameters of the measuring stand

The measurement system (Fig. 2) consists of a carriage with Hall sensors (Fig. 3) and a FHM07 measurement module (Fig. 4). The FHM07 has the following parameters:

Parameter	Value
Number of channels	8
Measured field range	±25 kGs
ADC Resolution	18 bits
Time between measurements	> 4 µs
Minimum pulse duration	1ms * ch

The FHM07 contains a stable current source, 7 channels for connecting Hall sensors and 4 service channels that measure sensor supply current, sensor line voltage, reference source voltage, and shorted input voltage. An important feature of the FHM07 is the ability to turn off the supply current to the Hall sensors.

The measuring carriage contains a row of 7 Hall sensors HE244 (Fig. 3) that moves along the magnet in 1 cm increments. The Hall sensors have a sensitivity of 10 µV/Gs, a low supply current (1 mA), very low temperature dependence of Hall offset voltage (1 mGs/˚C) and a stability of 150 ppm/K.

The measurement is performed by series connecting the input lines by a 8-channel differential multiplexer to the buffer amplifier and then to the ADC. Thus, the sampling period for each of the eight channels is 32 µs, and the minimum pulse duration will be no more than 8 ms.

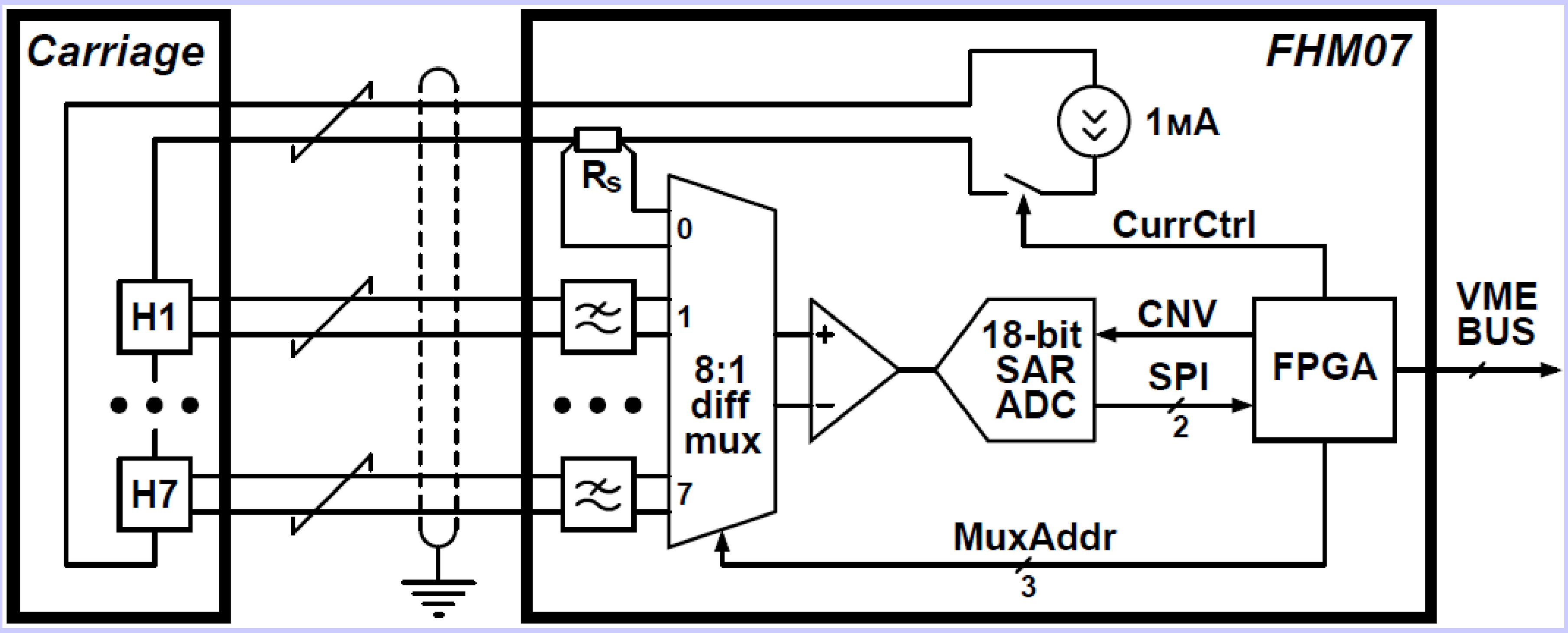

Figure 2. Pulsed magnetic field measuring system

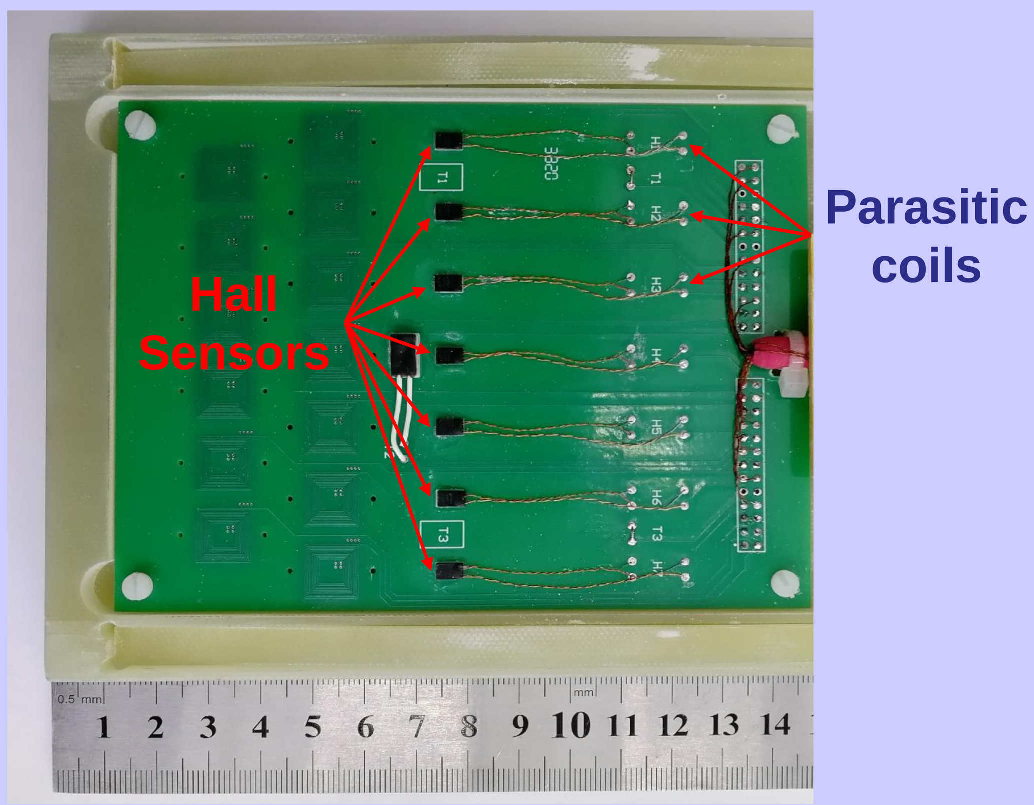

Figure 3. Carriage

Figure 4. FHM07

However, the dynamics of Hall sensors allows measuring pulse fields of sub-millisecond durations. The sampling period of the ADC in such a case must be about 1 µs, which excludes the use of multiplexers in the precision analog path. Therefore, the scheme with eight independent channels operating in parallel is more promising for further work with pulse fields.

NICA Booster-Nuclotron transport line

The described technique was used to measure the magnetic field map of long bending pulse magnets for the Booster-Nuclotron transport line of the NICA complex. The transport line is a complex three-dimensional structure (Figure 5) due to the location of the Booster and Nuclotron.

The result of the work is the measured distribution of the B_Y field component in the DU67 dipole magnet shown in Figure 6. Figure 7 shows that the measured values of the field integral differ from the calculated values by less than 10^{-3}, which meets the requirements to the field integral.

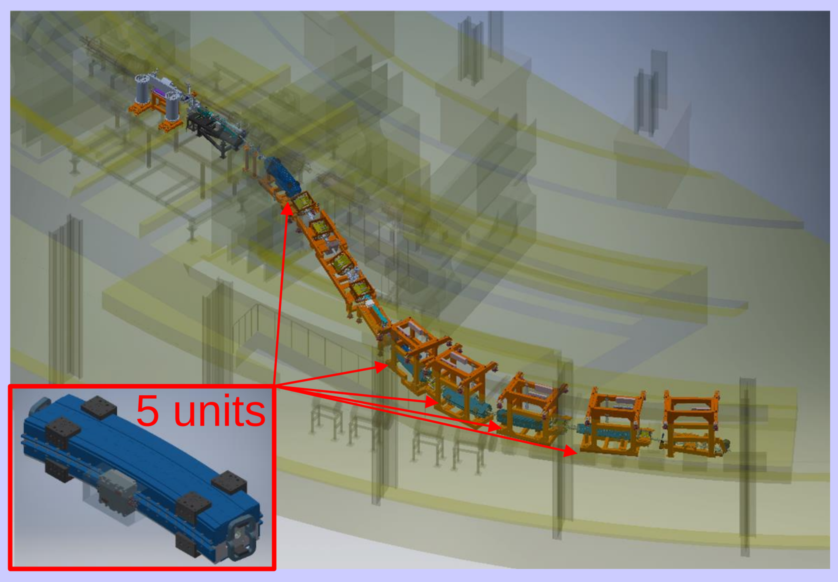

Figure 5. Booster Nuclotron transport line

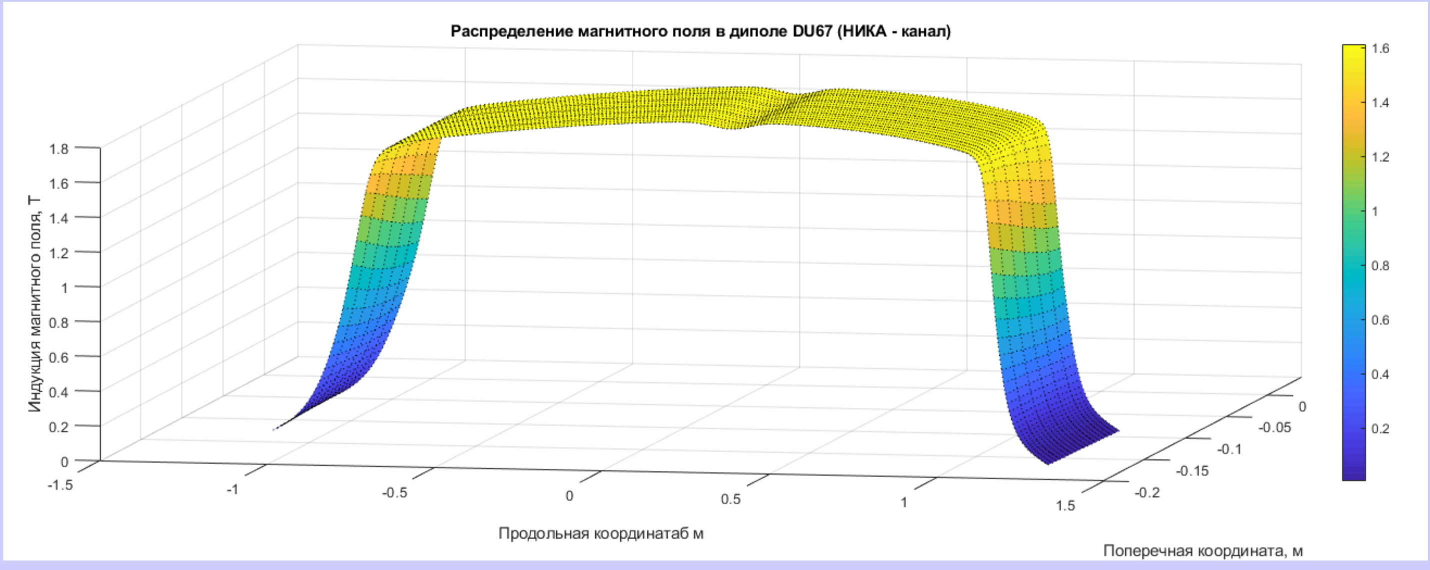

Figure 6. Measured field map

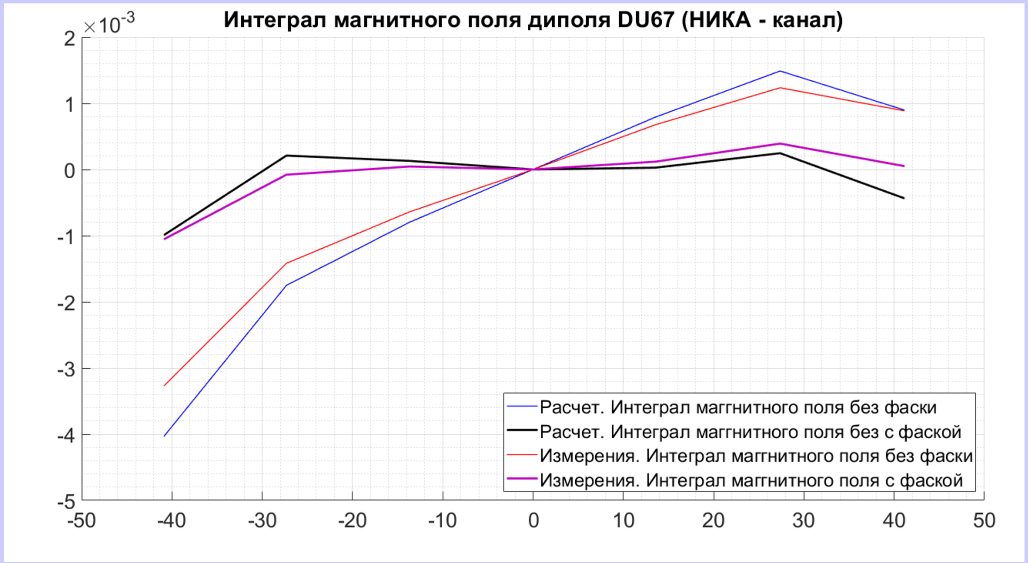

Figure 7. Transverse distribution of the magnetic field integral