DESIGN OF MAGNETIC BPM AND ERROR CORRECTIONS*

M. Shafiee, E. Ebrahimi, A.-H.Feghhi, Shahid Beheshti University, Radiation Application Technology, Tehran, Iran.

Abstract

For beam position monitoring (BPM) purposes, two prominent approaches as a physical effect have been applied including electrostatic and magnetic. In electrostatic types, secondary emission from the electrodes can be a problem when strong beam loss occurs, in such a situation, a magnetic BPM may be chosen. For this purpose we made a magnetic BPM including a square shape of polyethylene core with winding on each side. In this case study we used it for detecting the position of wire which is including a pulsed current (as an electron bunch) produced by a PROTEK G305 pulse generator. A Tektronix 2235A oscilloscope was calibrated and used to measure the induced voltage of magnetic BPM. Measurement results have been compared with simulation using CST software and performed error corrections which are presented, with this regard we could measure the wire position with high resolution furthermore we deduced the wire position hasn't linear relation with induced voltage and needs more physical and mathematical analyzing. This way propose us that we can use magnetic BPMs in this approach and calibrate them before installing on accelerators

INTRODUCTION

The magnetic BPM is a low-disturbance device since it uses magnetic properties of beam for purpose of determining position and such as beam transformer can mount around the vacuum chamber also it can be used for measuring beam intensity and determining beam position.
Since we had no access to an accelerator, we made a primary design and used it for determining the wire position, then we took notice that, this method can be useful as a calibrating system before using BPM at synchrotron, first of all we needed to know the differences between electron motion at vacuum chamber and wire. undoubtedly there are a lot of differences between them for example, instantaneous speed of electrons in copper at room temperature is about 1.6×10^8 cm/sec in random directions and bumpy way but the beam speed in vacuum chamber is about 3×10^{10} cm/sec and at same direction [1] in general, in spite of the differences it was imagined that the electrons move at wire and system must detect the wire position. Due to the limited instruments at lab, at first the system was tested with sine signal up to 7 MHz and after the corrections, wire position could be detected by using rectangular form signal up to 7 MHz produced by PROTEK G305. According to the mentioned frequency we simulated the pulse length of 0.07 µ sec and the interval distance of 0.07 µsec between two pulses as an electron beam.

DESIGN CONSIDERATION

To get the right choice of parameters of a magnetic BPM we need some requirements.
At first, the core was chosen Toroidal ferromagnetic with 4 coils, each one at horizontal and vertical opposite side, but it was impossible to observe outstanding alteration at induced voltage by displacing of wire position consequently we decided to use square polyethylene as a core.

Without any shielding and amplifier, the induced voltage was observed almost 100 mV when wire was near the coil and 24 mV when wire placed at the opposite side of core, after shielding by Al foil, mentioned the voltage increased.

The second consideration was the sensitivity of coil vis-à-vis the distance of wire, without shielding, it was 28 mm and with shielding it increased up to 32 mm which means at distance further than 32 mm of coil. We didn't observe any prominent changing at induced voltage by displacing the wire that is why we chose the size of core to be $30{\times}30mm^2$.

The third consideration was the number of winding. Since the equal inductance of coil related to the number of winding (see Eq. 1) and also we need long droop constant and fast rise time respectively we need most and low number of winding.(see Eq. 2,3)[4]

$$L \propto N^2 \tag{1}$$

$$\tau_{\text{droop}} = L/R \; H/\Omega \tag{2}$$

$$\tau_{\text{droop}} = \sqrt{LC} \; S \tag{3}$$

Meanwhile for a high sensitivity we need a low number of windings (see Eq. 4) [4].

$$S = R/N \; \Omega/* \tag{4}$$

Considering mentioned equations and compromising, the number of winding was chosen 45 turns.

DESIGN MODEL & SIMULATION

First of all we simulated the system by CST, after getting induced voltage at different position of wire, and measuring the coil parameter by LCR meter we used P-spice to see the rise time and desired fall time, 10ns for rise time and 23 ns for fall time was observed meanwhile at practical measuring we observed the shape of induced voltage at oscilloscope with ±10% rather to simulation.

By measuring coil parameters with LCR meter, equal circuit can be modeled as i.e. Fig 1 [2].

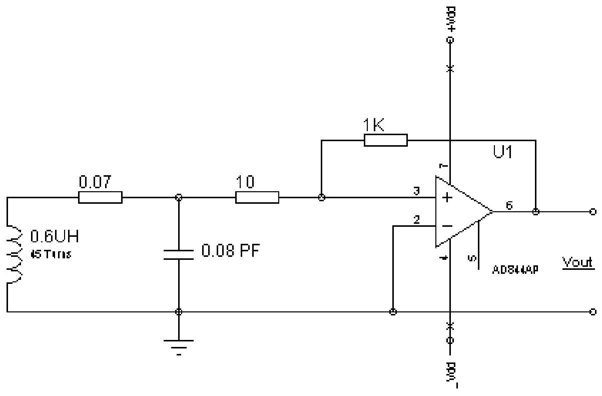

Figure 1: The equal circuit of system

Figure 2 shows a schematic view of circuit's block diagram. As you can see after amplifier it will be better to use fast ADC to convert to digital and increase the accuracy of measurements, furthermore using ADC gives the circuit the capability to employ microprocessor for more processing [3], however we used DMCA and observed the precise and digitized voltage, also Instead of beam, the wire which was connected to pulse generator and ground by 570Ω was employed. Under such condition we could produce 20mA pulsed current.

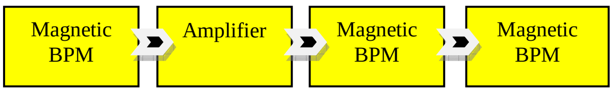

Figure 2: The Block diagram of system

To have calibrating source we simulated system by CST [4] at EM Studio i.e.Fig3. In this way we displaced wire position at horizontal and vertical directions and obtained the calibrating diagram, Mentioned results are just shown for coil 1at right side. However that is true for other coil by this regard when you close the wire to coil, the induced voltage will increase but there is not linear relation between the voltages and the position of wire.

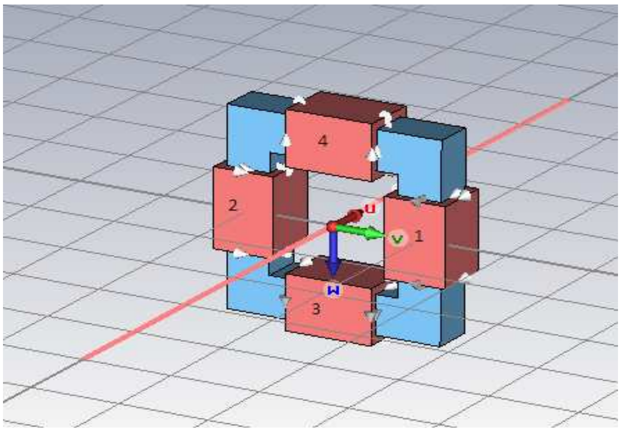

Figure 3: schematic of system at CST

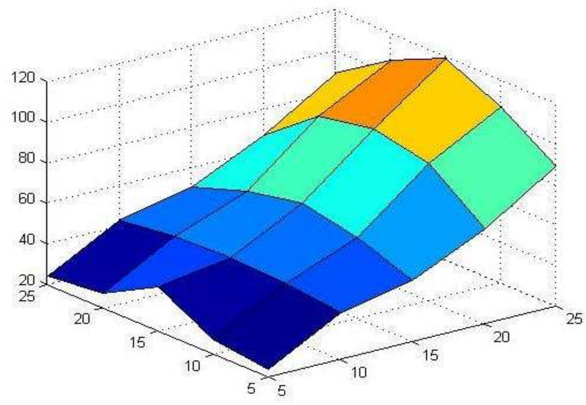

Figure 4: result of simulating, the induced voltage vs. wire position.

As mentioned we made a BPM i.e. Fig 5 and observed the results i.e. Fig 6 by different place of wire.

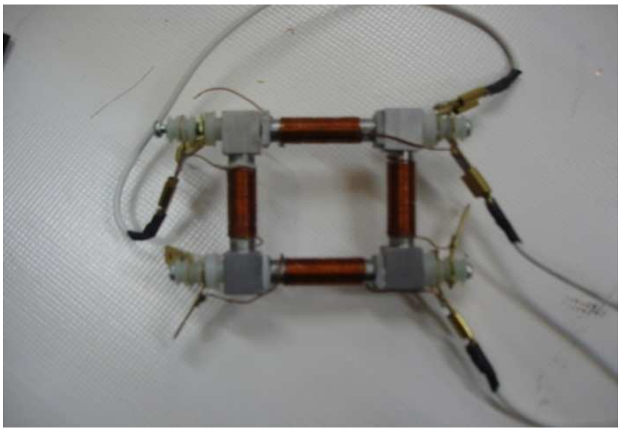

Figure 5: schematic of magnetic BPM

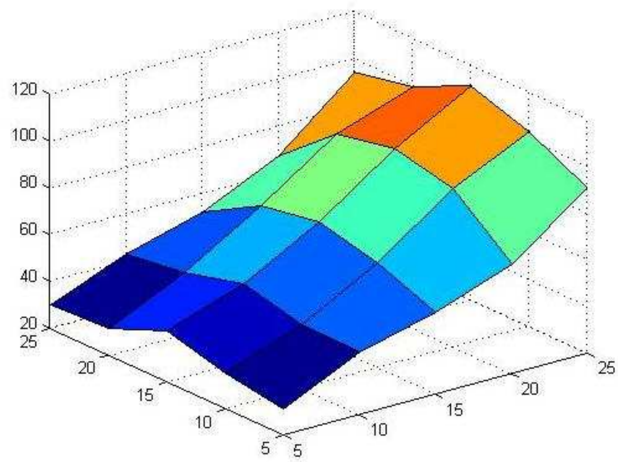

Figure 6: practical induced voltage vs. wire position

To compare the practical voltage with simulation's voltage ±10% difference between them was observed.

CONCLUSION

As you have seen, there are slight differences between induced voltages at coils in practical measurement compared with simulating results and both of them don't show any linear relation between induced voltage and wire position. We can calibrate the system by CST results and be able to determine the wire position with good resolution in mm unit.

To increase resolution, it is suggested to add other coils, meaning instead of 4 coils we would have 6, 8, etc depending on geometrical limits also that will be better to increase the frequency and using DMCA for fast analyzing.

a

REFERENCES

[1]. *C.* Kittel,"Introduction to Solid State Physics", 4th Edn. 1971 Wiley, pp 39, 248, 257

[2]. P. Strehl, "Beam Instrumentation and diagnostic", 2005 Springer, pp 38

[3] R. Kuphaldt, "Lessons in electric circuits volume 1-dc ", 5th Edn, 2006, pp 237

[4]. P. Forck, "Lecture Note on Beam Instrumentation and Daignostics

[5] www.CST.com