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50 Hz pulse magnetic field measurements – metrological possibilities of magnetic field meters

***Abstract**. This paper presents the metrological possibilities of magnetic field meters for measuring pulse magnetic fields (PMF). Briefly described magnetic fields and its presence in our daily life and pointed out, that also pulse fields are starting to emerge in our environment, mostly from industrial and medical sectors. Developed exposure system that allows to generate 50Hz pulse magnetic fields in wide range of parameters covering the field strength values related to environment protection and labour safety and presented magnetic field meters measurement results of PMF.*

***Streszczenie.** Impulsowe pola magnetyczne są często obecne w otoczeniu urządzeń wykorzystywanych w sektorze przemysłowym oraz medycznym, a ich pomiar miernikiem wzorcowanym w polu ciągłym może być obarczony znacznym błędem. W pracy przedstawiono możliwości metrologiczne mierników pola magnetycznego w kontekście pomiaru pola impulsowego o częstotliwości 50 Hz na specjalnie zaprojektowanym stanowisku wzorcowym impulsowego pola magnetycznego. **(Impulsowe pole magnetyczne 50Hz – możliwości metrologiczne popularnych mierników pola magnetycznego**).*

Keywords: magnetic field, MF, pulse field, measurements, broadband meters
Słowa kluczowe: pole magnetyczne, Pole-M, pole impulsowe, pomiary pola

Introduction

50 Hz magnetic field (MF) is present in our daily life, because it's related to mains power supply in our homes. It's more intense in the proximity of power lines and it's also used in the industry, where electric resistance welding is applied (ERW). Pulse field has it's practical application also in the medical sector, used for magneto-therapy purposes. Most commonly we are dealing with constant monochromatic magnetic field and also the available measurement equipment is dedicated (and calibrated) to measure CW magnetic field. Issues related to magnetic fields has been very widely described in various publications [1,2,3,4,5], but focusing on measurement methods or specialized sensors solutions. Authors also presented some aspect related to pulse electromagnetic fields [6,7,8] and concerning electromagnetic field (EMF) from machines used in the industry [9,10,11,12] or biomedical research [13], concerning measurements and measuring devices used for the purpose of environmental protection and labour safety, and showed, that pulse EMF measurements can be encumbered with significant errors. The scope of this paper is a continuation of research related to pulse fields.

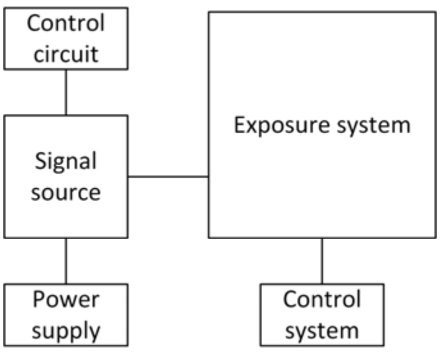

Fig.1. Standard setup diagram

Pulse magnetic field standard setup

Magnetic field standard setup is based on the concept presented in Fig. 1. In large simplification, it consist, of a signal source, control circuit, exposure system and measurement system. In the standard setup for 50 Hz field most of the elements can be simplified because of a reliable signal source, which is mains power supply. It has very stable frequency and amplitude and large power rated output. It's amplitude can be easily changed using a simple and cheap equipment – a transformer. The only factor, that needs to be take care of is the interferences present in the grid mostly due to other electrically powered devices, which generate high frequency disruptions to the grid. It can be easily eliminated using specialized filters. For magnetic field the exposure system is usually a coil (solenoid) or a setup of two coils known as the Helmholtz coil, which minimizes the nonuniformity of the field at the centre of the coils. As a control system, a power meter with magnetic sensor can be used, or also coil current measurement can be applied. Such standards are widely known and described and also calibration process of magnetic field meters [14] or uncertainty determination [15], so it will be omitted in this paper. Main scope will be regarding the pulse nature of electromagnetic field in the presented research.

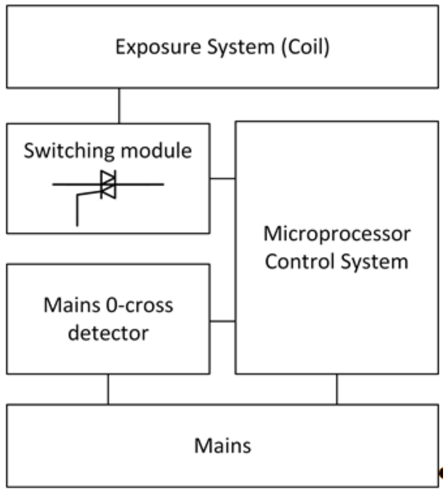

Fig.2. Pulse magnetic field standard setup diagram

Pulse magnetic field standard setup was built based on a CW standard setup supplemented by switching system allowing to generate pulses of 50 Hz signal. Schematics of the switching system is presented in Fig. 2. It can be divided in two parts: switching and control. First one consist of power supply with voltage stabilizer, 0-cross detector and switching circuit (triac with optical isolation). Control part consist user interface (LCD display with buttons and knob) and microcontroller (AVR family). The principle of operation is very simple, user is configuring two parameters: pulse width and pulse delay (both in ms). After selecting desired values the circuit starts to generate pulse signal (50 Hz/230V AC) according to defined parameters. To change the field strength in the exposure system, auto transformer is necessary. The most important thing is to perform the switching when the current in the coil has a zero value, because this might cause the damage of switching circuit due to overcurrent in the coil (discharge), and this part is made by the 0-cross detection circuit. Working prototype is presented in Fig. 3 and signals in Fig. 4.

Fig.3. Pulse magnetic field standard setup prototype

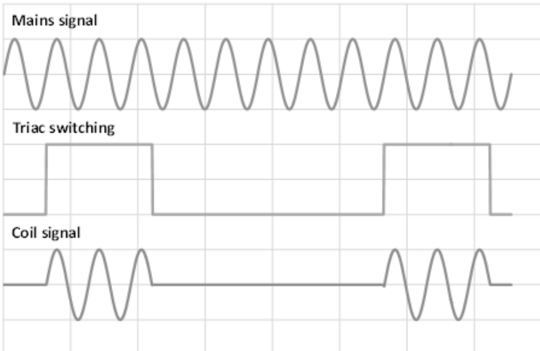

Fig.4. Signals in the switching circuit

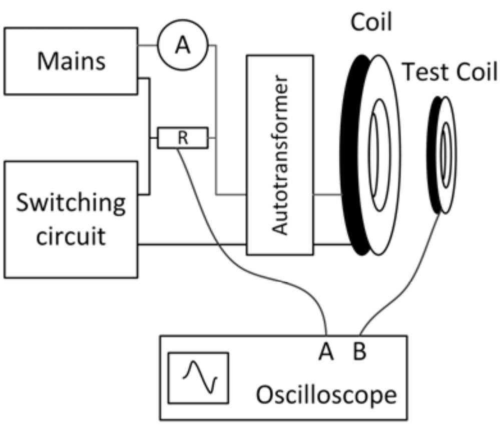

Fig.5. Measurement system for setup evaluation

Standard setup evaluation

Introduced standard setup was evaluated using measurement system presented in Fig. 5. Measurements were performed using digital oscilloscope by monitoring coil current (measuring the voltage on the resistor R) and coil signal voltage using indirect method (magnetic field measurement with magnetic coil). Obtained results confirmed the design assumptions and allowed to verify the capabilities of the system. Some of the measurements were showed in Fig. 6 and Fig. 7. Standard setup is capable to generate 50Hz magnetic pulse fields with parameters:

- Pulse width: 10 – 9999 ms
- Pulse delay: 10 – 9999 ms
- Voltage range (coil dependent): 1 – 240 V
- Current range (coil dependent): 1 – 16 A
- Dynamics range (coil dependent): 1mA – 8000 A/m
- Single pulse mode

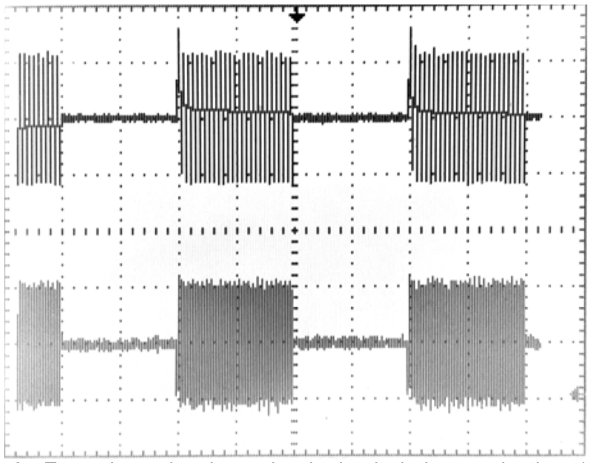
Fig.6. Exemplary signal graph obtained during evaluation (top signal –coil current, bottom signal – voltage)

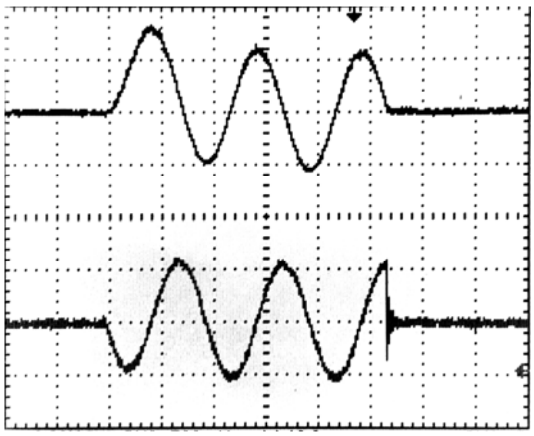
Fig.7. Close-up for the pulse package (top signal –coil current, bottom signal – voltage) – visible shift due to inductive load

Measurements

Preliminary measurements were performed on several popular magnetic field broadband meters with usage of single coil exposure system. For reference measurement used constant magnetic field with values of: 20 μT, 80 μT, 200 μT, 500 μT and 2 mT. Test were performed in pulse field with pulse length from 10 ms up to 1000 ms.

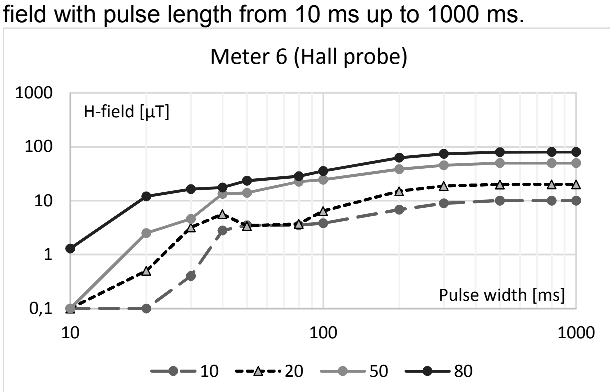

Fig.8. Meter with Hall probe indication in function of pulse length

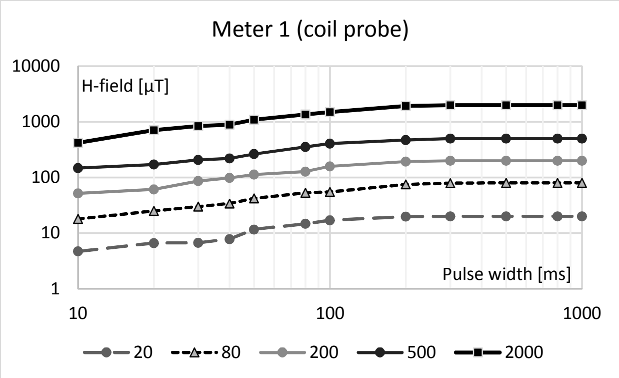

Fig.9. Meter with coil probe indication in function of pulse length

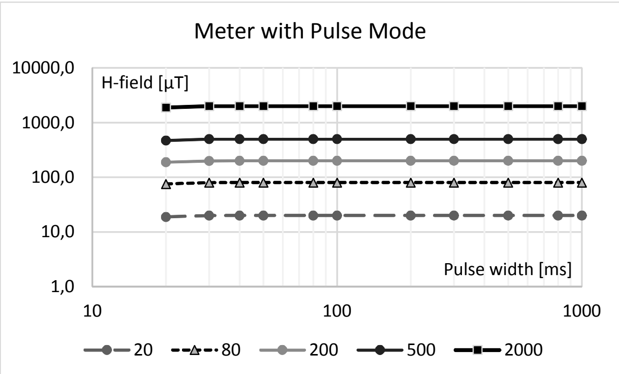

Fig.10. Meter with pulse mode indication in function of pulse length

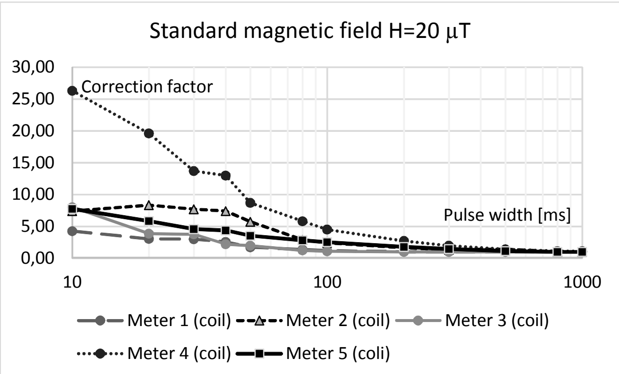

Fig.11. Correction factor in function of pulse length (H = 20µT)

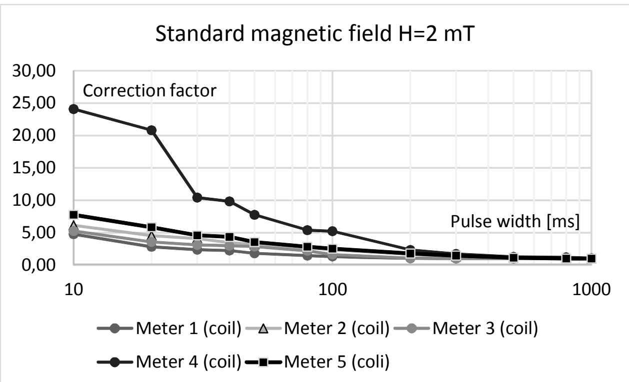

Fig.12. Correction factor in function of pulse length (H = 2mT)

Selected values are related to labor safety values in force in Poland [16,17,18] recently published due to harmonization with European Union directive [19]. Exemplary results presented in Table 1, 2 and 3. It can be noticed, that for the pulse up to 200 ms measurement error isn't significant, but below this value error is increasing. This problem exist both for meters with coil and Hall probes.

Table 1. Response to the pulse magnetic field of popular broadband magnetic meter with coil probe (meter 1).

Pulse width [ms]	**Magnetic field [µT]**				
	20	***80***	***200***	***500***	***2000***
10	4,7	18	52	148	420
20	6,6	25	61	171	706
30	6,7	30	86	207	840
40	7,8	34	98	220	890
50	11,6	42	113	263	1090
80	14,7	53	127	353	1360
100	17	55	158	405	1500
200	19,8	75	193	470	1925
300	20	79	200	500	2000
500	20	80	200	500	2000
1000	20	80	200	500	2000

Table 2. Response to the pulse magnetic field of popular broadband magnetic meter with hall probe (meter 6)

Pulse width [ms]	**Magnetic field [µT]**			
	10	***20***	***50***	***80***
10	0,1	0,1	0,1	1,3
20	0,1	0,5	2,5	12
30	0,4	3,2	4,6	16,4
40	2,8	5,6	13,3	17,5
50	3,5	3,4	14	23,5
80	3,5	3,7	22,4	28,5
100	3,8	6,4	24,5	35,5
200	6,8	15	38,3	62,5
300	8,9	18,7	45,2	73,6
500	10	19,9	49,6	79,6
1000	10	20	50	80

Table 3. Response to the pulse magnetic field of popular broadband magnetic meter with pulse mode

Pulse width [ms]	**Magnetic field [µT]**				
	20	***80***	***200***	***500***	***2000***
10	18,8	75,2	188	470	1880
20	19,9	79,6	199	498	1990
30	20,0	80,0	200	500	2000
40	20,0	80,0	200	500	2000
50	20,0	80,0	200	500	2000
80	20,0	80,0	200	500	2000
100	20,0	80,0	200	500	2000
200	20,0	80,0	200	500	2000
300	20,0	80,0	200	500	2000
500	20,0	80,0	200	500	2000
1000	20,0	80,0	200	500	2000

In preliminary studies 6 meters were tested, and all of them were prone to such large errors when measuring pulse field below 200 ms width, except the meter with pulse measurement mode (Table 3 and Fig. 9). It's probably related with the time constant of meter processing circuit. Measurement error in function of pulse length for tested meters presented in Fig. 8. In some cases measurement error excides 20 dB.

Conclusions

Obtained results clearly showed the range of problems related with pulse magnetic field measurements using broadband magnetic field meters, commonly present in labor safety measurements. Preliminary research indicates, that further research needs to be conducted and also wider range of frequencies should be checked, what requires the modification of presented standard setup. Based on the research it can be assumed, that:

- Most of the popular MF broadband meters are prone to significant errors when measuring pulse magnetic field
- Meters equipped with pulse measurement mode are immune to such errors allowing to measure pulse field even 10 ms (half of 50 Hz waveform period)
- Meters with Hall probe result with larger errors than meters with coil probe (Table 1 and 2 or graph in Fig. 8 and 9)
- Errors are not related to measured MF intensity level, what can be seen in similarities of Fig. 11 and 12

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