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The propagation of the electromagnetic field emitted by medical equipment

Abstract: *The electromagnetic fields are an environmental factor affecting living organisms. In medicine, an electromagnetic fields are used in a diagnostics and a rehabilitation. The paper presents the results of measurement tests of the emission of an electromagnetic field emitted by devices in physiotherapy laboratories. The obtained values of magnetic induction were compared with the Polish standards. The results confirmed the field emission both inside and outside the applicators, the emission values at any of the measuring points did not exceed the applicable standards. (The propagation of the electromagnetic field emitted by medical equipment).*

Streszczenie: *Pola elektromagnetyczne są czynnikiem środowiskowym oddziałującym na organizmy żywe. W medycynie pola elektromagnetyczne stosowane są w diagnostyce i rehabilitacji. W pracy przedstawiono wyniki badań pomiarowych emisji pola elektromagnetycznego emitowanego przez urządzenia w pracowniach fizjoterapii. Porównano otrzymane wartości indukcji magnetycznej z normami obowiązującymi w Polsce. Wyniki potwierdziły emisję pola zarówno wewnątrz, jak i na zewnątrz aplikatorów, wartości emisji nie przekraczały w żadnym z punktów pomiarowych obowiązujących norm. (**Rozprzestrzenianie się pola elektromagnetycznego emitowanego przez aparaturę medyczną**).*

Keywords: electromagnetic field, medical equipment, magnetotherapy.
Słowa kluczowe:pole elektromagnetyczne, urządzenia medyczne, magnetoterapia.

Introduction

Technological advances over the past decades have created a great number of artificial sources of the electromagnetic fields (EMF) that cannot be avoided in our surroundings. It accompanies us wherever we find devices powered by the electric network as well as devices related to transmission, distribution and reception of electricity: system power stations, distribution stations, transformer stations changing the average voltage to the values used in home installations (230/400 V) [1].

EMF emitted in the environment can be divided into two basic groups:

- low frequency EMF - up to 30 kHz,
- high frequency EMF (or radio frequency) - above 30 kHz.[2]

EMF emitted by devices powered from a 50 Hz industrial network belong to the group of fields with extremely low frequencies [3].

Research studies on the influence of EMF on living organisms has been conducted for many years. Despite more and more advanced technologies and wider knowledge of the processes occurring in organisms, the researches are extremely complex and requires interdisciplinary cooperation of scientists from various scientific fields. The results of such studies are often ambiguous, which forces the need to conduct further studies to improve human protection and apply it in diagnostics and rehabilitation.[4]

Research conducted by groups of scientists to assess the impact of EMFs on humans can be divided into several separate sectors. These are: epidemiological, cell culture, animal or human experimental studies. The effects on the entire body as well as structures at the cellular level are investigated [5].

The very dynamic development of medical sciences and diagnostics indicates more and more new diseases that require appropriate treatment, very often with the use of EMF, both electrotherapy and magnetotherapy, which are a very important element of the treatment process [6]. By magnetotherapy is meant a method of treatment with a pulsating magnetic field of low frequency. This method uses biophysical and biological mechanisms occurring in the human body. In physical medicine, it is assumed that the magnetic fields used in magnetotherapy are characterized by a frequency in the range of 10-100 Hz and a magnetic induction of 0.1-20 mT. In most cases, waveforms of sine, rectangular or triangular shapes and their halves are used. [7]. Both magnetotherapy and electrotherapy turn out to be very effective and bring satisfactory results in the treatment of many diseases in each medical specialization. Examples include injuries and post-traumatic conditions of locomotor organs, degenerative diseases, neurological, dermatological and pulmonary diseases [6].

Electrotherapy is a method of treatment using various types of electric currents. Electrotherapy treatments use both direct and alternating current. It is used in the treatment of joint degeneration, discopathy or neuralgia. Microcurrents can even be used in cases of side effects from the use of radiotherapy in the treatment of cancer [8]. One of current therapy method is Transcutaneous Electrical Nerve Stimulation (TENS), which uses low-frequency alternating currents whose pulses can be sinusoidal, rectangular, or triangular in shape. The most frequently used method is the high-frequency (HF-TENS) and low-frequency electro-acupuncture (LF-TENS) methods, which differ in the parameters of the used current. The differences between both methods result from the current parameters used during the procedure [9]. Transcutaneous TENS stimulation is also used to relieve labor pains [10].

Tabela 1. The values of magnetic induction and magnetic field strength for frequencies in the range <10,7 Hz do 5 MHz [11]

Limb exposure		
Frequency range [Hz]	B [mT]	H [A/m]
< 10,7	353	2,81×10^5
10,7 ÷ 3350	3790/f	3,02×10^6/f
3350 ÷ 5×10^6	1,13	900
Head and body exposure		
< 0,153	353	2,81×10^5
0,153 ÷ 20	54,3/f	4,32×10^4/f
20 ÷ 751	2,71	2,16×1^3
751 ÷ 3,35×10^3	2060/f	1,64×10^6/f
3,35×10^3 ÷5×10^6	0,615	490

Safe values of magnetic induction are specified in the IEEE C95.1 standard issued on October 4, 2019 by the Institute of Electrical and Electronics Engineers entitled: "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz ". The safety standards specified by the IEEE C95.1 standards for the controlled environment are shown in Table 1.

The aim of the presented research was to measure the value of EMF emitted by devices in physiotherapy laboratories, answering the question of whether staying in these rooms is safe for both staff (long time) and patients (short time) and whether the values of these fields do not exceed the levels indicated in the standards .

Measuring device

The measurements were carried out in physiotherapy laboratories, where there are strict conditions, and the value of EMF field should be constantly monitored.

Specialist EMF-Extech 480826 meters was used to measure the emitted EMF in physiotherapy clinics. This tester has the ability to measure EMF in three perpendicular axes - X, Y, Z. This device was designed to determine the magnitude of EMF emitted by power lines as well as electrical, industrial and medical devices. These measurements are possible thanks to the following meter parameters:

• Frequency band: 30 - 300 Hz;
• Supply current: constant current about 2.7 mA;
• Power source: 9V battery;
• Measurement speed: about 0.4s. [12]

Measured device

Four spool applicators and short-wave diathermy were selected for the measurement tests, as the devices most often used in laboratories. Measurements of the magnetic induction were made at points that were made in the places where the patients were during the therapy and personnel operating medical devices. The heights of the measurement points above the floor (Z axis) reflect the location of the most important human organs - the heart, brain and abdominal organs.

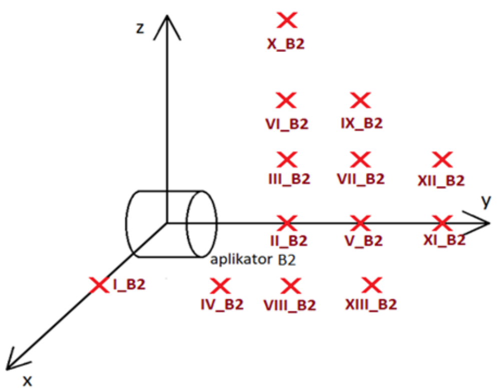

Fig. 1. Arrangement of measurement points for different heights and distances from the magnetronics - applicator B2 (Magner Plus)

Figure 1 shows an example of the arrangement of measurement points in relation to the center of the applicator for the selected spool applicator marked B2. There were selected as parameters of EMF as used most often during the treatment. The first tested applicator, designated B1, is used in the treatment of upper limb injuries, while the B2 applicator supports the treatment of lower limb injuries.

Operating parameters used in therapy with applicators B1 and B2:

• Frequency: 40Hz;
• Field shape: rectangular;
• Magnetic induction range: B1 applicator from 1.4 to 10 mT; B2 applicator from 0.7 to 8.7 mT.

Another tested applicator, marked as II, placed on the couch is used in the therapy of the spine and hips area, while the applicator III, placed on the movable table, supports the therapy of upper and lower limbs.

Operating parameters used in therapy with applicators II and III:

• Frequency: 50Hz
• Box shape: rectangular
• Magnetic induction range: from 2 to 20 mT.

The total induction of the magnetic field affecting the body was determined on the basis of the measured induction of the X, Y, Z components based on the formula 1:

(1)

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2}$$

where: B- total magnetic induction, B_x, B_y, B_z- components of magnetic induction for individual axes.

The distances of successive measurement points from the adopted origin of the coordinate system were determined on the basis of the measured values along individual axes. These distances were determined from formula 2:

(2)

$$L = \sqrt{x^2 + y^2 + z^2}$$

where: L- the distance of individual points from the origin of the coordinate system (an applicator center); x, y, z- distances along individual axes from the origin of the coordinate system.

Measurement studies were carried out on two types of medical devices: short-wave diathermy and two models of magnetronics:

• Magner Plus (Astar, Poland) - magnetronic, spool applicators marked as B1, B2.
• Magnetronic MF-10 (EIE) - magnetronic, spool applicators marked as II, III.
• BTL-6000 SHORTWAVE 400 by BTL - short-wave diathermy,

These devices generate an electromagnetic field of low frequency (diathermy) and extremely low frequency (magnetronic).

Measurement results

We selected the physiotherapy clinics and specialized devices used in therapies. The emitted EMF were studied around them. The measurements were made in three axes, and then the field emission values were calculated. The electromagnetic field emitted by Magnetronik Magner Plus was measured with the operation of two spool applicators (B1 and B2) at a frequency of 40 Hz and predetermined different values of the magnetic induction:

- The applicator with a diameter of 20 cm, marked as B1 at magnetic induction: 1.4 mT; 2.7 mT; 4 mT; 5.4 mT; 6.7 mT; 8 mT; 9 mT; 10 mT;
- The applicator with a diameter of 35 cm, marked as B2 at magnetic induction: 0.7 mT; 1.3 mT; 2 mT; 3.3 mT; 4.7 mT; 6 mT; 7.3 mT; 8.7 mT.

Figures 2 - 6 show the measurement results for the tested applicators B1 and B2, and the individual values of the magnetic induction set on the applicator are marked with different colors.The dependence of the tested values of the emitted field (magnetic induction) on the distance from the applicators is shown in Figures 2 - 3.

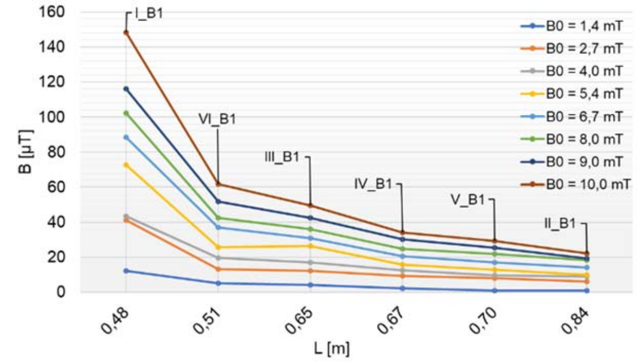

Fig. 2. The dependence of the measured magnetic induction on the distance to the center of the B1 applicator for different values of the induction set on the device

The highest value of the emitted field, equal to 148.47 μT, was obtained at a distance of 0.48 meters from the center of the applicator at the induction set on the device of 10.0 mT. The field emission does not exceed the value indicated in the safety standards, which proves that both the patients and the staff are safe during the operation of the device.

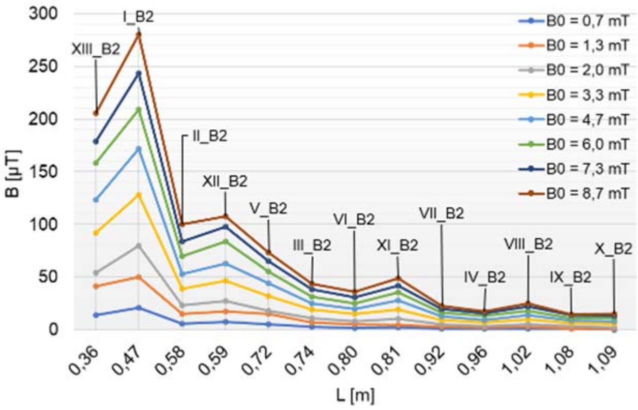

Fig. 3. The dependence of the measured magnetic induction on the distance to the center of the applicator B2 for different values of the induction set on the device

At a distance of 0.47 meters from the center of the applicator and the magnetic induction of 8.7 mT set on the device, the emitted field reaches a maximum value of 279.86 μT, being nevertheless a safe value, not exceeding the limit value set in the device.

Another tested device was the Magnetronic MF-10. Measurements of the electromagnetic field emitted by it were performed at a frequency equal to 50 Hz for two reel applicators in three combinations (applicator II, applicator III, applicators II + III) with the set magnetic induction values equal: 2 mT; 6mT; 10mT; 14mT; 17mT; 20mT:

- An applicator with a diameter of 60 cm, marked II,
- An applicator with a diameter of 31.5 cm marked as III.

Figures 4 - 5 show the dependence of the magnetic induction on the distance for individual applicators at different magnetic induction values set on the device, and Figure 6 shows the overlapping fields emitted by both applicators.

The field with the highest value of magnetic induction (equal to 49.05 μT) was achieved with the induction set on the device equal to 20 mT and the distance of the point from the applicator II center equal to 0.74 meters (Fig. 4). The obtained value of magnetic induction does not reach the maximum value allowed by the standards, which means that staying in this room during the treatments is not dangerous..

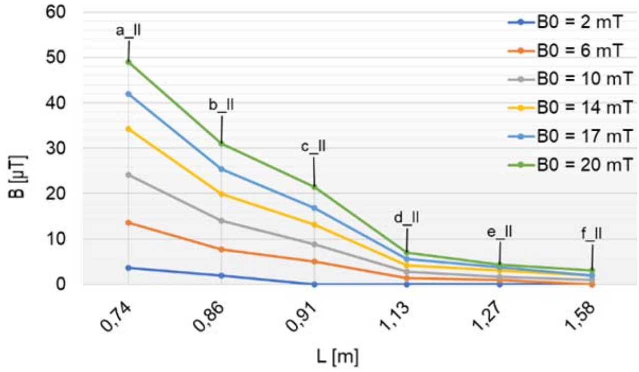

Fig. 4. The dependence of the measured magnetic induction on the distance of the point to the center of the applicator II for different values of the induction set on the device

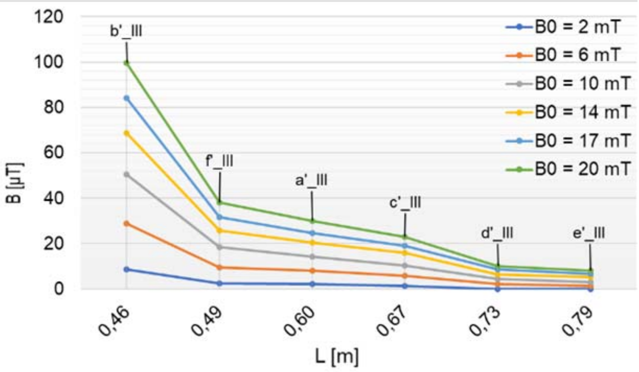

Fig. 5. The dependence of the measured magnetic induction on the distance of the point to the center of the applicator III for different values of the induction set on the device

The highest obtained value of the emitted field, equal to 99.57 μT, was achieved at a distance of 0.46 meters from the center of the applicator III and at a given induction of 20 mT. The obtained values are within the safety standards.

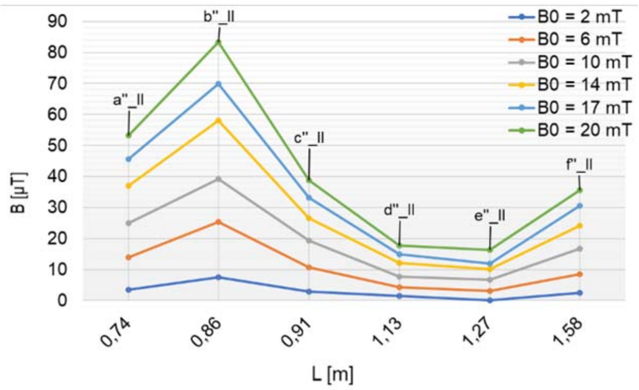

Fig. 6. The dependence of the magnetic induction measured during operation of both applicators (II + III) on the distance of the point to the center of the applicator II for different values of the induction set on the device

Simultaneous activation of two applicators (II + III) caused the emission of the field with the highest value of magnetic induction amounting to 83.22 μT. This value was obtained with the magnetic induction set on the device equal to 20 mT and the distance of the point from the center of the applicator II equal to 0.86 meters. Appropriate setting of the applicators, despite their parallel operation, does not increase the field values above those allowed by the standard.

The research was also carried out for short-wave diathermy BTL-6000 SHORTWAVE 400 equipped with capacitor applicators. The device operated at a constant frequency of 200 Hz. Device power values have been changed. Measurements were made at the power of: 10 W; 50 watts; 100 watts; 150 watts; 200 watts; 240 watts; 280W; 320 watts; 360 watts; 400 W. As the distance from the applicators increased, the value of the magnetic induction decreased, not exceeding the value of the applicable standards.

Conclusions

The technological progress and the development of civilization meant that we spend more and more time surrounded by sources of EMF emissions with different frequency values. EMF used in a magnetotherapy is characterized by a magnetic induction of 0.1-20 mT and a frequency in the range of 10-120 Hz. Fields with such parameters have a positive effect on the regenerative processes taking place in the body, and thus shorten the recovery period of patients [13].

The measurement of EMF in the area where patients are present and where medical devices are operated is a complex issue. Correct measurement of EMF requires knowledge both in the field of metrology itself, but also knowledge of problems resulting from exposure to this measuring factor. The selection of the appropriate measurement method, the correct selection of measurement points and the correct interpretation of the results and their comparison with the relevant provisions of the Environmental Protection Act will give a complete picture of the emission of EMF in the places where the therapy is carried out and whether it is safe to stay there. [14]

The paper presents the results of measurement tests of the emission of extremely low frequency EMF around medical devices used in physiotherapy offices. Appropriate parameters of therapeutic devices were selected based on the instructions of the physiotherapists operating the equipment. There were selected the parameters which were most frequently used during the treatments..The values of the magnetic were compared with the values contained in the applicable standards.

The conducted tests of EMF emission have shown that the magnetic induction value decreases with increasing distance of the measuring points from the center of the applicator. However, there were measuring points where, despite the closer distance from the applicator, the magnetic induction value was lower. They were in a straight line to the center of the applicator, covered with a casing that limited the emission of EMF. The nature of changes in the emitted field is the same for all values of the magnetic induction set on the device. Based on the research carried out, it can be concluded that the measured value of the magnetic induction strictly depends on the parameters set on the device - with the increase of the induction value, the measured value increases, and the increase is approximately linear. It was observed that the individual components of the field induction values differ from each other – there was confirmed the field distribution characteristic for the solenoid. The measured values of the magnetic induction were compared with the values allowed by the standards in force in Poland and no values above the limit were observed. Measurement studies have therefore shown that EMF generated by medical devices in physiotherapy laboratories does not pose a threat to both patients and employees.

In order to better understand the mechanisms taking place in cells that absorb the electromagnetic radiation there is needed a lot of interdisciplinary research. In our previous studies, we showed the effect of EMF on tissues and cells [15, 16]. Further research is needed to fully understand the effects of EMF at the molecular level.

Conflicts of Interest: The authors declare no conflict of interest.

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