SPACE CONFIGURATION OF LOW FREQUENCY MAGNETIC FIELD, GENERATED BY APPARATUS FOR MAGNETO-THERAPY USING GIRDLE COIL

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Abstract

An experimental investigation of space configuration of low frequency magnetic field generated by girdle coil is described in the paper.

The results of preliminary mathematical calculation and computer simulation of low frequency magnetic field of girdle coil are compared with the results of experimental measurements of module of magnetic induction in the girdle coils. The differences between results of calculation and results of experimental measurements are very small. Experimental histograms of space distribution of module of magnetic induction in the girdle coil in the case of static activation and in the case of "moved" magnetic field are given in the paper.

INTRODUCTION

It's well known that the space configuration of low frequency magnetic field in the patient's area is very important in the process of magnetotherapy[1,2]. Therefore the precise calculation of low frequency magnetic field as well as an easy-to-understand visualization of field distribution over the patient's area are of great importance for the reliability and predictability in the process of experimental measurement of magnetic induction of the constructed electromagnetic device. An electromagnetic device (girdle coil) has been constructed for use as a therapeutic tool in magnetotherapy (Fig. 1).

The calculation exposes a low frequency magnetic field solver that allows to evaluate the field strength throughout the volume influenced by the coil.

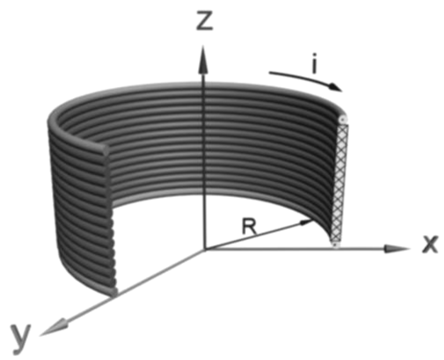

Fig. 1. Girdle coil

DESIGN STAGE

The evaluation of the low frequency magnetic field distribution and its visualization is a difficult task and usually requires a lot of time depend on the environment geometry and applied visualization techniques [1,2]. Additionally fields are often represented as large sums of field contributions of individual current turns. The calculation of field in space (off-axis form) requires field formulas that involve elliptic integrals or other complicated expressions that have to be approximated somehow. [3,4]

In the particular case the task is to evaluate the values of magnetic field induction at each point of the area of space enclosed into the coil with sizes according to the above Fig. 1. For the axial symmetry of the generated low frequency magnetic field the calculations can be performed only for the section perpendicular to the coil plain and going through the center of the coil. To achieve better effectiveness of the calculations as well as to decrease the memory necessary to store the results, the values of magnetic induction are evaluated only for one half of this section (right half). Magnetic induction B is stored together with its two ingredients – radial component Bρ and axial component Bz for a future use to obtain vector form of accumulated field data.The magnetic induction B generated by a separate turn with radius R at an arbitrary point M in the girdle coil (Fig.2) is calculated using a method based on magnetic vector-potential .

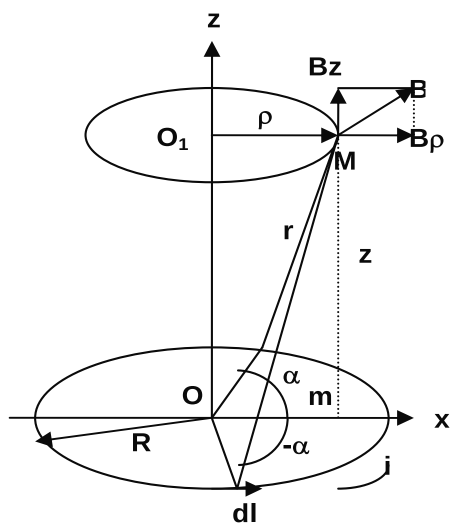

Fig. 2

The key equations used to calculate the two components components Bρ and Bz of magnetic induction B in a arbitrary point in the girdle coil:

$$B_\rho = \frac{\mu_0 i}{2\pi}\frac{z}{\rho\sqrt{(R+\rho)^2+z^2}}[\frac{R^2+\rho^2+z^2}{(R-\rho)^2+z^2}L-K] \quad (1)$$

$$B_z = \frac{\mu_0 i}{2\pi}\frac{1}{\sqrt{(R+\rho)^2+z^2}}[\frac{R^2-\rho^2-z^2}{(R-\rho)^2+z^2}L+K] \quad (2)$$

$$B = \sqrt{B_\rho^2 + B_z^2} \quad (3)$$

where:

K and *L* are full elliptical integrals;

R is the radius of the girdle coil (Fig.2);

ρ is the radius of an imaginary turn of the arbitrary point M (Fig. 2);

z is the vertical axis (Fig. 2);

i is the value of current in the girdle coil;

μ_0 is the absolutely magnetic permeability.

EXPERIMENTAL RESULTS

The presented article illustrates one approach to calculate and visualize a low frequency magnetic field distribution in 2D. The field is used for therapeutic purposes in magnetotherapy and is generated by a coil with a radius R into the range 200mm – 300mm. The coil consists of a number of current turns with the radius 1 mm. The results of calculation of magnetic induction can be compared with results of experimental measurement of magnetic induction, also. The histogram of experimental measurements of module of magnetic induction in the plane XOZ (Fig.1) can be seen on Fig. 3.

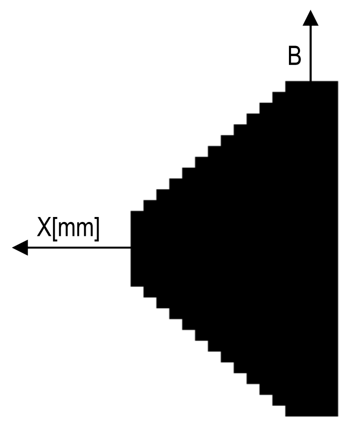

Fig. 3. Experimental histogram of the module of magnetic induction in the case of static activation of the girdle coil

Often the girdle coil consists several separate girdle coils, which can work as independent coils. This construction allow activation of the separate coils one by one and it can provide a "movement" of magnetic wave on the axis Z .A separate girdle coil can be seen on Fig. 4.

EXPERIMENTAL SETUP

A small coil (diameter $d = 8mm$, height $h = 10mm$ and current turns $w = 2x300$) has been used as sensor for measurement of the value of magnetic induction. This coil has been connected with the inputs of differential amplifier in the input of apparatus for measurement of magnetic induction of low frequency magnetic field. The measurement has been done for the sinusoidal current in the girdle coil with frequency $f = 50Hz$. It's well known that the frequency band $f = 10Hz - 100Hz$ is used in the process of magnetotherapy. The sensor has been putted in different points around the girdle coil. The measurement of the gidle coil's current has been done by ordinary ampermeter. The measurement of module of magnetic induction on the axes X and Z (Fig, 4) has been done. The results of experimental measurements together with the results of calculation of the module of magnetic induction on axis X can be seen on Fig. 5.

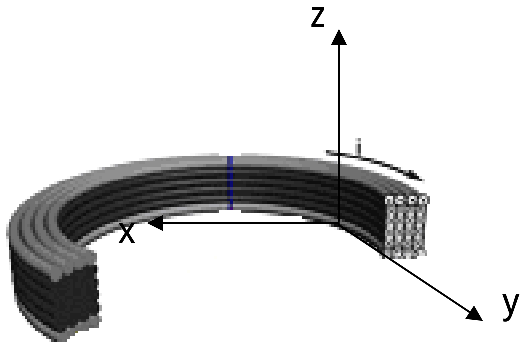

Fig. 4. A separate girdle coil

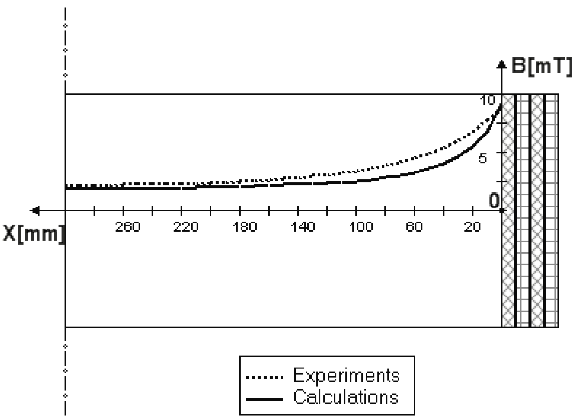

Fig. 5. Module of magnetic induction on the axis X

The results of experimental measurements together with the results of calculation of the module of magnetic induction on axis Z can be seen on Fig. 6.

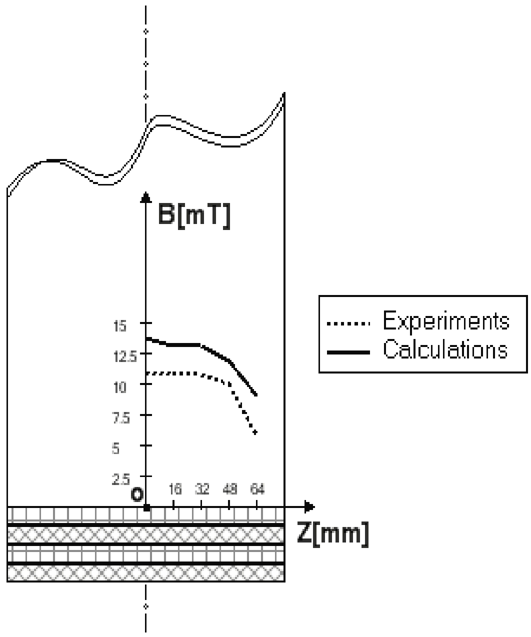

Fig. 6 Module of magnetic induction on the axis Z

LEVEL OF ERRORS

The main causes for errors between calculated and measurement results are: the finite sizes of the sensor, the permanent error of the place of sensors in it's putting in different points and orientation of it's axis (the angle between the vector of magnetic induction and the axis of sensor), the error of the measurement of current in the girdle coil, the influence of other magnetic fields with the same frequency $f = 50Hz$. Some of these errors have been reduced using differential coil as sensors. The results of calculation and results of experimental measurements are similar. It was the main goal of investigation. Of course it's possible to obtain more precise methods and measurement devices, but it's not necessary in the case of magnetotherapy, where usually the values of magnetic induction are 10-30mT and 10% error is acceptable. It's clear that only one small translation of the human body in the girdle coil would be enough for an error of the value of module of magnetic induction in an arbitrary point of the human body ,more than 10%. The value of relative magnetic permeability of live tissue $\mu_r \approx 1$ as in the air.

Therefore computer simulation can be used successfully for future investigation of space configuration of low-frequency magnetic field in the human body, also. This is the main conclusion of the above investigations.

EXPERIMENTAL HISTOGRAMS

Some experimental histograms of space distribution of module of magnetic induction in the coils can be seen on Fig.7a, Fig7b and Fig.7c in the case when the separate coils are activated one by one and the magnetic field "moves" on the axis Z .

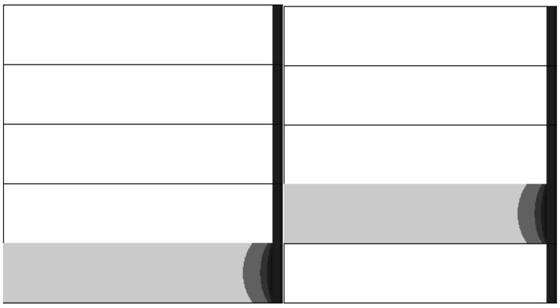

Fig. 7a

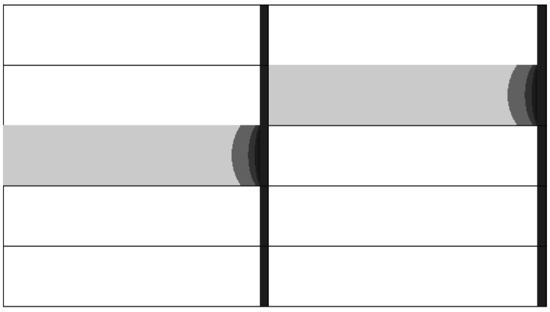

Fig. 7b

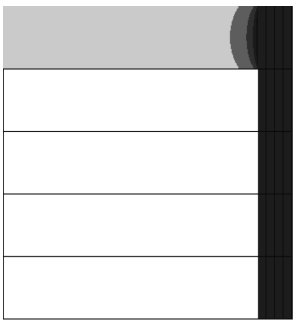

Fig. 7c

Fig. 7. Experimental histogram of the module of magnetic induction in the case of "moved" magnetic field

CONCLUSION

Visualization, calculation and experimental investigation of the space configuration of low frequency magnetic field in the patient's area is of great importance as preliminary result not only for the process of experimental measurement of the value of magnetic induction in magnetotherapy, but for evaluation of the effectiveness of developed electromagnetic devices, also. Additionally these two processes can be used to assist the design of such devices. Into the particular case of therapeutic magnetic field the calculation and visualization are intended to allow the user visually evaluate the strength of the field into the influenced area of space.

The data structures developed for geometric and calculated data representation are designed to store both radial $B\rho$ and axial Bz components of magnetic induction for future visualization of a vector field in 2D and 3D. At the implementation stage the data structures are chosen in such a way to allow data to be shared between different applications.

The experimental measurements of the module of magnetic induction in girdle coil confirms results, obtained by computer calculation.

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