Evaluation of the magnetic field homogeneity inside experimental system for sensitive medical devices measuring

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Abstract

This article describes the design, implementation, and experimental validation of a system intended for future investigations into the effects of low-frequency electromagnetic fields (EMFs) on sensitive medical devices. The primary objective is to assess the homogeneity of the magnetic field generated within the proposed experimental setup.

The first part of the article focuses on the theoretical design and calculation of Helmholtz coils intended to generate a homogeneous low-frequency EMF. In research practice, systems with relatively small dimensions, typically on the order of 15 cm, have been reported . To enable investigations within a working volume comparable to the size of an adult human torso, a custom system was designed and implemented. The dimensions were selected with regard to the requirements of the planned experiments.

The second part describes the implementation of the proposed system. Calibrated induction probes were used to measure the magnetic flux density. The excitation system consists of two symmetrical coils designed to generate a low-frequency electromagnetic field.

In the final part, the measured data are evaluated and presented graphically, providing an overview of the spatial distribution of magnetic flux density within the experimental volume.

Index Terms: *Helmholtz coils, magnetic field homogeneity, low-frequency magnetic field, magnetic induction, 3D field visualization.*

I. INTRODUCTION

The electromagnetic immunity (EMI) of sensitive electronic devices is ensured by the manufacturer in accordance with applicable standards [1] [2]. Similarly, the electromagnetic compatibility and immunity of implantable cardiac pacemakers to electromagnetic interference are verified by the manufacturer in accordance with the relevant EMC requirements. ISO 14117 defines test methods and limits for evaluating the immunity of cardiac pacemakers to electromagnetic fields [3]. Laboratory experimental methods for testing the electromagnetic immunity of medical devices in the RF range have also been described, for example [5] [4] Described systems has small excitation coils with a diameter of the order of 15 cm. To achieve a magnetic induction value of the order of 1 mT, a small generator power is sufficient. However, the homogeneous experimental area is of small dimensions. [5] Experiments investigating electromagnetic emissions from commercially available wireless power transfer systems and their effects on medical devices are relatively common [6] A different situation applies to the effects of low-frequency (LF) and extremely low-frequency (ELF) electromagnetic fields on medical devices, particularly car diac pacemakers [7].

For the experimental methodology, the recently introduced IEC TS 60601-4-2:2024 [7] is of particular importance. This document specifically addresses the assessment of the ability of medical electrical equipment and medical electrical systems to operate without unacceptable degradation of performance in the presence of electromagnetic disturbances. It also defines general test conditions, equipment configurations, patient simulation, and test levels. However, the standard does not focus specifically on a particular frequency range.

Experimental verification of the electromagnetic immunity of medical devices under controlled conditions requires a sufficiently large test volume to accommodate biological material in the form of an adult human torso phantom together with the medical device under investigation. For this reason, an experimental system was developed with the following capabilities: