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# Impact of electromagnetic fields in residential areas

Abstract: This article deals with the impact of electromagnetic fields arising in the vicinity of electric equipment in a residential area and their impact on the human body. This work was based on measurements of magnetic induction using of magnetometer and by computational simulation in ANSYS for individual appliances in the home. From the individual results there are set out recommendations for practical action in the form of elimination of harmful electromagnetic radiation.

Keywords: electromagnetic field, electromagnetic radiation, magnetic induction

## I. INTRODUCTION

Currently there it sets a large development and growth of electrical and power equipment that are sources of electromagnetic radiation. Electromagnetic fields are all around us, whether in natural or artificial forms. The most based and also the largest source of electromagnetic field is the Sun. Its non-ionizing radiation has a significant effect on the existence of life on Earth. The spectrum of the solar electromagnetic radiation has a wide range, which includes visible, ultraviolet, and infrared frequencies. In the industry, these fields are produced in the manufacture, distribution and consumption of AC electric power or as a side-effect of technological processes based on the passage of direct electrical current. The above sources generate electromagnetic radiation that have an adverse effect on the human body. Individual electromagnetic fields are biologically active throughout its whole range, which was as experimental as well as extensive statistics proved [2].

The biological effects of electromagnetic fields vary and depend on several parameters [3]:

- the frequency range
- duration of action
- size of intensity

Furthermore, it obviously also depends on subjective parameters, i.e. the chemical-physical properties such as [3]:

- dimensions, weight and thickness of the layers (skin, fat layers, muscles)
- clothing material
- water content
- mental and health condition of the body

Since the human body can be described as an environment that is highly variable and complex, since it comprises an aqueous electrolytic solution, the cell number of smaller structures such as cell membranes and different ones. Biological tissues contain a number of layers which are different not only from the biological as well as dielectric properties, which results in changing the effect of the electromagnetic fields. In principle we recognize two kinds of effects of electromagnetic fields: thermal and non-thermal [4].

*Thermal effects* depend mainly on the size in proportion to the frequency, i.e. that with the increasing frequency also increases the thermal effect of electromagnetic fields and are most severe in the microwave band. Given that the microwaves penetrate only to shallow depth due to the large decrease in the tissues, most at risk is the brain, the eyes and the male sex organs [6].

The *non-thermal effects* are related to long-term treatment with the weak fields. They are intended primarily to instantaneous amplitude of low-frequency radiation. Their effect increases with the repeated exposure to low intensity fields, particularly in the operation of the pulse of the fields in which the total energy is relatively small, but the instantaneous amplitude is large [6].

## II. MEASUREMENTS OF MAGNETIC INDUCTION AROUND THE APPLIANCES

The measurement of the magnetic induction nearby the appliances was performed using Gauss Meter/Teslameter Model 8030 (Figure 1).

Figure 1. Illustrations of investigated sources of electromagnetic field commonly used in a household

This apparatus is a three-channel magnetometer, which is able to measure and display up to 7 different parameters. To measure it must be accompanied by a specialized probe that is of the sixth generation, which uses Hall effect. The probe comprises of three probes, each being stored in one of the axes *x*, *y*, *z*. Before measuring, it was necessary to calibrate the device using the zero-setting probe.

Sufficient to increase the accuracy of measurement, it was necessary to eliminate the factors affecting the measurement uncertainty. One of the main factors that affect the measurement and thus the measurement results were metal subjects. Therefore, as a basic worktop on which the appliance was placed measured appliance (microwave oven, hair dryer) was a wooden table.

The following Table I shows the measured power consumption of appliances:

TABLE I
Power consumption of measured appliances:

| Appliance | Type | Input power (W) |
|---|---|---|
| Microwave oven | Electrolux EMS 2320X | 800 |
| Induction cooker | Baumatic BHI615 | 2×2000, 2×1500 |
| Hair dryer | ETA Colorino | 1800 |

Microwave oven Induction cooker Hair dryer

Figure 1. Illustrations of investigated sources of electromagnetic field commonly used in a household

## III. GEOMETRICAL MODELS

Particular two-dimensional models represent appliances and human that have been modeled using ANSYS Mechanical APDL. Two-dimensional simplified models were chosen for easier and faster computations. Particular appliances and human were modeled using the 2D areas. The outer area (air) was modeled as a rectangle of 2×2,8 m with no influencing subjects (that could affect the results of electromagnetic field) (see Figure 2). Through this model (appliance and human) there was created non-symmetrical logarithmic mesh (Figure 3) because of respecting skin depth due to high frequencies.

The below Table II shows the material properties required for the simulation. These parameters represent the relative permeability and electrical resistivity of each material [1]. The value of the relative permeability was set according to blood flowing that was supposed higher due to erythrocytes (ferromagnetic material).

TABLE II
Material properties

| No. | Material | Relative permeability $\mu$ [H·m$^{-1}$] | Resistivity $\rho$ [Ω·m] |
|---|---|---|---|
| 1 | Air | 1,00005 | $1{,}3 \cdot 10^{16}$ |
| 2 | Copper | 0,99994 | $1{,}68 \cdot 10^{-8}$ |
| 3 | Skin | 20 | 1,66 |

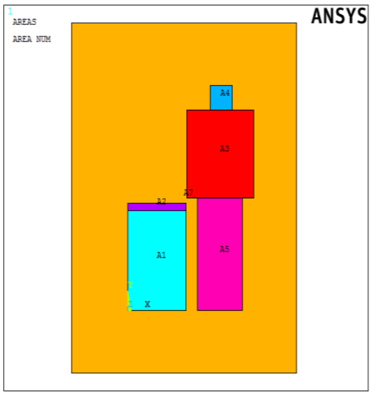



Figure 2. The geometrical model of induction cooker and human (A1 – stand for induction cooker; A2 – induction cooker; A3 – human torso; A4 – human head; A5 – human legs; A7 – air)

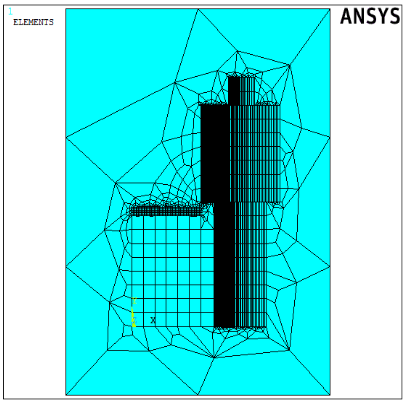



Figure 3. The generated logarithmical mesh (due to skin-effect) of induction cooker and human

## IV. RESULT COMPARISON OF PARTICULAR APPLIANCES

According to simulation there was created the curve representing the characteristics of magnetic induction decreasing with an increasing distance from the source. On the graph (Figure 4 to 6) one can see the allowable value of magnetic induction from the particular appliance.

Allowable value of magnetic induction according to standard [5] for the frequency 2,45 GHz, close to microwave oven is 0,2 µT.

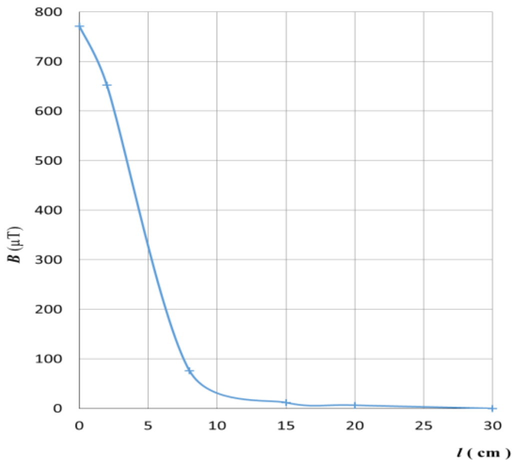



Figure 4. Dependence of magnetic induction from a distance (microwave oven)

Allowable value of magnetic induction according to standard [5] for the frequency range of induction cooker 20 ÷ 50 kHz, close to induction cooker is 6,25 µT.

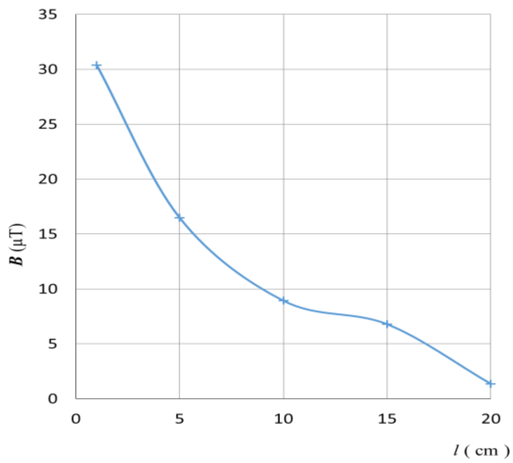



Figure 5. Dependence of magnetic induction from a distance (induction cooker)

Allowable value of magnetic induction at 50 Hz, close to hair dryer could be calculated as follows (according to standard [5]):

$$B_{\text{allow}} = \frac{5}{f} = \frac{5}{50} = 0{,}1\,\mu\text{T} \quad (1)$$

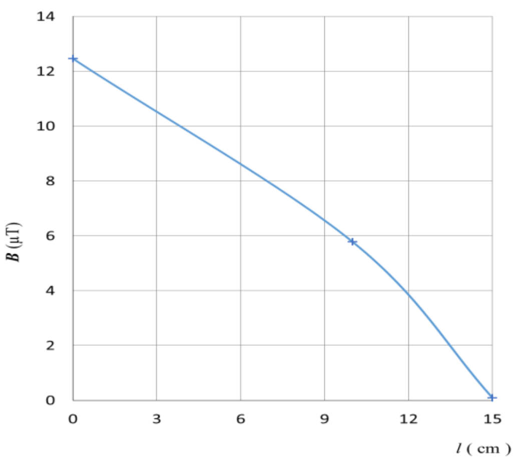
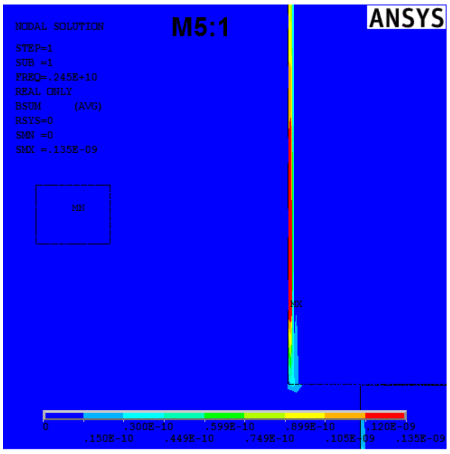



Figure 6. Dependence of magnetic induction from a distance (hair dryer)

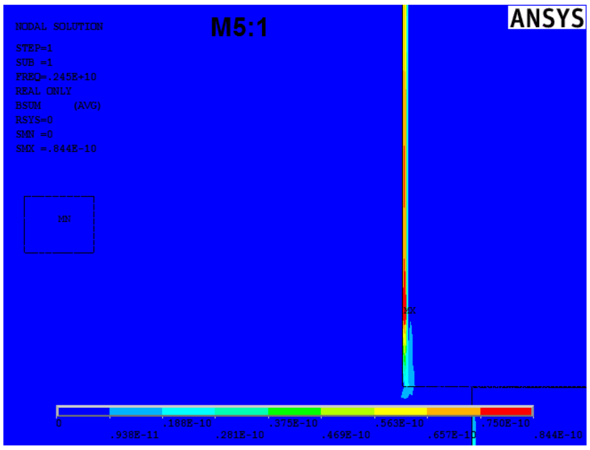
## V. ELECTROMAGNETIC FIELD DISTRIBUTION IN THE BODY INFLUENCED BY APPLIANCES

The following figures (Figure 7 (zoomed for better view of magnetic field absorption) and Figure 8) show the distribution of magnetic induction ***B*** in the human body at different distances from the source of electromagnetic radiation. One can see the distribution of magnetic field lines around a person and induction cooker (Figure 9) where the densely distribution of magnetic field lines represents the highest value of magnetic intensity ***H***, and thus the higher density of eddy currents. For this reason, the manufacturers of domestic appliances must take into account the appropriate shielding covers on appliances preventing human against to electromagnetic field of dangerous amplitudes.

*A. Microwave oven graphical results (close-up of a human torso)*



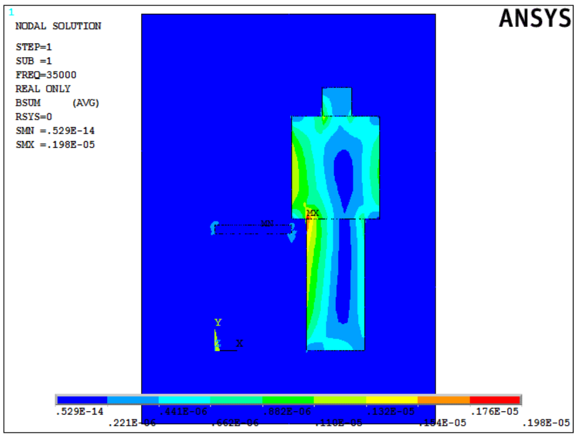

a)



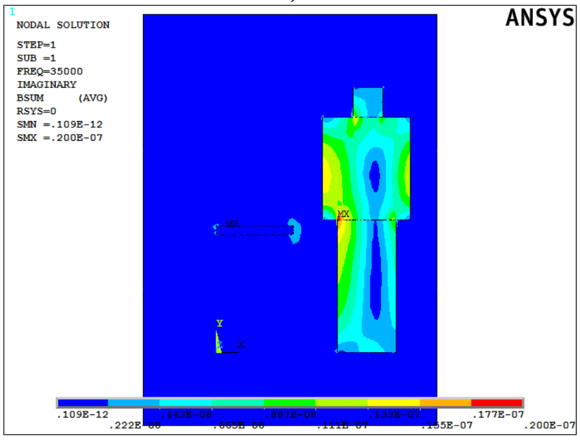

b)

Figure 7. a) distribution of the magnetic induction in the person's torso at a distance of 0 cm; b) distribution of the magnetic induction in the person's torso at a distance of 20 cm

*B. Graphical results of the induction cooker*




a)




b)

Figure 8. a) distribution of the magnetic induction in the person's torso at a distance of 0 cm; b) distribution of the magnetic induction in the person's torso at a distance of 20 cm

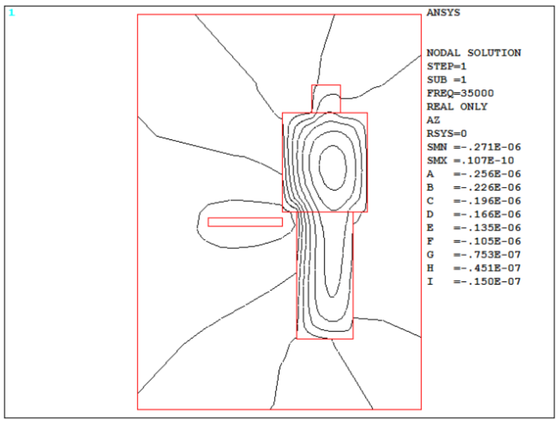



Figure 9. Distribution of magnetic field lines around a person and induction cooker

## VI. EVALUATION OF MEASURED RESULTS

From the measured result as well as the results of the simulation indicate that the greatest value of the magnetic induction ***B*** reaches from the microwave oven. We can also observe that with increasing distance from the appliance, the value of magnetic induction decreases, thereby decreasing the effects of electromagnetic fields. When measuring the microwave oven, we found that allowed distance at which the magnetic induction is permitted, is value more than

30 cm. At a distance of less than 30 cm people would not linger near the appliance in operation, respectively. They should move away as soon as possible. According to the results of the simulation it confirmed the theoretical assumptions and is such that the electromagnetic radiation in the microwave band penetrates only to shallow depth. When measuring the induction cooker it is possible to determine that a safe distance above the induction cooker is more than 16 cm. It is therefore necessary during the cooking use sufficiently long kitchen utensils made of non-metallic materials in order to avoid the adverse effects of electromagnetic fields on the human body. When measuring the value of a hair dryer, there was observed 830-times higher value than the permissible value, so the usage time of the appliance should be minimal. Also for drying hair the required minimum distance is 15 cm from head to keep it within the permissible value of magnetic induction. All these values were compared with exposure action values for electric, magnetic and electromagnetic fields defined in the Health Ministry Decree no. 534/2007 Collection of Laws [5].

## VII. CONCLUSION

There are several ways to eliminate the adverse effects of electromagnetic fields on the human body. One of the basic ways resulted from the simulation as well as the measurement is the distance from the source. When a man is staying away from electrical appliances, the effects of electromagnetic fields is weaker. Another way is the protection time, which is that the shorter time to use electric appliance, and the effects are weaker. There is still the possibility of the elimination of electromagnetic radiation by shielding.

We therefore propose to manufacturers of electrical appliances to deal with the detailed research of electromagnetic fields and materials used for absorbing electromagnetic fields of type permalloy or anti-magnetic foils, special coatings based on graphite. Another recommendation is to provide information on permissible times and distances when working with electrical appliances so as to avoid adverse effects on the human body and therefore it could be necessary to enact in laws in Slovakia.

## ACKNOWLEDGMENT

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## REFERENCES

[1] O. Hirka: *Posúdenie vplyvu elektromagnetického poľa v obytných priestoroch*. (Assessment of the impact of electromagnetic fields in residual areas). Bakalárska práca. Košice: Technická univerzita v Košiciach, Fakulta elektrotechniky a informatiky, 2016.

[2] J. Myslík: *Elektromagnetické pole, základy teorie*. Praha, BEN, 1998. 157 s.

[3] A. S. Presman: *Electromagnetic field and life*, Springer US: 1970, DOI: 10.1007/978-1-4757-0635-2.

[4] CELENEC: *Expozícia EMP v pásmu vysokých kmitočtů (10 kHz – 300 GHz)*, Bruxelles, CELENEC, 1995, 44 s.

[5] Vyhláška .534/2007 Zb. Ministerstva zdravotníctva Slovenskej republiky zo 16. augusta 2007 o podrobnostiach o požiadavkách na zdroje elektromagnetického žiarenia a na limity expozície obyvateľov elektromagnetickému žiareniu v životnom prostredí.

[6] D. Mayer: *Aplikovaný elektromagnetizmus*. Nakladatelství Kopp, České Budějovice 2012.

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