School Experiments with High-frequency Electromagnetic Field Analyser HF35C

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In this contribution we present some suggestions and 6 worksheets for experiments with the HF35C measuring device. We also present the results of the measurements of the electromagnetic field that we obtained with our students both outdoors (in the neighbourhood of a school building and a residential building) and indoors (in proximity of microwave ovens, wireless phones, mobiles and wi-fi). We also introduce a project called "High-frequency electromagnetic fields in a student's environment". We introduce a questionnaire that our students used to map the usage of mobiles by students of our school before the experiments.

Introduction

Many people use devices that work on the principle of high-frequency (HF) electromagnetic fields (EMF) today such as microwave ovens, cellular and wireless phones and wifi. There are many often contradictory opinions on the influence of HF EMFs presented in the media (TV and radio broadcasting, newspapers and magazines) and on the Internet [1-6]. Because of this, we decided to realize a student project in which we would measure the values of such fields both outdoors and indoors and compare them to the valid health limits. The project was preceded by preparation of a brochure with experiment proposals.

Although professional measurements of HF EMFs are very demanding and required devices are expensive, there is an option how to measure HF EMFs in one's own environment. It is the HF35C device that is made by Gigahertz Solutions in Germany. This company produces expensive devices for professionals as well as cheaper ones for the people (amateurs) who are interested in the quality of the environment.

The aim of this contribution is *to present proposals on "simple" pilot experiments* with the HF35C gauge that may be carried out in school or home environment. The next aim is *to present the project* called "High-frequency EMFs in a student's environment" that was realized by us at the St. Nicholas Grammar School in Prešov.

High-frequency analyzer HF35C

The digital high-frequency analyzer of electromagnetic fields HF35C (high-frequency analyzer, see Fig. 1) is capable to measure EMFs in the frequency range from 800 MHz to 2.5 GHz. This frequency range is important because it covers mobiles (GSM800, GSM1900, TDMA, CDMA, AMPS, iDEN), wireless phones (2.4 GHz) and microwave ovens (2.45 GHz) as well as the UMTS generation technologies (3G)

and Bluetooth that have been experiencing fast development nowadays. All the frequencies in between are covered too [7].

The HF35C analyzer consists of the measuring device and a probe – sensor (see Fig. 1). The sensor of HF radiation is a logarithmic-periodic antenna. It has one favourable feature – directionality. This means that one can find the direction from which the radiation comes and thus locate its source [7]. Determining the direction to the radiation source is an important precondition for effective shielding.

Fig. 1 HF35C Analyzer

The display of the measuring device indicates the energy flux of the electromagnetic field *S* that flows through the antenna in $\mu W/m^2$ (surface integral of the area of the antenna viewed from the direction of the source). The range switch provides two sensitivities: 199 $\mu W/m^2$ and 1999 $\mu W/m^2$. The signal switch allows for measuring the average signal value (mittelwerte) or the maximal amplitude (peak werte; *recommended mode*). It is possible to activate audio frequency analysis function.

Proposals on experiments with HF35C

There are many possibilities how to use the HF35C analyzer. We decided to perform some "simple" pilot experiments in the local environment of a typical student that can be carried out in school and at home, respectively. The instructions for these experiments are presented in an instantly usable form in Slovak in the brochure called "Školské experimenty s analyzátorom vysokofrekvenčného elektromagnetického poľa HF35C" (School experiments with high-frequency electromagnetic field analyzer HF35C). The brochure can be found on the Internet address

http://physedu.science.upjs.sk/degro/pokus/pokusy.html

We divided the experiments in two groups:

Outdoor experiments:

Determination of energy flux *S* out of residential and school buildings.

Determination of energy flux *S* inside a flat and a school building.

Indoor experiments:

Determination of energy flux *S* in the proximity of a microwave oven.

Determination of energy flux *S* in the proximity of a wireless phone.

Determination of energy flux *S* in the proximity of a mobile.

Determination of energy flux *S* in the proximity of a wi-fi access point.

Students should compare measured values to valid health limits after they would have carried out the experiments and evaluated the results.

Note: We must not forget to notify students of Safety Instruction. All devices but the one with which we do an experiment should be turned off during the experiment.

Grammar school project

We realized a project called "High frequency EMF in a student's environment" at St. Nicholas Grammar School in Prešov. The project had four stages.

In the *first stage*, students studied various references on the influence of HF EMF on health. *Results:* review material in printed form, formulation of hypotheses.

In the *second stage*, students used a survey to map the usage of mobile phones by grammar school students. *Results:* questionnaire and column plots. Questionnaires and plots are available at

http://physedu.science.upjs.sk/degro/dotaz/dotaz.html
http://physedu.science.upjs.sk/degro/pokus/pokusy.html (1)

In the *third experimental stage*, students carried out measurements of HF EMF with the HF35C analyzer both outdoors and indoors. *Results:* Tables and plots in printed form.

In the *fourth stage*, students compared measured values to health limits. *Results:* Evaluation of measured values and formulation of conclusions.

Students presented the results of the project delivering a presentation at the competition of talented high-school-level students (SOČ) in the end of the project.

Presentation of representative results

Health limits

It is necessary to get acquainted with health limits for HF electromagnetic field before we analyze the experimental results. The Slovak national standards of the Legal code n. 325/2006, n. 329/2006 and n. 534/2007 define the requirements on the health limits of energy flux S of HF radiation in W/m^2 and limiting health values of specific absorption rate (SAR) in W/kg for population and employees [10, 11, 12]. Health limits are reference values that should not be exceeded. The Slovak limits are based on the materials of International Commission on Non-Ionizing Radiation Protection (ICNIRP) [13, 14].

Table 1 shows reference values of energy flux of the electromagnetic field S for population and employees

Tab.1. Reference values of energy flux for planar wave [10, 11, 12].

Frequency range	S (W/m^2) *employees*	S (W/m^2) *population*
10 MHz < 400 MHz	10	2
400 MHz < 2000 MHz	f/40	f/200
2 GHz < 300 GHz	50	10

Microwave oven in the kitchen

Qualitative experiments with microwave detectors MW1AK and MT-128 [8, 9] (Fig. 2) showed that the microwave oven (MWO) is safe – the dial pointers did not a bit move from zero. Yet, the experiments with HF35C showed that there is an inhomogeneous non-stationary EMF around the MWO. We drew a floor plan of the kitchen (Fig. 3) with marked measuring points and the position of the MWO before carrying out quantitative experiments. We did the experiment and evaluation according to the worksheet that is available at the address (1).

Fig. 2 Microwave oven in the kitchen. MW1AK (left) a MT-128 (right).

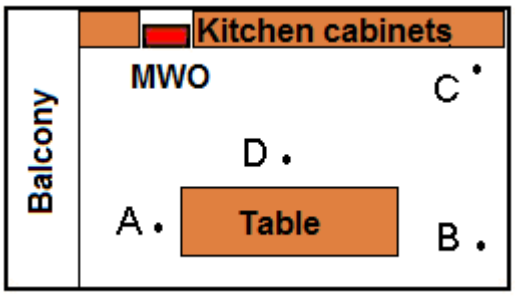

Fig. 3 Kitchen floor plan: 2.80 m x 4 m; A, B, C a D measuring points; MWO – Microwave oven

Fig. 4 shows the time evolution of energy flux S with the MWO turned off (the so called background) in three different measuring points. Fig. 5 shows the same dependences and one more with the MWO turned on.

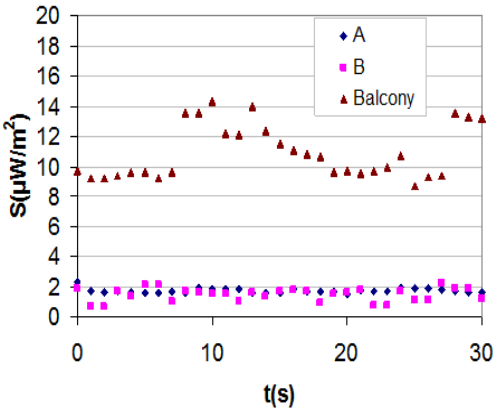

Fig. 4 Time evolution of energy flux S on three different places in the kitchen (see Fig. 3) MWO is off.

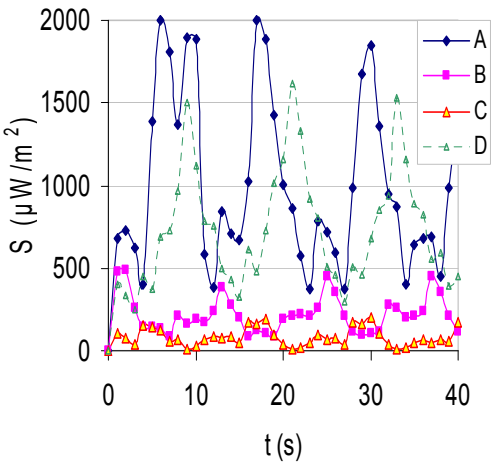

Fig. 5 Time evolution of energy flux S in three different places in the kitchen (see Fig. 3) MWO is on.

A comparison of dependences shown in figures 4 and 5 indicates that the switched on MWO is a source of HF EMF. This field, present in the whole kitchen, is non-stationary and inhomogeneous. The values of *S* depend on the distance to the MWO. The values of *S* are at least 1000 times lower than the limit (2 W/m^2), yet they are 100 to 1000 times higher than the background. There are strong or even extreme anomalies of HF EMF in the kitchen, according to SBM2008 [15]. The experiments showed that the MWO radiates mostly through the front door.

Wireless phone in the study room

We measured HF EMF produced by a wireless phone (WP) in a study room (Fig. 6). Figure 7 shows a floor plan of the study room with measuring points marked in it. We did the experiment and its evaluation according to the worksheet taken from (1).

Fig. 6 Wireless phone on the table in the study room

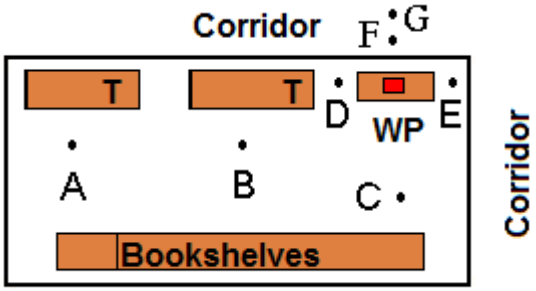

Fig. 7 Floor plan of the study room (6.5 m x 2.5 m); A, B, C, D, E, F, a G measuring points; T – table, WP – wireless phone

Fig. 8 shows the time evolution of energy flux *S* in three different measuring points with WP switched off (docking station is unplugged from the mains) – the background. Fig. 9 shows the same dependences (and one more) with WP plugged into the mains but without making a call.

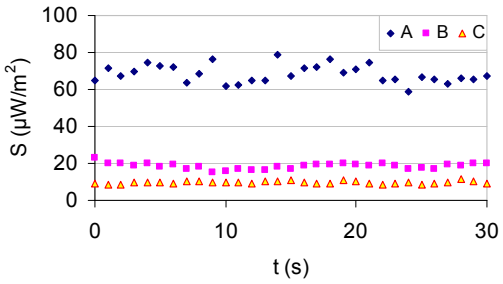

Fig. 8 Time dependence of energy flux S in various places in the study room (see Fig. 7). WP is unplugged – the background

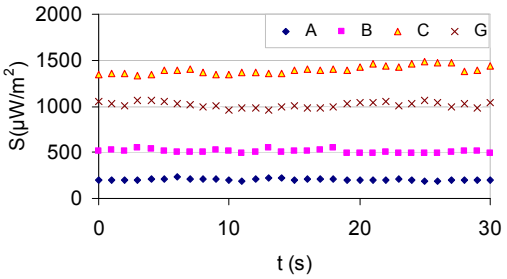

Fig. 9 Time dependence of energy flux S in various places in the study room. WP is plugged in, no phone call is being made

From the comparison of the dependences *S*(*t*) shown in figures 8 and 9, it is celar that a switched on WP is a source of HF EMF. This field is stationary and inhomogeneous in the whole study room. The amplitude of *S* depends on the distance from the WP. The values of *S* are at least 1400 times lower that the Slovak health limit (2 W/m^2) but they are 20 to 150 times higher than the background. There are strong or even extreme anomalies of HF EMF in the study room, according to SBM2008 [15]. The experiments showed that the values of *S* were higher than 2000 μW/m^2 at points D and E. The radiation passed through the wall to the corridor, the point G is distant from the wall.

HF EMF in the outdoors. We measured values of *S* ranging between 10 and 500 μW/m^2 near blocks of flats in a housing estate, between 20 and 200 μW/m^2 around a school building and between 0.0 and 3.0 μW/m^2 in a forest.

Mobile phone (MP). Measurements showed that an MP radiates only when we are making a call with it. Repeated measurements of the *S*(*t*) dependence often yielded different values – the network is probably varying according to its current state (we plan to study this issue further). It is possible to generally conclude that the intensity of radiation is large for the first 10-15 seconds of the call and then it drops somehow.

Survey (answered by 400 students) on using mobile phones and its evaluation can be found at

http://physedu.science.upjs.sk/degro/dotaz/dotaz.html .

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