Electric fields and environmental health education
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Abstract. The paper presents the way in which the teaching activities relating with the subject of Electromagnetic Compatibility were enhanced through applying some original methods of learner involvement. The actions proposed for enhanced involvement include fieldwork and mini-projects. The mini-projects were approached through the PBL-method (Project Based Learning). One of the themes of this mini-project is the effect of electromagnetic field on human health. People are worried about radiation health effects due to the increasing number of antennas. A group of residents in the immediate vicinity of antennas exhibited symptoms which they suggested were due to a strong electric field. This paper presents the results of electric field intensity measurements in the most used frequency range. The results are compared with the limit values allowed by national and international legislation and with values measured in a different location. A final analysis of the measurement data shows that the value of the high frequency electric field is below the permissible limits and the average value of the low frequency electric field is also below the permissible limits. Compared to the witness location, the electric field values are higher due to a greater proximity towards the GSM communications antennas and a higher density of electric power cables.

Key Words: electric field, electromagnetic compatibility, engineering education, environmental health.

Introduction. With the Department of Electrical Engineering and Computer Science of Brașov the first section that introduced Electromagnetic Compatibility (EMC) in 1996 was the section of Electrical Engineering and in 2007 they started to teach it with Applied Electronics and Telecommunications. To start the activity they used information of the experience of departments that had started teaching this subject some time ago (Jost 2003).

In 2007 the Romanian Agency of Quality Assurance in University Education defines in the document ARACIS (2007) EMC as being a subject both for Electrical Engineering and for Electronics and Telecommunication Engineering.

The first initiatives to introduce this subject in Brașov are due to the illustrious teacher, prof. dr. Eng. Elena Helerea. In 1999 a team belonging to the chair of Electronics and Computers made the first steps to introduce the subject with Applied Electronics and published a book that was meant to back the lecture for undergraduates, who were going to study the subject. To introduce undergraduates to research activities and to arouse their interest for subjects of great importance in the society of today, they used a mini project in the development of the subject: the influence of the electromagnetic field on health.

People are worried about the effects of radiation on their health because of the growing number of antennas and the mass media that does not treat the subject correctly. A group of inhabitants in the immediate vicinity of some antennas complained because of possible symptoms in the case of a very strong electrical field.

This problem of the inhabitants was investigated together with the undergraduates by measuring the intensity of the electric field in the zone in the proximity of the antennas, and then in another area, far away from the antennas; finally the results were compared. The undergraduates appreciated the activity and they were interested in the results and actively participated with the measurements and the interpretation of the results.
The subject Electromagnetic Compatibility. The subject was made up such that it could offer the undergraduates practical knowledge of EMC. Before bringing the subject to the undergraduates the authors held short lectures for specialists in electronics in the industrial park of the town. These short lectures were the starting point to establish the scheme of the university lecture.

A special mention is worth to be made about the chapter that treats the interaction between the electromagnetic field and the living matter. The fear of electromagnetic fields, especially of those generated by high voltage lines and those generated by the mobile phone was increased because of the fact that the phenomena were mediatized but there was no conclusion agreed on the grade of peril. The approach of this problem in the EMC lecture leads to an increased interest with the undergraduates. The lecture on this subject is very dynamic, including animated discussions among the undergraduates and also subjects for future preoccupations. Thus, an undergraduate of Applied Electronics made a machine with remote control to measure the electric field in areas of transformers of the distributor of electrical energy where the level of the electric and magnetic field may be dangerous for humans (Figure 1).

![WiFi controlled machine for the measurement of the electric field. Thesis of Bartha Lorant (2012).](image)

For laboratory and thesis activity they chose the PBL ((Project Based Learning) learning method. The activity was carried out with the same programme as the classical laboratory activity. In the first class the undergraduates are given a theme they work on alone or in a team; said theme is developed during the hours in the laboratory and in individual activity. Undergraduates may choose the theme, should they be interested in a certain aspect of EMC. In the last laboratory session the undergraduates present their results in Power Point. The advantages of this approach are:

- increase of responsibility with undergraduates because of individual work;
- training of documentary work through the reading of many references online;
- increase of the interest towards EMC issues;
- regular discussions among undergraduates with the teacher as mediator are dynamic and train the undergraduates for their future activities;
- training of oral defence and answers to questions in front of fellow students in the defence of a theme.

One hour of laboratory is used for the measurement of the electromagnetic field under high-voltage power lines and in the proximity of GSM antennas. This activity was introduced as a result of the increasing interests of the undergraduates for the field – living matter interaction issue. As measurement apparatus they use portable spectral analysers that are connected to notebooks. During the meeting they also interpret the results and check if they fit in the maximum permitted values.

This laboratory can be attended by all undergraduates of the faculty who are interested. Figure 2 shows such an action.
The approach of the subjects to EMC and the protection of the environment was a real success, as the interest of the undergraduates was great. Thus we can mention some outstanding results of the undergraduates during the activity of this subject. A group of undergraduates of Telecommunications made a set of simulations in Simulink of GSM and WiFi transmissions attenuated by materials and perturbed by the movement of the receiver. The articles were published in international specialty conferences. Some of the aspects of the initiative that was proposed in Brașov were published (Ogruțan et al 2010).

**Measurement of the intensity of the electric field.** Radiations are classified in:

1. **Non-ionizing** (electromagnetic) radiations with effects on health that still are discussed but in which the carcinogenic effect could not be proved. We quote the statements of the World Health Organization: „Based on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields. However, some gaps in knowledge about biological effects exist and need further research.” (WHO 2012).

2. **Ionizing radiations** where the carcinogenic effects are proved.

    Antennas are placed on many blocks of flats in Brașov. Their placement above special buildings such as the Children’s Hospital of Brașov (Figure 3 left) and the Maternity Brașov (Figure 3 right) may give rise to some discussions.

Some researches (Kheifets et al 2005) advise precaution concerning the exposure of children to electric fields because of their developing nervous system. This issue brings about animated discussions between the teacher and the undergraduates. World Health Organization states: “The overall weight of evidence shows that exposure to fields at typical environmental levels does not increase the risk of any adverse outcome such as spontaneous abortions, malformations, low birth weight, and congenital diseases.” (WHO 2012).
The measurements of the electromagnetic field were made in two frequency codes where the intensity of the field may be higher in the range of low frequency of 50Hz and in the range of high frequency for mobile communications.

There are many determinations in different places where, as a rule, they follow a single type of radiations. Henderson & Bangay (2006) display the results of the measurements of the electromagnetic field in the range of frequency for mobile telephony CDMA800, GSM900, GSM1800, and 3G in 5 Australian cities at a distance between 50 and 500m in 60 base stations, with measured levels less than about 2% of the permitted limit. Hutter et al (2006) pursued the same range of frequency and analysed the symptoms with a group of 365 individuals. They speak of the difficulty to make a distinction between the effects of the electromagnetic field and the psychological effect created by the proximity of antennas. Mantiply et al (1997) offer data about the medium level of electric and magnetic fields in dwellings and offices in Sweden and Norway where the top values range between 54V/m and 15V/m. The work of Mild et al (2002) takes into account a large range of frequencies between 10 kHz and 30GHz, as well as a large range of field sources with the largest value of 500V/m measured in the immediate vicinity of an antenna.

Electric field measurements have been carried out with two spectral analysers, one in the range 1Hz-1MHz (NF 5010) and one in the range 1MHz-6GHz (HF 6060). The analysers are portable, and they are able to memorize a number of measurements and to transmit measured data through a USB connection to a computer. This enables the later procession in Excel and is very important for the understanding of electric phenomena.

**Measurement of the intensity of the high frequency electric field.** In Figure 4 are presented the result of the measurement in the range 400MHz-2100MHz that covers the range of mobile communications. In Romania mobile communications are made in the bands of 900MHz and 1800MHz (2G) and 2100MHz (3G). A few operators carry out communications in the band of 450MHz. Frequencies where they registered peak values are shown in Figure 5.

![Figure 4. Intensity of the electric field in the range 400-2100MHz.](image)

![Figure 5. Frequencies where they registered peak field values.](image)
Figure 5 shows that the most peak values are in the band of 900MHz followed by the 2100MHz band.

The results of the field measurement in the initial reference point are given in Figure 6. One can notice a weak field intensity so that we added a scaled display on the right side.

The frequencies where the registered peak values of the field are shown in Figure 7. We can notice that in this place there are no peaks of 3G communication but the distributions of the peaks is nevertheless similar with 900MHz and 1800MHz.

Measurement of the low frequency electric field. The graphical presentation of the low frequency electric field of about 50Hz is shown in Figure 8, and the frequencies the peaks were registered are presented in Figure 9.

The uniformity of the electric field can be noticed except the initial area where variations appear due to the fact that operators were present near the measuring probes.

The graphic of the intensity of the reference location is like in Figure 10 and shows the same features as the test location.
Comparative experimental results of the intensity of the electric field. One can find a summary of the measurements of the intensity of the high frequency electric field in Table 1. A summary of the measurements of the intensity of the low frequency electric field can be found in Table 2.
Table 1

<table>
<thead>
<tr>
<th>Date</th>
<th>Average value [mV/m]</th>
<th>Average value with the reference location [mV/m]</th>
<th>Permitted limit [mV/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01</td>
<td>12.84</td>
<td>0.17</td>
<td>40000</td>
</tr>
<tr>
<td>12.01</td>
<td>5.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.01</td>
<td>7.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.01</td>
<td>24.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.01</td>
<td>24.29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Average value [V/m]</th>
<th>Average value with the reference location [V/m]</th>
<th>Permitted limit [V/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.63</td>
<td>2.28</td>
<td>2000</td>
</tr>
</tbody>
</table>

The permitted limits for electromagnetic fields have been established in Europe in the Directive 2004/40/EC (2004) and in Romania through the Order 1193/2006. The limits established for the population in the above mentioned Order are given depending on the frequency thus in the range 0.025kHz-0.8kHz the limit is 250/f, whereas in the range 400-2000MHz the limit is $1.375f^{1/2}$. Aspects taken during the measurements are shown in Figure 11.

Figure 11. The SPECTRAN probe, mounted on a tripod stand connected to a notebook (left) and measurements with the students of a field of high frequency in the proximity of the communication antennas on the Tâmpa (right).

Results of a pilot study concerning the attitude and the results of the students.

We carried out a pilot study the scope of which was to identify the attitude of the undergraduates in their 4th year of study, specialty Electrical Engineering and 3rd year specialty Applied Electronics towards the EMC lecture. The main scope was to find out the professional satisfaction of the undergraduates concerning this lecture and secondarily to establish some correlations between the attitude towards EMC and the academic performance of this subject. The academic performance was measured by means of the grades the students obtained.
In order to determine the changes in time of the students’ attitude questionnaires were filled in twice: the first time at the beginning of a semester, after 7 lectures and the second time after they sat for the examination at the end of the semester. We used the design pre-test and post-test. The lecture took place once a week and lasted two hours for 14 weeks. Participants with the test were 50 students, 17 students from Applied Electronics and 33 students from Electrical Engineering. The study was carried out by the tenured professors of EMC courses with Applied Electronics and Electrical Engineering with the support of the Department of Psychology and Educational Sciences.

In the following they analysed some significant results obtained selecting some answers of the undergraduates of Applied Electronics. They selected answers that offer information about students’ perceptions concerning the difficulty of the subject, its importance, the interest the subject foments, the degree the study of this subject is stimulating and how much the course was adequate at the end of the period. The results of the undergraduates to these questions are presented as a graphic in Figure 12 in the form of the number of students on the ordinate and the 5 variants of answers on the abscissa. We analysed the answers of the students given in the questionnaire after the examination.

![Figure 12. Difficulty (S1), importance (S2), interest (S3), stimulation degree (S4), satisfaction (S5).](image)

The subject is considered to be of medium difficulty (S1). Thus, 64.7% of the students evaluated the difficulty between very difficult and very easy. As for the importance of the subject (S2), 58.8% think that it is important and very important. 70.5% of the students say that they were interested and very interested of the subject (S3), and 64.7% consider that they had been stimulated to study and the stimulation was good and very good. An important number (70.5%) of students state that they are satisfied and very satisfied with this subject.

Grades were sorted in 5 categories so that they could be compared with the degree of satisfaction. Category 1 means grades 1 and 2, category 2 grades of 3 and 4 (meaning that the first two categories did not pass the exam), category 3 grades of 5 and 6, and so on. An important percentage of 50% of the undergraduates failed the examination or did not sit for it. Only 7.14% of the undergraduates got grades 9 and 10. The comparative display shows that 17.65% of the undergraduates were very satisfied with the lecture and only 11.77% were dissatisfied with it.

In Figure 13 there are shown - as a percentage - the grades given by the undergraduates (S1) and the degree of satisfaction (S2), the same as in the previous figure.
Figure 13. Display of the grades (S1) and the degree of satisfaction in percent.

**Conclusions.** A final analysis of the measured results show that the value of the high frequency electric field is under the permitted limits (0.007%) and that the average value of the low frequency electric field is also below the permitted limits (0.072%). Compared to the reference field the values of the electric field are higher due to the GSM communication antennas and the higher density of cables that transport electric energy in the public net.

From the educational point of view the measurement excursions of the electric field and the active participation of the undergraduates in activities concerning the interaction man - electric field was a success. Following to an anonymous analysis of the feedback of the undergraduates made by the University independently from the study of the author, the satisfaction degree of the students of Applied Electronics with EMC in the academic year 2012-2013 was of 4.36 and the activity of the teacher of 4.50. These outcomes confirm the results of the pilot study and the fact the way a subject was approached by the author was a correct one.

**References**

ARACIS (The Romanian Agency for Quality Assurance in Higher Education), 2007 Specific standards for study programs in the field of engineering sciences. Available at: http://www.uvvg.ro/site/docs/legislatie/stiinte%20ingineresti.pdf [in Romanian].


