EMC Pre-Compliance Tests and Educational Aspects

Lia Elena Aciu [1], Petre Lucian Ogrutan [2], Marius Daniel Calin [1], Mariuta Popanton [3]

[1]*Transilvania University of Brasov,Electrical Engineering and Applied Physic Department, Brasov, Romania*
[2]*Transilvania University of Brasov, Electrics and Computer Department, Brasov, Romania*
[3]*I.C.P.E. Bistrita, Romania*

Abstract **– The aim of this paper is to present the obtained results at the pre-compliance EMC measurements according to the European standards for a microcontroller based device. The EMC measurements fulfils the students' education in electronics and electrical engineering, who after building microcontroller devices can see the impact on the environment and the immunity to electromagnetic disturbances.**

Keywords **– Electromagnetic compatibility, education, embedded system, pre-compliance measurements, student's skills.**

1. Introduction

As technology develops, more and more electronic products are applied to the daily lives. The advanced electronic products are more complicated than ever and demand more functions in one single device.

The electromagnetic compatibility (EMC) pre-compliance measurements have gained major importance in modern society due to the increase in the number of electrical and electronic equipment and in the probability of mutual disturbance.

DOI: 10.18421/TEM72-25
https://dx.doi.org/10.18421/TEM72-25

Corresponding author: Lia Elena Aciu,
Transilvania University of Brasov,Electrical Engineering and Applied Physic Department, Brasov, Romania
Email: lia_aciu@unitbv.ro

Received: 30 March 2018.
Accepted: 18 May 2018.
Published: 25 May 2018.

© 2018 Lia Elena Aciu et al; published by UIKTEN. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 License.

The article is published with Open Access at www.temjournal.com

Reference [1] contains a description of EMC problems dedicated to the designers; a chapter has been dedicated to the problem of pre-compliance according to the international standards. In the central area of Romania many companies in the field of automotive have formed research and development teams besides the production one. In the field of automotive EMC compliance and pre-compliance are important, a few issues being presented in [2,3].

The research team within the Faculty of Electrical Engineering and Computer Science from Transilvania University of Brasov is a partner with I.C.P.E. Bistrita in a research contract whose objective is to conceive, design and create a device with microcontroller for consumer protection to overvoltage, over-current, current leakage to ground and electric arc with the integration of the device by IoT (Internet of Things) in the smart network of Brasov city. In reference [4] there is presented a device with similar functions. Public network integration of renewable energy sources makes necessary the use of such devices and tracking their behavior through IoT [5,6].

The research contract requires for the protective device to be brought into a close stage of completion to be produced in series. For this reason the device has been tested from the point of view of EMC. Some Master's students also participated to the research being extremely excited about achieving EMC pre-compliance measurements. That was a clue for the future implying of students from the bachelor degree into EMC testing.

Over the past several decades, there has been a demand in formal education to include the 21st century skills, also named 'the skills for the future'. Therefore, 'critical thinking, real problem solving, collaboration and communication skills are the main skills that characterize our life today' [7].

The professional success lies in 'being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to marshal and expand the power of technology to create new knowledge, and in expanding human capacity and productivity' [8].

Teachers from the Faculty of Electrical engineering and Computer science for the Transilvania University of Brasov, Romania, have included new competencies for the ways of thinking and working by applying PBL (Project-Based Learning). That helps students to develop applications that teach them the curriculum concepts and allow them to apply their acquired knowledge. PBL also promotes serious creativity and out-of-the-box thinking [9].

'Project-Based Learning (PBL) is an innovative approach to learning that teaches a multitude of strategies critical for success in the twenty-first century. Students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge. From gleaning new, viable technology skills, to becoming proficient communicators and advanced problem solvers, students benefit from this approach to instruction' [7].

'This skill set is critical for all people who hope to participate productively in the workforce. That's why students need 21st century skills to participate meaningfully in our digital world rather than being steamrolled by it' [10]. Even more importantly, employers have increasing demands of them.

A real connection to the world is expressed by authentic projects. They are the measures of the success in the future work. Through PBL, students develop applications that can solve real-world problems, have real-world tasks and their designed devices are able to function properly in real conditions [11].

The importance of complying with electromagnetic compatibility standards on new devices created by engineers is incontestable, arguments are brought, for example, in [12], [13]. In a 2014 paper [14] the authors describe a set of lab works devoted to the study of perturbations driven and generated by a switching source. An Electromagnetic Compatibility (EMC) Center at Grand Valley State University was designed to provide EMC education and EMC pre-compliance testing [15]. The same goal - to familiarize students with performing EMC measurements according to standards using microcontroller modules is presented in [16].

The most applications designed and implemented by students meet the rule configuration from Figure 1. – where the elements represent:

S L/S- source (linear or with a switching power supply)
M- microcontroller
S- sensors
A- actuators
W- wireless module

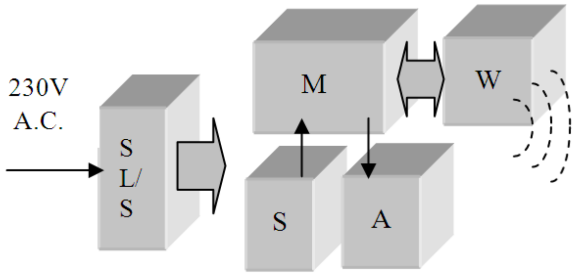


Figure 1. Block diagram for a microcontroller based device

After designing the devices, the students test their functionality through simulations. Thus, for a real functioning they also test the electronic systems for electromagnetic compatibility, emission and immunity.

2. Radiated disturbances measurement

The standard used for the measurement of disturbance radiated by the electronic devices with microcontroller is EN 61000-6-3, Electromagnetic compatibility (EMC)-Part 6-3: Generic standards-Emission standard for residential, commercial and light-industrial environments. EN 61000-6-3 is a standard for average emission for residential, commercial and industrial emissions, easily sets limits to the electromagnetic emissions in the frequency range of 30 MHz-230MHz (30dBμV/m) and 230MHz-1000MHz (37dBμV/m) measured at 10 m from the Equipment Under Test (EUT). Measurements were made in the chamber shielded with spectral Analyzer Rohde Schwarz ® FSH4 & R&S, (9kHz-3.6 GHz) and a Spectran HF-6060 V4 (10 MHz-6 GHz). In Figure 2 is shown the picture of the shielded room in which the measurements took place.

Figure 2. Shielded room

Figure 3. is a picture of the measurement set up in the shielded room. The EUT was the microcontroller based device developed in the research project and it can be seen under the wooden tripod on which the antenna is mounted.

TEM Journal. Volume 7, Issue 2, Pages 421-427, ISSN 2217-8309, DOI: 10.18421/TEM72-25 May 2018.

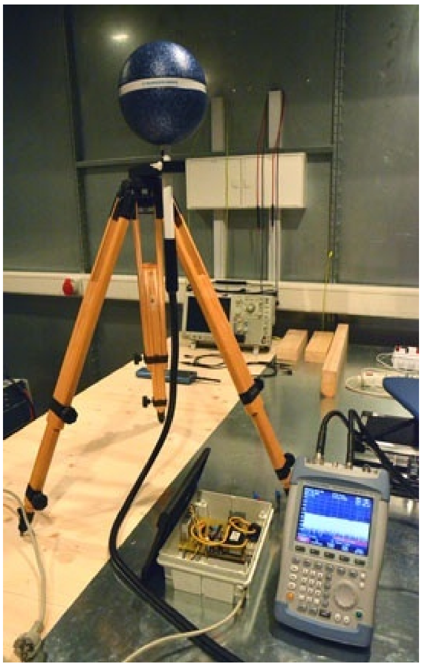


Figure 3. Radiatedelectric field measurement set up

The measurement results are given in Figure 4. and Figure 5. The electric field levels are in the frequency range of 100MHz-860MHz. Figure 4. represents the electric field strenght values in μV/m and in Figure 5 the levels of electric field are expressed in dBμV/m.

In the beginning of the measurements, was determined the level of the noise from the measurement chamber. The level of perturbation introduced by the device is obtained as differences between the results obtain with the device in function and the noise level. This explains the negative field values that appear in the two figures.

It can be seen (Figure 5.) that the values of the field radiated by the device are below the limits set by the standard EN 61000-6-3in the frequency band represented in the figure, and are below the maximum measured across the band (30MHz-1GHz). The measured values with the spectrum analyzers have been stored as a .csv file (Coma Separated Values), imported into Excel, processed and then plotted.

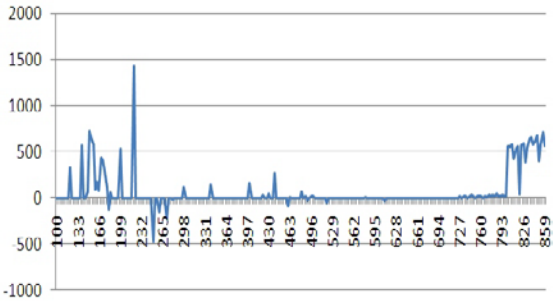


Figure 4. Measured frequency spectrum with values of μV/m in the range of 100MHz-860MHz

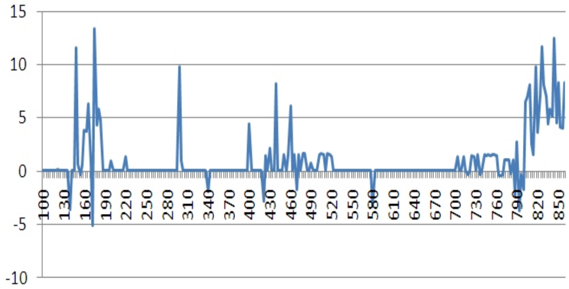


Figure 5.Measured frequency spectrum with values of dBμV/m in the range of 100MHz-860MHz

3. Conducted disturbances measurements and immunity testing for conducted disturbances

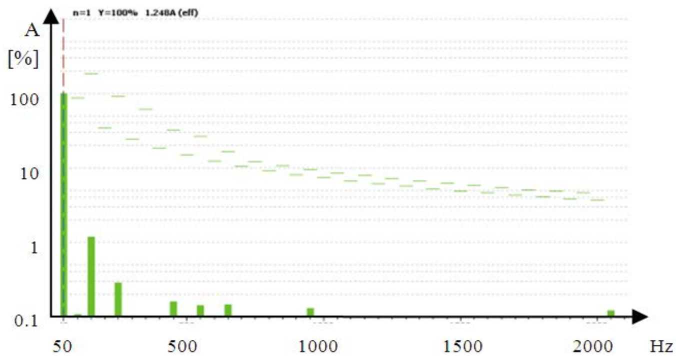
The real conditions are given also by the electromagnetic environment given by the surrounded systems. The testing for the electromagnetic compatibility was done with the support of the students in electrical engineering that have specialized equipment for this test at the University Research Institute, with the Netwave 30 EM Test equipment.

Groups of students from both programme studies worked together to fulfill the plans in order to develop a device that could function in real conditions.

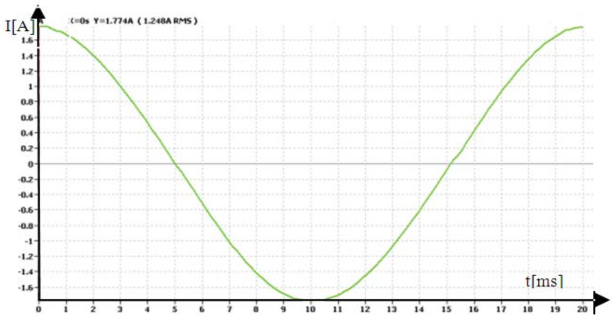
The pre-compliance test for electromagnetic compatibility is according to the following standards:

1. EN 61000-3-2 Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase). The limits for the emission are given by the test equipment.

The standard aims to verify the harmonic currents injected into the public main supply and to fit them within certain limits. The limits of the currents' harmonic components that can be produced by the equipment under test /under specified conditions are defined. Figure 6 shows a graph of the current harmonics (A) in percentage of the frequency basis value for a designed device with a linear source as well as the values admitted by the standard.



a.



b.

Figure 6. Generated harmonic (a) in the network by a device having a linear power supply and the current waveform(b)

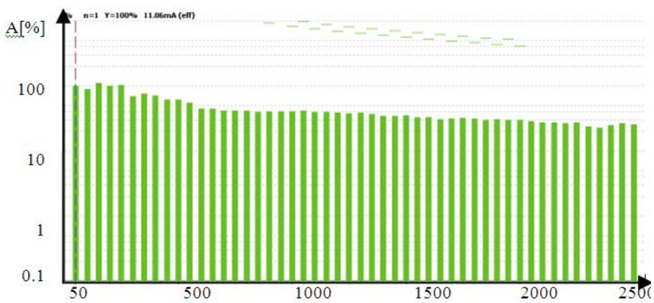
Figure 7 presents the graph of the current harmonics for a designed device with a switching power supply.

Analyzing the results, students can compare the harmonics obtained after the test and decide what the best solution in supplying their device is.

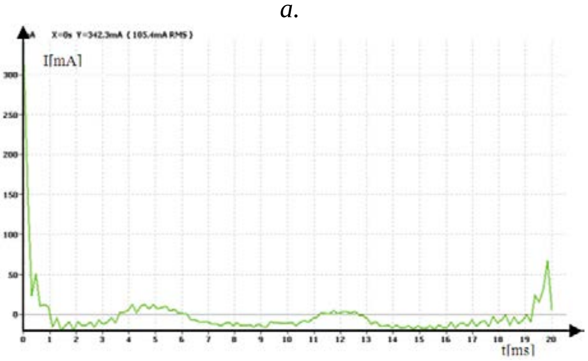
Figure 6 and Figure 7 show that the switching power supply, due to the controlled semiconductor elements introduce significant harmonics by conduction, also a conclusion from the background knowledge but now also a conclusion from the EMC tests.

Figure 8 shows the generated harmonics if inserting an EMI (electromagnetic interference) filter between the switching power supply and the network supply.

In this manner the students from Applied Electronics can test their creative solutions in solving real task relative to the conducted disturbances generated by their developed device.

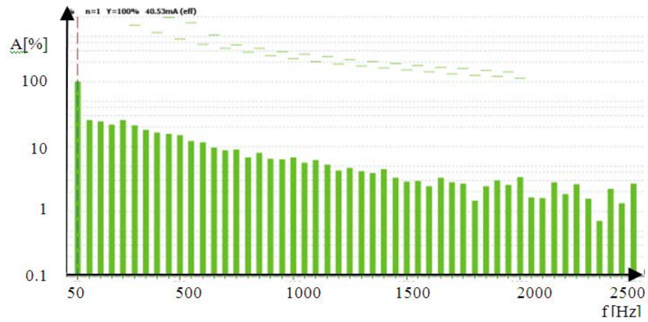


a.

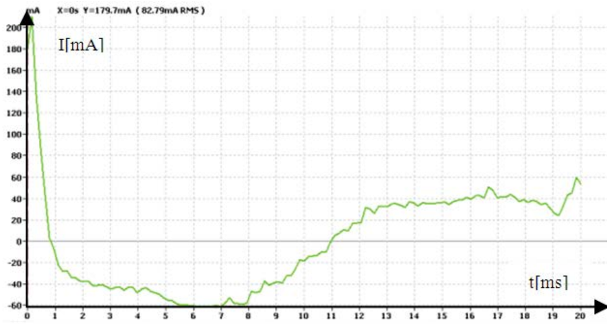


b.

Figure 7. Generated harmonic (a)in the network by a device having a switching power supply and the current waveform (b).



a.



b.

Figure 8. Generated harmonic (a)in the network by a device having a switching power supply with an EMI filter and the current waveform (b)

2. EN 61000-4-11 Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests.

This standard defines the immunity test methods and test voltage range for voltage drops, short-term interruptions and voltage variations for electrical and electronic equipment connected to low-voltage power supply networks. The tests are conducted separately for each category (voltage drops, short-term interruptions and voltage gaps), but also for combined testing of all these power failures.

Through this type of test, students can see the test voltage waveform and if the test is passed or not for the designed device.

3. EN 61000-4-13 - Electromagnetic compatibility (EMC) - Part 4-13: Defines the methods necessary to measurement and interpretation of results for power quality parameters in AC power supply systems with a declared fundamental frequency of 50 Hz or 60 Hz. Measurement methods are described for each relevant parameter in terms that give reliable and repeatable results, regardless of the method's implementation. Measurement of parameters covered by this standard is limited to conducted phenomena in power systems.

The power quality parameters considered in this standard are power frequency magnitude of the supply voltage, flicker, supply voltage dips and swells, voltage interruptions, transient voltages, supply voltage unbalance, voltage harmonics and inter-harmonics, mains signaling on the supply voltage, rapid voltage changes, and current measurements.

For this type of test, students can only see if the test is passed or not for the designed device.

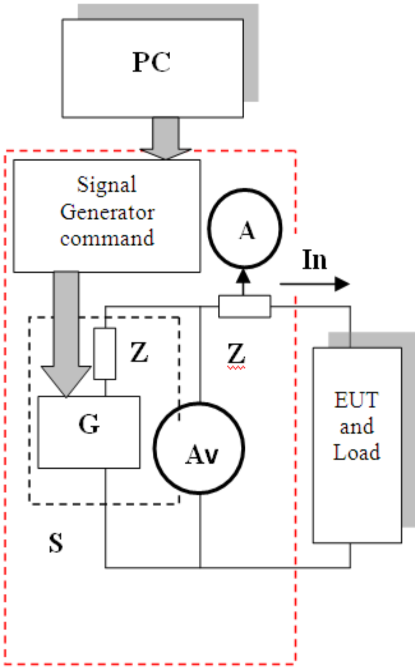


Figure 9. Test block diagram

The blocks in the diagram are: G - signal generator (a function generator that ensures the desired test voltage shape and composition), S - source, Zs - source impedance, Zm - impedance for current measurement, A – spectrum current analyzer, Av spectrum voltage analyzer, In – EUT and load current and a computer connected externally to control the stand operation.

The Netwave 30 EM Test equipment is shown in Figure 10.

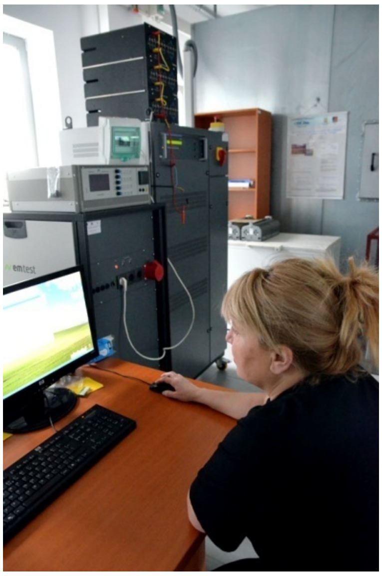


Figure 10. The EMC test equipment

4. EN 61000-4-14 - Electromagnetic compatibility (EMC) - Part 4-14: Testing and measurement techniques - Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase.

For this type of test, students can only see if the test is passed or not for the designed device.

The students can study the immunity to the supply voltage variation of their device. The limits for each class of equipment are given in the standard.

5. EN 61000-4-28 - Electromagnetic compatibility (EMC) - Part 4-28: Testing and measurement techniques - Variation of power frequency, immunity test for the equipment with input current not exceeding 16 A per phase.

For this type of test, students can only see if the test is passed or not for the designed device. They can verify the behavior of their device when there is a frequency variation of the supply voltage.

4. Teaching aspects

One of the academic courses for the students from the Applied Electronics programme from the Faculty of Electrical Engineering and Computer Science addressed to those in their 4th year of study *is Embedded Systems*. By applying PBL the students develop microcontroller based devices.

Another important course is *Electromagnetic Compatibility* that includes, besides the general principles a chapter dedicated to the EMC measurement. Very few students understand the link between the Embedded Systems and the EMC.

The initiative to complete diploma projects containing microcontroller devices with pre-compliance EMC measurements made them understand the link between these two disciplines.

Students present the results of their research within the frame of the Students Research Conference. The participation of students since 2015 is given in Table 1. Companies participate at the Students Research Conference through representatives and often offer prizes to the best scientific papers.

Table 1. Report from the Students Research Conference

Year	**2015**	**2016**	**2017**	**2018***
Scientific Papers	28	25	14	26
Microcontrollers Applications	24 85.7%	19 76%	9 64.28%	21 80.76%
Software applications	4 14.28%	6 24%	5 35.71%	3 11.53%
Automotive applications	13 46.42%	14 56%	7 50%	15 57.69%
Award-winning papers	3 10.71%	8 32%	3 21.42%	-

* registration in progress

The interest of the students from the Applied Electronics programme to develop applications with microcontrollers is seen in results (Table 1.) From the total scientific papers, many students studied aspects related to microcontrollers and software topic (other than embedded software), and also to automotive (hardware and software). Unfortunately, there was no EMC topic among the research papers. Students didn't appreciate the importance of the EMC tests.

The students' focus on the microcontrollers based applications can be explained by the demand of the employers in using microcontrollers. Some companies give real-task and support students to solve real-problems by implementing their concept and designed device. One of the success stories is the collaboration with an automotive electronics company that has organized training courses for university students pointing out the importance of EMC tests [16].

Companies interested in hiring graduates are involved in modernizing the educational process and watched with satisfaction the initiative to train the students in the EMC tests. In [17,18] the design takes into consideration future compliance of EMC standards. Zhao and See [19] stated that many graduates from electronics don't have the necessary knowledge of EMC compliance and the industrial employers experience this lack.

Figure 11.Microcontroller based device for automotive implemented by a rewarded student at the 2016 Students Research Conference

5. Conclusions

The concept, design and realization of a microcontroller based device that can be picked up and produced by a company requiresEMC testing and to determine the behavior of the device within the limits established by the European standards. The device was designed to be supplied by a linear source or by a switching power supply, the second option being smaller, having a better efficiency and lower price.The EMC pre-compliance tests performed in the shielded room showed that the harmonics generated by the switching power supply are much higher than those generated by linear source, so there is a need for an EMI filter. All types of the tested devices (the device with a linear source, the device with *a switching power supply* and the device with a switching power supply and EMI filter) generate harmonics that are in the range specified in the 61000-3-2

The research team also included master students who were very interested in EMC testing. Their positive reaction led to initiate actions for the undergradute students from the final year to also make pre-compliance EMC test for their developed devices for the diploma project.

This is only a begining but the initial results are promising. Students are pleased to see the sequence of test operations and to improve their device. Moreover, specific automotive companies from the central region of Romania have already appreciated the initiative because of their interest in the EMC.

Acknowledgements

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, project number PN-III-P2-2.1-PED-2016-0570, within PNCDI III. We hereby acknowledge the structural founds project PRO-DD (POS-CCE, 0.2.2.1., ID 123, SMIS 2637, ctr. No. 11/2009) for providing the infrastructure used in this work.

References

[1]. Williams, T. (2016). *EMC for product designers*. Newnes.

[2]. Braglia, G., Barmada, S., & Duffy, A. (2016). Simulations and experiments for EMC compliance in automotive environment. *Proceedings of the Wireless Information Technology and Systems and Applied Computational Electromagnetics, 2016 IEEE/ACES International Conference*, 1-6.

[3]. Silaghi, A. M., Tolan, E., De Sabata, A., &Buta, A. (2016, October). Measurement of radiated emissions from an automotive cluster. *Proceedings of the 12th IEEE International Symposium on Electronics and Telecommunications*, 21-24.

[4]. Fernández-Caramés, T. M. (2015). An intelligent power outlet system for the smart home of the internet of things. *International Journal of Distributed Sensor Networks*, *11*(11), 1-11.

[5]. Gonen, T. (2016). *Electric power distribution engineering*. CRC Press.

[6]. Manditereza, P. T., &Bansal, R. (2016). Renewable distributed generation: The hidden challenges–A review from the protection perspective. *Renewable and Sustainable Energy Reviews*, *58*, 1457-1465.

[7]. Microsoft Learning Partners & Pearson Foundation(2013).*21st Century Skills and the Workplace, suggest new relationships between skills development, job success and school*, Galup.

[8]. Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In *Assessment and teaching of 21st century skills* (pp. 17-66). Springer, Dordrecht.

[9]. Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39-43.

[10]. McManus, C. (2017). *Teaching 21st Century Skills For 21st Century Success Requires An Ecosystem Approach*. Forbes (2017/07/18).

[11]. Heinman, D. (2017). Standard Education, *IEEE Communications Standard Magazine, 1*(3), 8-12.

[12]. Meyerhoff, J. D., & Rotter, S. J. (2017, August). EMC education for the citizen-engineer. In *Electromagnetic Compatibility & Signal/Power Integrity (EMCSI), 2017 IEEE International Symposium on* (pp. 1-4). IEEE.

[13]. Tarateeraseth, V. (2014). Educational laboratory experiments on EMC in power electronics. *IEEE Electromagnetic Compatibility Magazine*, *3*(3), 55-60.

[14]. Adamczyk, B., Teune, J., &Mee, S. (2014). *University-based EMC Precompliance Center and its Impact on the EMC Education*. Faculty Scholarly Dissemination Grants. 994.

[15]. Väänänen, O., Hannu, J., & Jantunen, H. (2016). Alternative EMC measurements for teaching purposes. *Engineering Education on Top of the World: Industry University Cooperation*.

[16]. Stanca, A. C., Ogrutan, P., Kertesz, C. Z. (2015). Elective Courses with Support from Automotive Electronics Industry, *Bulletin of the Transilvania University of Brasov*, *8* (57), 91-98.

[17]. Jerse, T. A., & Steffka, M. A. (2007, July). Establishing EMC education: The ten-year contribution of the University Grant Program. In *Electromagnetic Compatibility, 2007. EMC 2007. IEEE International Symposium on* (pp. 1-4). IEEE.

[18]. Thorsteinsson, G., & Page, T. (2013). Electronic Circuit Design for Electromagnetic Compliance through Problem-Based Learning. *i-Manager's Journal on Circuits & Systems*, *2*(1), 1-6.

[19]. Zhao, Y., & See, K. Y. (2003, June). A practical approach to education of electromagnetic compatibility at the undergraduate level. In *Antennas and Propagation Society International Symposium, 2003. IEEE* (Vol. 3, pp. 454-457). IEEE.