Electromagnetic Compatibility of Arduino Development Platform in Near and Far-Field

Stanislav Kovar, Václav Mach, Jan Valouch and Milan Adámek

Tomas Bata University in Zlín, Faculty of Applied Informatics
Nad Stráněmi 4511, 760 05 Zlín, Czech Republic.

Abstract

The electromagnetic compatibility is a very popular scientific discipline that widely affects the electronic devices. The electromagnetic radiation can be associated with many distortion and errors in the microcontrollers. The main purpose of this article is to examine the EMC of a cheap development kit, namely Arduino. In addition, the article provides the comparison of the results in terms of electromagnetic susceptibility and interference.

Keywords: Electromagnetic interference, electromagnetic susceptibility, arduino, gigahertz transverse electromagnetic cell, semi-anechoic chamber, near-field, far-field.

INTRODUCTION

Electromagnetic compatibility (EMC) constitutes a serious problem for the design and operation of electronic and electrical devices, especially in today's world where the number of electronic items in homes and workplaces has significantly increased. [1]

The EMC can be divided into two parts. First part is Electromagnetic Interference (EMI), which is generated by every electronic device. This radiation may have an impact on the other devices. The second part of this article is about the Electromagnetic Susceptibility (EMS) which is passive protection against the radiation. [2] [3]

Many industrial devices follow the standard which every product has to accomplish. However, simple devices such as Arduino miss this attention. This article deals with the EMS and EMI of developmental devices namely Arduino. The paper refers to the findings mentioned in [4], which are dedicated to the Closed Circuit Television (CCTV). Like the cameras, also the developmental boards are very sensitive to the radiation.

All measurements are done by certified facilities and it is also followed by the international standards for the EMC. The fundamental standards are following:

- CSN EN 61000-6-3 Electromagnetic compatibility - Part 6-3: Generic standards - Emission standard for residential, commercial and light - industrial environments.

- CSN EN 55032 Electromagnetic Compatibility of Multimedia Equipment.

- CSN EN 55024 Information technology equipment - Immunity characteristics - Limits and methods of measurement.

- CSN EN 61000-6-1 Generic standards - Immunity for residential, commercial and light-industrial environments.

EQUIPMENT UNDER TEST

The Arduino platform is gaining interest in many of branches of electrical engineering because it is a small, cheap, powerful and suitable solution for many applications. This article is focused on the Arduino Mega2560, which is one of the most used models from Arduino family. The Arduino Mega2560 gets its name from the used ATmega2560 the microcontroller. This microcontroller operates at 16 MHz and it is mounted into Quad Flat No-leads (QNF) package and it is the main component on the whole board. There is also another ATmega16 the microcontroller which is responsible for the serial communication via the Universal Serial Bus (USB). Both microcontrollers emit into space electromagnetic radiation. The main level of radiation is expected to be at 16 MHz because it is the main frequency of the microcontrollers. This frequency is divided by the frequency divider by /2/4/8/16/32/64/128. The system needs to use also frequency for the USB. The 48 MHz which is used for the High-speed USB (48 MHz × 10 = 480Mbit/s) is done by the PLL register. The most important frequencies are following:

- 48 MHz (USB clock)

- 16 MHz (external clock)8 MHz (internal RC clock)

- 48 MHz (USB clock)

- 16 MHz (external clock)

- 8 MHz (internal RC clock)

All these frequencies can be also disturbed by the external source of electromagnetic interference. When the distortion occurs in threshold level, the system can be very distorted which can lead to errors or to the destruction of the system.

MEASURING EQUIPMENT

This section describes the workplaces and equipment, which were used for testing and measuring of electromagnetic interference and immunity.

Semi-anechoic Chamber

A semi-anechoic chamber presents another solution for the EMS test. A semi-anechoic chamber is a special room designed to completely absorb reflections of electromagnetic waves. The chamber is also insulated from exterior sources of noise. The combination of both aspects means that the semi-anechoic chamber simulates a quiet open-space of infinite dimension, which is useful when exterior influences would otherwise give false results. [10] The interior of the chamber is also equipped with absorbent materials, i.e. materials specially developed and formed to absorb incident electromagnetic radiation. Unlike GTEM chamber, the semi-anechoic chamber can be equipped with different kinds of antennas depending on the required task. [5]
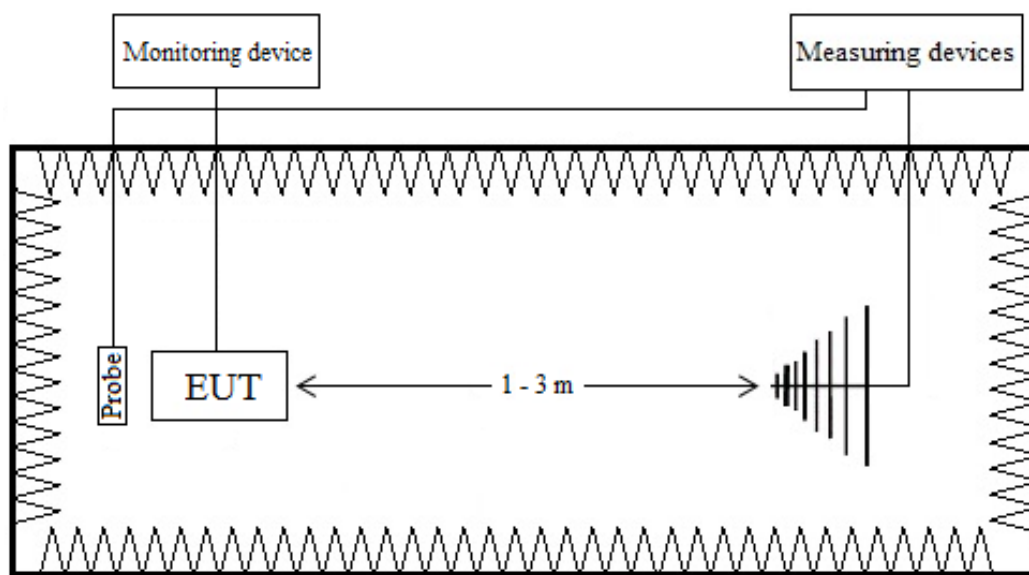

Figure 1: Disposition of Equipment under Test in Semi-anechoic Chamber. [5]

In following lines, there are listed the measuring devices used for purpose of experiment:

- HL046 (Rohde&Schwarz) - a log-periodic antenna,

- CBL 6112 - BiLog antenna

- HI-6105 (ETS-Lindgren) - an electric field probe,

- SMB 100A (Rohde&Schwarz) - a signal generator (9kHz - 6GHz),

- ESU (Rohde&Schwarz) - EMI test receiver (20Hz - 8GHz),

- 150W1000 (Amplifier Research) - an amplifier (80 - 1000MHz, 150W),

- 80S1G4 (Amplifier Research) - an amplifier (0,7 - 4,2GHz, 80W),

- 150A250 (Amplifier Research) - an amplifier (100kHz - 250MHz),

- OSP 130 (Rohde&Schwarz) - a switch and control unit,

- OSP 150 (Rohde&Schwarz) - a switch and control unit,

- EMC32 (Rohde&Schwarz) - EMC measurement software.

Gigahertz Transverse Electromagnetic Cell

The TEM test chamber offers a practically perfect solution for EMS, enabling generation of a homogeneous transverse field without unwanted emissions into the environment. TEM chambers are specially designed electromagnetically shielded spaces developed for EMC purposes, both for testing electromagnetic immunity and for measurement of disruptive emissions. [5] The Figure 2 depicts the configuration of measuring facilities.
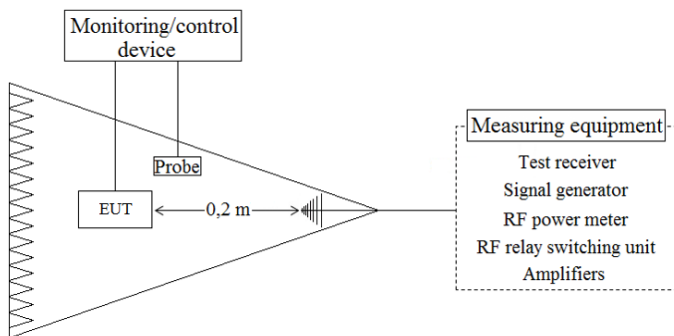
Figure 2: Disposition of Equipment under Test in GTEM Cell. [5]

The process of determining the level of electromagnetic compatibility required the use of these measuring devices:

- SMB 100A (Rohde&Schwarz) - a signal generator (100kHz - 40GHz),

- PMS 1084 (Frankonia) - a power meter,

- RSU (Frankonia) - Relay Switching Unit,

- FLG-10F (Frankonia) - RF-Power Amplifier (2GHz - 6GHz),

- FLG-5A (Frankonia) - RF-Power Amplifier (0.8GHz - 2GHz),

- FLH-20B (Frankonia) - RF-Power Amplifier (20MHz - 1GHz),

- Emc-gtem-250 (Frankonia),

- ESPI (Rohde&Schwarz) - a test receiver (9kHz - 7GHz),

- Narda Software (Narda Safety Test Solutions) - software for the probe.

PROCESS OF MEASUREMENT

The process of measurement is the same for both GTEM cell and semi-anechoic chamber. In the case of electromagnetic susceptibility, the level of radiation is 10V/m as the EN 61000-4 standard specifies. Conversely, the interfering level emitted by Arduino was determined experimentally. Because the goal of this paper was acquired information about the level of electromagnetic interference generated by the individual components.

The entire process of measurement can be summarized in the next few steps. [5]

a) Preparing the workplace

The first phase consists of preparing a workplace, i.e. selection of suitable measuring equipment such as an antenna,

probes, a measurement environment (semi-anechoic chamber or GTEM cell) and the deployment of the equipment in the chamber.

b) Configuration of EUT

The second step comprises of the configuration of the test device, such as identification of the parts to be tested, determining the location of the EUT and the preparation of all parts of the EUT.

c) Wiring of EUT

The next step determines the wiring of EUT which involves connecting all parts of the device, a revision of wiring and all system functions.

d) Changes in measurement

This phase includes all the changes of configuration or equipment during measurement, such as a change of distance between the antenna and EUT, a change of position of the equipment.

e) Evaluation of results

The last phase includes the analysis and evaluation of results. [5]

RESULTS OF MEASUREMENT

This section is devoted to results of experiments regarding electromagnetic immunity and interference of Arduino.

Gigahertz Transverse Electromagnetic Cell

The first two figures illustrate the waveforms of electromagnetic radiation generated by Arduino Mega 2560. Figure 3 describes the waveform just up to 30MHz, conversely, Figure 4 depicts the waveform of interference up to 1GHz as it is specified by the EN55032 standard. Maximum and minimum values of disturbance are as follows:

a) Dependence of Radiation Level on Frequency up to 30MHz.

- maximum level: 50.49dBμV/m (24.009MHz),

- minimum level: 16.213dBμV/m (13.056MHz).

b) Dependence of Radiation Level on Frequency up to 1GHz.

- maximum level: 45.010dBμV/m (91.711MHz),
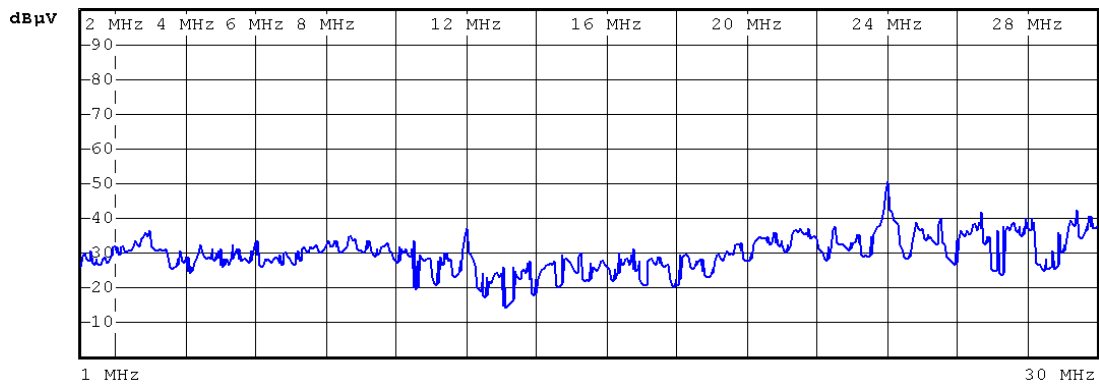
- minimum level: 17.541dBμV/m (986.739MHz).

Figure 3. Dependence of Radiation Level on Frequency up to 30MHz.
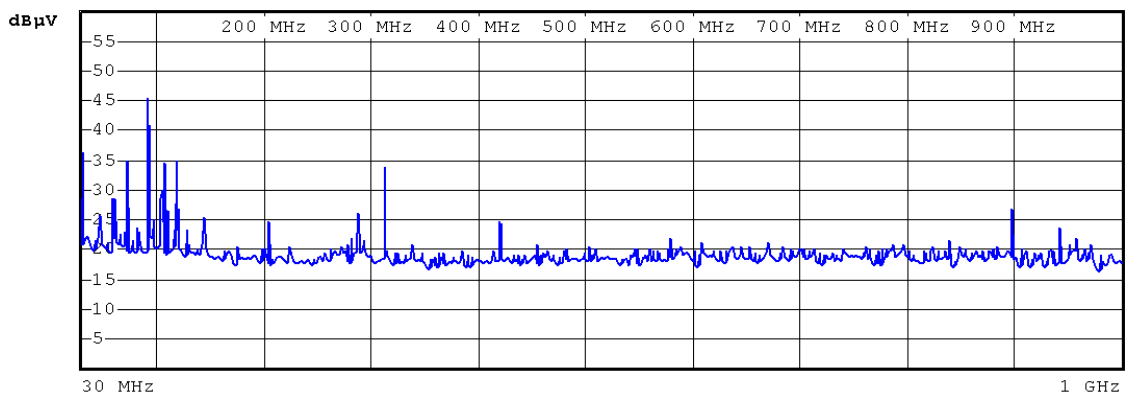

Figure 4: Dependence of Radiation Level on Frequency up to 1GHz.

The result revealed that USB port operated at the 24MHz frequency generated the most radiation in comparison with other expected components of the device described in the introduction. Another peak at the frequency of 91.711MHz was caused by an incoming radio signal from a nearby radio station. The emission of the device must not exceed the values of 50dBμV/m according to CSN EN 55032 standard.

More interesting part of this section are results of electromagnetic susceptibility. Figure 5 shows the waveforms that the device was exposed to during the experiment, specifically, it is maximum even so minimum field strength and recommended field strength by standards.

The equipment under test (EuT) was exposed to the field strength about 10V/m and it worked reliably during the test without any failures or disruptions. Verification of the functions of Arduino after the tests did not reveal any problems with the device.
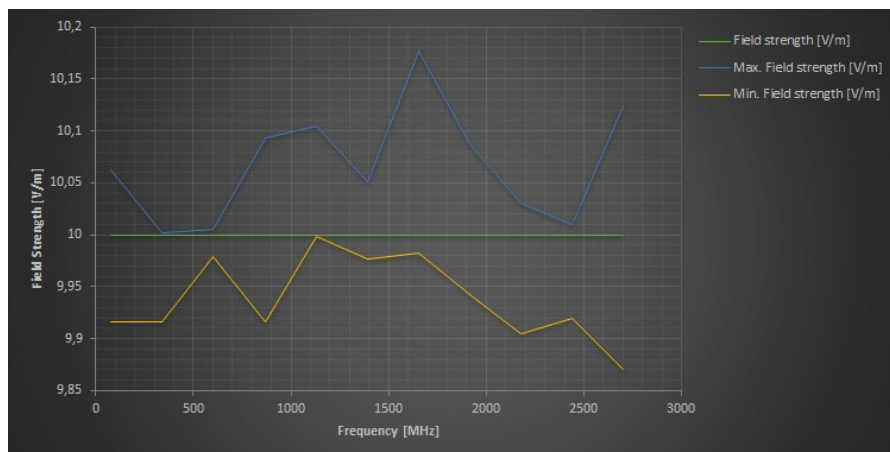

Figure 5: Dependence of Field Strength on Frequency.

Semi-anechoic Chamber

Another part of this paper is focused on the test of electromagnetic susceptibility in far-field. Far-field defines regions of the electromagnetic field around a device and its border is described by: [3]

$$r = \frac{\lambda}{2\pi} \qquad (1)$$

For this purpose, the semi-anechoic chamber was chosen. Following figures show the immunity level and sensor level waveforms depending on the frequency. Maximum and minimum values of disturbance are as follows:

- maximum level: 10.3dBμV/m (207.5MHz),

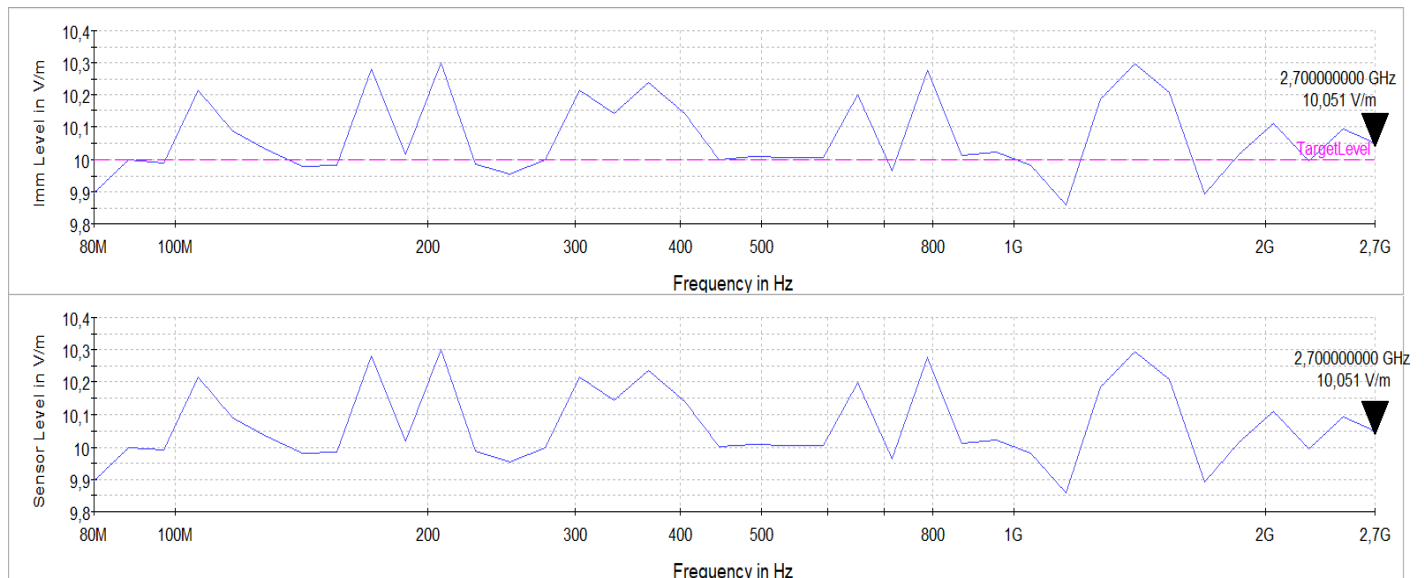- minimum level: 9.858dBμV/m (1.154MHz).

Figure 6: Dependence of Field Strength on Frequency up to 2.7GHz.

The equipment under test was exposed to the electromagnetic field again and the situation was the same as in the previous case, the device worked as intended. It means the components of Arduino are able to resist to effects of electromagnetic radiation up to 10V/m.

CONCLUSION

This article summarizes the issue of electromagnetic compatibility of Arduino platform. This cheap, small and powerful device is a popular tool for the development of equipment and its implementation in practice is very common in recent years. However, there are not many research publications devoted to the issue, therefore, the idea was born to create a paper describing this research area. The results of electromagnetic interference show that Arduino generates higher radiation level than expected. Nevertheless, this level still meets in limits of standards. In the case of electromagnetic susceptibility, the device was able to work in the environment where the field strength was within 10V/m. The main purpose of this paper was to obtain the information about the state of electromagnetic compatibility of Arduino platform. The purpose was met, the paper provides the basic knowledge about this issue.

ACKNOWLEDGMENTS

REFERENCES

[1] SVAČINA, Jiří. Electromagnetic compatibility: principles and notes. Issue No. 1. Brno: University of Technology, 2001, 156 p. ISBN 8021418737. (in Czech)

[2] KOVÁŘ, Stanislav, Jan VALOUCH, Hana URBANČOKOVÁ and Milan ADÁMEK. Comparison of Security Devices in Terms of Interception. In: The Tenth International Conference on Emerging Security Information, Systems and Technologies (SECURWARE) 2016. Nice, France, 2016. pp. 141-145. ISBN: 978-1-61208-493-0. 5 p.

[3] PAUL, Clayton R. Introduction to electromagnetic compatibility. 2nd ed. Hoboken, N.J.: Wiley-Interscience, c2006. ISBN 978-0-471-75500-5.

[4] KOVÁŘ, Stanislav, Jan VALOUCH, Hana URBANČOKOVÁ and Milan ADÁMEK. Impact of Security Cameras on Electromagnetic Environment in Far and Near-Field. In: International Conference on Information and Digital Technologies 2016. Poland, Rzeszów, 2016. pp. 156-159. ISBN 978-1-4673-8860-3. 4 p.

[5] KOVÁŘ, Stanislav. *Immunity of camera systems against electromagnetic interference*. Zlín, 2017. Faculty of applied informatics in Zlín.

[6] Eugene Rhee a Changjae Kim. Feature Analysis of Electromagnetic Interference Measurement Facilities. International Journal of Digital Content Technology and its Applications [online]. 2013-6-30, 7(10), 155-162 [cit. 2017-04-01]. DOI: 10.4156/jdcta.vol7.issue10.16. ISSN 1975-9339. Available at: http://www.aicit.org/jdcta/global/paper_detail.html?jname=JDCTA&q=3345

[7] VALOUCH, Jan. Technical requirements for Electromagnetic Compatibility of Alarm Systems. In: International Journal of Circuits, Systems and Signal Processing. Volume 9. USA, Oregon: North Atlantic University Union, 2015. p. 186 – 191. ISSN: 1998-4464. p. 6.

[8] VALOUCH, Jan. Integrated Alarm Systems. In Computer Applications for Software Engineering, Disaster Recovery, and Business Continuity. Series: Communications in Computer and Information Science, Vol. 340, 2012, XVIII. Berlin: Springer Berlin Heidelberg, 2012. Chapter, p. 369 -379. ISSN 1865-0929.