Testing of an Intrusion and Hold-up Systems for Electromagnetic Susceptibility - EFT/B

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***Abstract*—** The development of electronics in the last decades has clearly shown that for each electronic device is important to know its electromagnetic susceptibility and its own electromagnetic radiation. This knowledge allows us to determine the suitability of the placement of the given type of device to a specific environment, which requires not only its correct functionality, but also the functionality of other devices. The intention of the security alarm systems is to detect and signal the presence, ingress or attempted ingress of the intruder into the building. It is therefore important for components of security systems to be tested for electromagnetic susceptibility. Their trouble-free operation must be ensured not only in the residential and commercial environments, but also in the industrial environments.

***Keywords*—** Electromagnetic compatibility, electromagnetic susceptibility, immunity, fast transient, burst.

I. Introduction

Electromagnetic compatibility as an individual scientific and technical discipline was established in the United States in the sixties of the 20th century. At the beginning this topic was interesting just few experts working in the military and cosmic industry. With the progress of electronic, microprocessor and communication technology the electromagnetic compatibility reach our everyday life and still more and more scientists start to study it. [1]

Electromagnetic compatibility is basically the ability of coexistence of devices and systems in the common electromagnetic environment without significant influence of their normal function. Within security alarm systems electromagnetic compatibility is important especially in the cases of mutual integration of alarm and non-alarm applications. With regard to stability of function of security systems cannot come to changes in their condition, to damage of their components or essential features by the effect of electromagnetic interference. [2]

All around us there are much electromagnetic interference that could lead to a malfunction or complete inability to service of the electronic devices. For this reason, tests of electromagnetic immunity must be carried out on all electronic devices, which are now sold in our market.

The aim of this paper is to explain the problems of electromagnetic compatibility with a focus on electromagnetic susceptibility follow by proposal and realization of testing workplace of electromagnetic susceptibility for testing electrical fast transient/burst consistent with the basic standards of electromagnetic compatibility.

II. Terminology and Definitions

Electromagnetic compatibility (EMC) is the ability of equipment, system or device to function satisfactorily in its electromagnetic environment. In this environment are present sources of electromagnetic signals, which can have adversely effect. Electromagnetic signals can have natural or artificial character. Another part of EMC is the ability of equipment, system or device to function without introducing intolerable electromagnetic disturbances to anything in that environment. The division of EMC is shown in Fig. 1

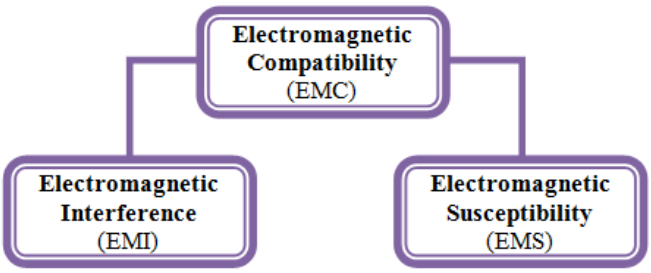

Fig. 1 The basic breakdown of problematic of EMC

Electromagnetic interference (EMI) is the process of transmitting signal, which is generated by the source of interference, into the disturbed system. This signal is transmitted by the electromagnetic binding. Particular it is about the identification of sources of interference, their description and measurement of interference signals, identification of parasitic transmission paths and establishing of actions primarily in the resources of interference and their transmission paths. EMI deals with the causes of disturbance and their removal.

Electromagnetic susceptibility (EMS) (immunity to a disturbance) is the ability of a device, equipment or system to function without degradation in the presence of an

electromagnetic disturbance. They must work without error or with clearly defined of possible influence. EMS deals with the technical measures which increase electromagnetic immunity of receivers. EMS is focused on removing the consequences of interference, without removing their causes.

The electromagnetic susceptibility of the technical system is divided into:

- Internal EMS - it is a system immunity against interfering sources contained inside its own system;
- External EMS - it is the resilience of the system against external sources of electromagnetic interference.

By reason of proposal and realization of testing workplace of electromagnetic susceptibility for testing electrical fast transient/burst we should be familiar with the following terms and abbreviations:

- *EUT* - abbreviation of the equipment under test;
- *EFT/B* - electrical fast transient/burst;
- *Transient* is pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest;
- *Burst* (of pulses or oscillations) is a sequence of a limited number of distinct pulses or an oscillation of limited duration; [3]
- *I&HAS* (Intrusion and hold-up systems) is a complex set of technical equipment which solve the protection against unauthorized entry to the building.

The real operating electromagnetic environment - it is an environment in which the equipment operates or will operate. The disadvantage of this environment for use for testing EMS is its variability over time, which means the inability to reproduce the measured results.

The artificial electromagnetic environment - clearly defined environment in which tests of EMS can be repeated - again reproduce the environmental conditions. The artificial environment defined:

- the arrangement of individual components of the test facility,
- qualitative and quantitative parameters of EMI simulator, setup and operating status of the EUT.

III. Normalization in the Field of EMC

Due to the impossibility of achieving absolute electromagnetic immunity of devices, systems or equipment they need to be established specific unified international standards, recommendations and EMC regulations. These documents are describing, for example unified standards and limits of the maximum permitted interference level for specific types of equipment or accurate and reproducible conditions for the measurement and verification of the electromagnetic susceptibility equipment.

Directive 2004/108/EC Electromagnetic Compatibility (EMC) (Directive 2004/108/EC repealing Directive 89/336/EEC is valid in all countries of the European Union). This directive is strictly monitored and sanctioned. It provides the general requirements of the EMC for commissioning of the equipment or system on the market. Devices are prohibited to sell, to exhibit or advertise if they do not comply requirements from the directive and there are not demonstrated its requests. Such device can be financially sanctioned and prohibited.

When we need to explain the terms related to the issue of EMC we should have the International Electrotechnical Vocabulary (IEV) IEC 60050 - Chapter 161: Electromagnetic compatibility. It describes all the basic terms. Czech version of this dictionary is CSN IEC 60050. [4]

Standards relating to EMC are multitude, but the basic sets of standards have a designation of CSN IEC 1000 and CSN EN 61000. Interference immunity is especially devoted to set of standards CSN EN 61000-4. Primarily, we follow the standard CSN EN 61000-4-4 ed. 2 Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test in this contribution. Another important standard is the standard for the electromagnetic immunity for security systems CSN EN 50130-4 ed.2 Alarm systems - Part 4: Electromagnetic compatibility - Product family standard: Immunity requirements for components of fire, intruder, hold up, CCTV, access control and social alarm systems.

IV. Test Levels, Equipment, Set and Documentation

EFT/B represents the low-energy broadband interference pulses in the form of the groups of short transients. Usually they are created from the influence of inductances of switching processes in the power supply, signal or data networks. They may be also created by the influence of contact bounce electromechanical relays or the influence of switching high-voltage switches. Their typical characteristics are very short rising edge, short duration, low total energy (10-3J) and high repetition frequency. Generally EFT/B does not cause the direct damage to electronic equipment, but by its wide spectral range (up to approx. 200 MHz) they produce a significant high frequency electromagnetic interference. This interference is undesirable especially in numeric systems. Process EFT/B interference is similar to the work signals of the numeric devices and so it may arise an error in the transmitted signals in the numeric systems. [1]

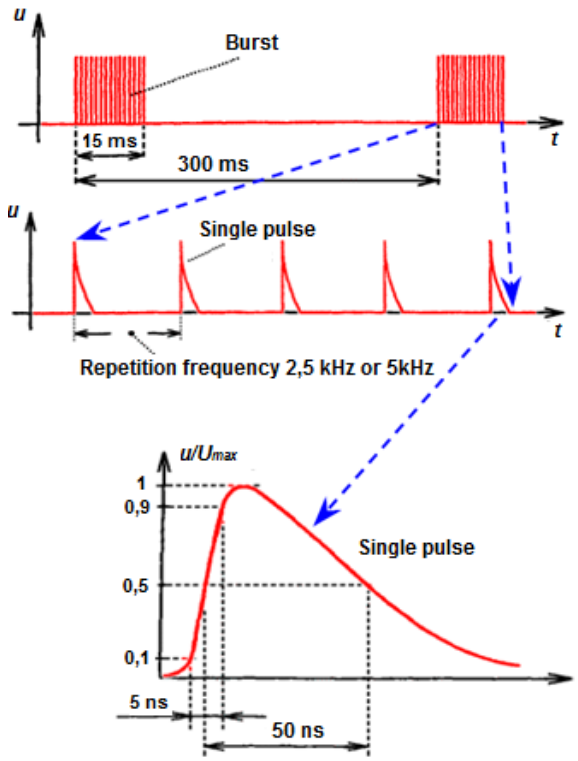

Fig. 2 The course of electrical fast transients [1]

In Fig. 2 shows the rising edge impulse (the rise time - the time interval between the moment when the immediate value of the impulse initially reaches 10% and then 90% of the voltage) takes only 5 ns and the total length of impulse (time until the impulse reaches gradually from 10% through 100% to 50% voltage) takes 50 ns. Impulses are grouped into groups with a duration of 15 ms and time between the beginnings of each group of impulses is 300 ms. Impulses repetition frequency in the group is 2,5 kHz or 5 kHz. Individual impulses tend to have a size of 0,5 to 4 kV, and the output load of the generator is 50 Ω.

Test conditions for testing of fast transient / burst are described in the basic standard CSN EN 61000-4-4 ed. 2 [3]. The aim of the test is to demonstrate the immunity of the EUT against fast transients, which arise at the switching contact or repeated discharge on the rebound contacts (relays, contactors, switching inductive loads). During the testing EUT is exposed to the groups of pulses containing a large number of fast transients, which are introduced to the input/output power supply, control, signal and data ports of the test devices. The interfering signal is represented by the Electrical Fast Transients grouped into groups of pulses (burst). [5]

Test levels for testing fast transient phenomena are presented in the Table 1. This are the test levels usable for the power supply, grounding, signal, data and control inputs and outputs of the test equipment.

Table 1 Test levels

Output testing of open-circuit voltage and repetition frequency of pulses				
Level	**On AC and DC power supply ports**		**On signal, data and control ports I/O (input/output)**	
	Open-circuit peak voltage kV	**Repetition frequency** kHz	**Open-circuit peak voltage** kV	**Repetition frequency** kHz
1	0,5	5 or 100	0,25	5 or 100
2	1	5 or 100	0,5	5 or 100
3	2	5 or 100	1	5 or 100
4	4	5 or 100	2	5 or 100
X	special	special	special	special
„X“ is the open level, which should be determined in the specifics of a particular device				

Selection of the test level is realized on the base of the expected and the most realistic of installation and environmental conditions in which the device should work. It will be followed by the immunity test of the device at these levels. Test levels are divided into 5 levels.

- Level 1: well protected environment - normal environment with low levels of interference, in which it can be used also sensitive instruments;
- Level 2: protected environment - environment with a mild levels of interference such as households, shops and offices;
- Level 3: typical industrial environment - demanding environment with a high level of interference;
- Level 4: adverse industrial environment - a special environment with very high levels of interference, such as heavy industry, power plants and distribution systems;
- Level 5 (X): Special situations which must be analysed.

The key device for testing electromagnetic susceptibility is the generator of impulses (burst), which in our case is chosen the testing device AXOS5 from Haefely EMC Technology. The main elements of the generator are:

- high voltage source (U),
- charging resistor (Rc),
- energy storage capacitor (Cc),
- high voltage switch,
- pulse duration shaping resistor (RS),
- impedance matching resistor (Rm)
- DC (direct current) blocks capacitor (Cd).

Simplified diagram involvement of the generator is shown in the Fig. 3.

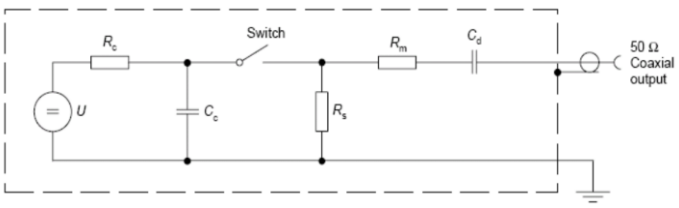

Fig. 3 Simplified diagram of the generator of the electrical fast transient/burst

For acceptance test of the input/output AC/DC (alternating current/direct current) power supply is requested coupling/decoupling network (such as three-phase power network). Capacitive coupling clamp provide a bond of fast transient/burst into the test circuit without galvanic connecting with terminal input/output EUT, with the shielded cables or other part of EUT.

The test suite for testing EMC for electrical fast transient/burst contains the following basic test equipment:

- test generator,
- coupling equipment (network or clamp),
- decoupling network,
- ground reference plane. [3]

For the test of immunity EUT is arranged and connected the way that it meets all the functional requirements specified for installation of the device as intended by the manufacturer. The test equipment is placed on an insulation pad with a thickness of 0,1 m, which is located on an appropriately grounded metal ground plane (ground reference plane must be a metal sheet or aluminium or copper one, the minimum thickness of 0,25 mm, using of other-metallic materials must be a minimum thickness of 0,65 mm).

Also, all the cables to the EUT must be placed on an insulation pad 0,1 m above the ground reference plane. If it is a desktop device, the EUT is placed on a wooden table in the high 0,8 m above the ground metal reference plane with a minimum area 1 m^2. Ground plane must extend beyond the EUT on all sides by at least 0,1 m. EUT distance from the all other metal objects must be bigger than 0,5 m. Test generator with a coupling/decoupling network must be directly connected to the ground reference plane and this plane is for safety reasons connected with protective earth.

Based on carried out immunity test must be processed test plan containing:

- type of test (laboratory or in situ - test carried out on the device in the conditions of its final installation)
- test level,
- mode of binding,
- polarity of the test voltage (both polarities are required according to standard)
- test duration inputs / outputs (can not to be less than 1 min),
- the frequency
- I/O EUT which are being tested
- representative operating conditions of the EUT,
- sequence of applications of the test voltage to the inputs / outputs of the EUT,
- auxiliary equipment.

After that, the test results are assessed from the perspective of the loss of function or degradation of operation of the test equipment in relation to the level of influence defined by the manufacturer, or in relation to requirements of the applicant for the test or the customer. Standard EN 61000-4-4 recommends resulting classification

a) normal function, which is within the limits established by the manufacturer, the test applicants or customers,
b) temporary loss of function or degradation of operation - after the test, the normal functioning of the EUT renewed itself,
c) temporary loss of function or degradation of operation - after the test, the EUT normal functionality restored after intervention by the operator,
d) loss of function or degradation of operation - after the test, it is not possible to restore the full functionality of EUT, technical equipment or software was damaged or data was lost.

The last part of the immunity test is processing a test report, which must contain all relevant information for repeating the test. The basic parts of the test report are:

- points specified in the test plan,
- identification of the EUT and other associated equipment - brand name, product type, serial number,
- any special environmental conditions in which the test was carried out (eg. a shielding cover)
- any specific conditions necessary to allow the test,
- the test assembly drawings and arrangement of the EUT,
- functional levels defined by the manufacturer, the applicant for test or the customer,
- functional criterion specified in the generic standard, product standard or in the standard of the group of products,
- a description of any effects on the EUT observed during or after the application of test interference and dwell time effects,
- all types of cables, including their length, which are connected to the EUT input / output interface,
- justification for the decision whether the EUT passed the test or failed to pass,
- any specific conditions used - eg. cable length, cable type, shielding, grounding, EUT operating conditions, etc.[3]

V. The criteria of EMS

The criteria of electromagnetic susceptibility define the limits of disturbance of the functions of technical equipment, either quantitatively or qualitatively.

The quantitative immunity limit is defined as the achievement of a certain value of the selected variables. During the development of electronic equipment is detected the size and shape of the interference signals at the selected points in involvement and is determined value of selected variables witch does not cause unwanted changes in the electronic device just yet. That value is thereafter considered a criterion of electromagnetic immunity for all devices of that type.

The qualitative (functional) criterion of electromagnetic susceptibility is a more significant criterion for the average user and operator of electronic device, since this is an assessment of changes in the operating conditions or effect on the functionality of the electronic device. According to standard EN 50082 the malfunction is defined as the change in operational capability of the equipment under test.

Based on qualitative criterion can be distinguish:

- *The functional criterion A* – during the test the equipment must continue its activities as intended and there is not

allowed any deterioration in operation of the equipment or loss of functionality.

- *The functional criterion B* – after the test the equipment must continue its activities as intended, there must not be deterioration in operation of the equipment or loss of functionality. During the test it is allowed deterioration in operation of the equipment, but it is not allowed change of the actual operating status of the equipment or change of the data in memory.
- *The functional criterion C* – the equipment is allowed temporary loss of function during the test, but function of the equipment must be restore by itself after the test or by the control system or operator.

In the literature is often mentioned other functional criterion witch describes the irreversible loss of function of the equipment, its damage or destruction. [1]

VI. Proposal and the Design of the Workplace

The testing of the electromagnetic susceptibility of devices is performed with the help of interference simulators (EMC simulators). Based on the testing is practically verified EMS degree of the test equipment or its individual components.

For the testing of EMS are for the components of alarm systems specified tests and related test level (values of the voltage drops, test voltage, the field strength, frequency range and modulation type of interference signals etc.). These tests and test levels are determined for indoor and outdoor applications, for fixed, moving and portable devices.

On the testing device, which is a component of I&HAS - wireless relay AC82, we will perform the test in an accordance with CSN EN 50130-4 ed. 2 [6]. A time of each test is set at 1 minute. The value of the test voltage is corresponds to the level 3 according to basic standard CSN EN 61000-4-4 Ed. 2 [3], which is characterized as a typical industrial environment. There are not suppressed EFT/B in the power supply and signal circuits, industrial circuits are not completely separated from other circuits, power supply lines is not completely separated from control, signal and communication cables and moreover there are used dedicated cables for power and signal lines. [5]

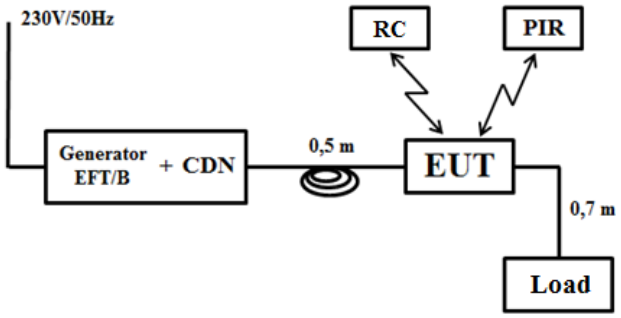

Fig. 4 Diagram of the proposed workplace for the testing EMS

Description of the testing set up shown in the Fig. 4:

- Generator EFT/B + CDN (coupling/decoupling network) - testing device AXOS5;
- EUT - wireless relay AC82;
- Load - two 15W light bulbs;
- RC – remotely control RC86W;
- PIR – PIR detector JA83P.

The proposed workplace was placed on a wooden table 80 cm high, with the upper surface of 150x100 cm. Table was placed on the ground reference plane and on the entire surface of the table was also placed ground reference plane. EUT and all cables connected with the EUT were placed as described in the standard CSN EN 61000-4-4 Ed. 2 on an insulating underlay of 10 cm above the ground reference plane and at a distance of 0.5 m from the other conductive structures (e.g. walls of the room). Testing device AXOS5 was powered from the network 230V/50Hz and all the test set was properly grounded.

The parameters of the testing device AXOS5 from Haefely EMC Technology (Fig. 5) satisfy the requirements arising from the provision set of standards CSN EN 55016 Specification for radio disturbance and immunity measuring apparatus and methods. On the tested wireless relay AC82 (Fig. 6) was connected load in the form of two 15W light bulbs and EUT wirelessly communicate with the PIR detector and remotely control.

Fig. 5 Testing device AXOS5

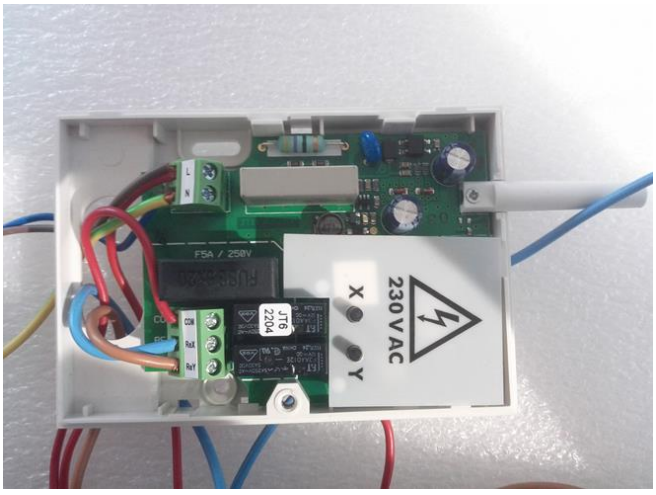

Fig. 6 Wireless relay AC82

At the beginning of the testing was on the EUT performed functional tests and EUT was subsequently connected to the proposed test workplace. During testing the device was monitored whether or not the EUT occur status change at any of the tested voltage peak and after each test was verified full functionality of the EUT. Repetition frequency for fast transients was set to 100 kHz, and the length of one test was 1 minute (Fig. 7). According to the criteria for meeting the requirement in accordance with CSN EN 50130-4 ed. 2 it must not experience any damage, malfunction or change of status of the EUT during testing. Only the flashing indicator was permissible if it does not occur any residual change in the EUT. To these requirements the wireless relay AC82 complied since during testing, there were no changes in status, faults or damage to the EUT (Table 2).

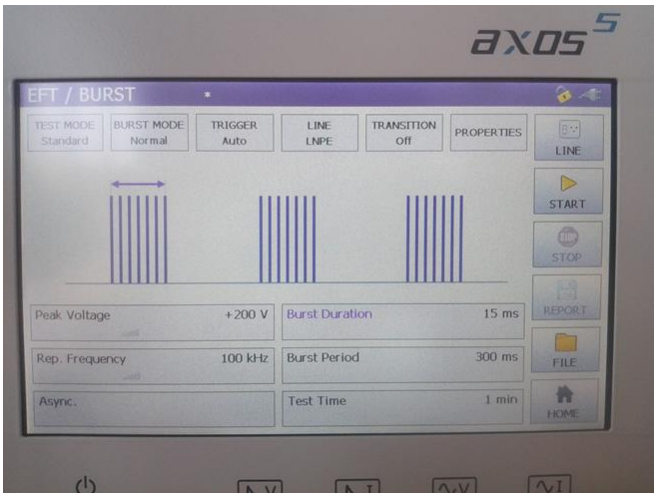

Fig. 7 AXOS 5 - setting of testing EFT/B

Table 2 Record of the measurements of the EUT

Number of measurements	Peak voltage	Regime of the EUT	Change during testing	Functionality of the EUT
1.	+ 200 V	OFF	none	full functionality
2.	+ 200 V	ON	none	full functionality
3.	- 200 V	OFF	none	full functionality
4.	- 200 V	ON	none	full functionality
5.	+ 1000 V	OFF	none	full functionality
6.	+ 1000 V	ON	none	full functionality
7.	- 1000 V	OFF	none	full functionality
8.	- 1000 V	ON	none	full functionality
9.	+ 2000 V	OFF	none	full functionality
10.	+ 2000 V	ON	none	full functionality
11.	- 2000 V	OFF	none	full functionality
12.	- 2000 V	ON	none	full functionality

VII. Conclusion

In the present the level of interference critically increases as a result of increasing amount of electrical equipment and appliances in our environment. This interference exist in the frequency ranges from 0 Hz till hundreds GHz and possibility of mutual interference between devices is high. For this reason every electronic device should be tested if it meets the requirements for electromagnetic compatibility. Frequently sensitive electronic devices have to work in the environment with strong interference and based on their insufficient electromagnetic immunity happens many errors and unwanted situations. This type of unwanted situation is for example damage of faxes, answering machines and telephones in the storms. The reason is their low overvoltage resistance and improper or missing overvoltage protection.

Because of the impossibility of eliminating all the real or potential sources of interference signals is necessary to ensure, that the electronic equipment function properly in their presence. Great accent on the electromagnetic immunity is given to components of I&HAS. Their aim is to detect and signal the presence, ingress or attempted ingress of the intruder into the building, or the alarm status caused intentionally by the user. It is therefore important for components of I&HAS to be tested for EMS. Their trouble-free operation must be ensured not only in the residential and commercial environments, but also in the industrial environments.

Rules and processes for performing of the test of susceptibility to interference of type electrical fast transient/burst are generally described in the standard CSN EN 61000-4-4 ed. 2. EFT/B can arise when the switching contactor is repeated discharge on the rebound contacts (relays, contactors, switching inductive loads, etc.). Though EFT/B usually does not cause the direct damage to electronic equipment, it is a short overload of the circuit, which is unwanted for us. The influence of overload can arise faulty transfer of information, which for I&HAS components may cause unwanted change in the status of the equipment, or induce false alarm.

To the EMS for components of I&HAS, CCTV, access control and social alarm systems there is a separate standard CSN EN 50130-4 ed. 2, which describes more the individual immunity tests for each type of interference that they have an effect on these devices. According to this standard the EUT was exposed to the fast transients fed to the power input during the test for susceptibility to EFT/B. Test function of the EUT was performed according to the instructions before was started testing and after each one test. During the testing with different voltages of the EUT was monitored whether does not occur some change in its status. Wireless relay AC82 complied all the requirements. The EUT was fully functional during all the time of testing and at each test there was no fault or status changes.

Acknowledgment

The work was performed with financial support by grant No. IGA/FAI/2015/043 from IGA (Internal Grant Agency) of Thomas Bata University in Zlin, of research project NPU I No. MSMT-7778/2014 by the Ministry of Education of the Czech Republic and also by the European Regional Development Fund under the Project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

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