Comparison of Security Devices in Terms of Interception

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***Abstract*— Currently, electromagnetic interference presents a major problem in the design of electronic and electrical equipment and systems. Equipment must be designed to ensure that its operation does not negatively affect itself or the devices in its vicinity. To demonstrate how this can be achieved, the paper aims at comparing the electromagnetic interference generated by analog and IP cameras where the measurement fulfils the strict requirements described in the ČSN EN 55022 ed. 3 standard.**

Keywords-electromagnetic interference; semi-anechoic chamber; closed circuit television; transmission path; far-field.

I. Introduction

Electromagnetic compatibility (EMC) continues to be a current research topic, especially in today's world where the number of electronic items in homes and workplaces have significantly increased. EMC is defined as the ability of electronic or electrical devices or systems to work correctly in an environment where other sources of electromagnetic signals operate. Devices or systems, for example Closed circuit television (CCTV), can be perfectly reliable, but they are not usable if they cannot work in the electromagnetic environment. In the case of CCTVs, the system consists of multiple devices (security camera, monitoring unit, control unit, etc.) each of which generates a different frequency range.

Electromagnetic compatibility [4] is typically classified into two categories namely electromagnetic susceptibility (EMS) [9] and electromagnetic interference (EMI) [3]. Electromagnetic interference is a process wherein the signal generated by the source of interference is transmitted via electromagnetic constraints to disturbed systems. EMI is concerned with identifying causes of disturbance. On the other hand, EMS is set up to remove the effects of EMI. In effect, EMS tasked to establish a limit in which the device can operate without failures, which potentially can adversely affect its function [1][9]. There is a limited number of research publications that deal with the interception of the video signal, and this is the reason why this contribution exists.

The purpose of this research is to investigate whether the cameras generate a sufficient level of interference that could be eventually exploited to acquire the transmitted information.

Sections 2 and 3 clarify what kinds of devices were used for the experiment. Section 4 defines the process of measurement followed by the configuration of an equipment under test during the analysis. In Section 6, the results are shown. The contribution of the paper is described in Section 7.

II. Equipment under Test

CCTV is defined as an information technology equipment used to obtain, transmit, display and store video information. Basically, the camera captures the image of a scene. The information captured by a camera is transmitted via a transmission medium to a control unit (notebook, Network Video Recorder). Subsequently, the control unit displays the information in the display unit (monitor). Finally, the information can be stored (memory disks, cloud computing) with strict adherence to privacy and data protection laws governing the area of operation.

For the purpose of this paper, a CCTV consists only of a control / display unit (notebook) sensing unit (IP and analog camera) and communication medium (twisted‑pair cable). Cameras intended for the test are IP camera VIVOTEK FD8136B F3 and analog camera HIKVISION DS-2CE56C5T-AVPIR3.

III. Measuring Equipment

The electromagnetic interference testing was performed in the laboratories of electromagnetic compatibility at the University of Tomas Bata in Zlin. The equipment under test (EUT) was placed in a semi-anechoic chamber equipped with pyramidal absorption materials. The absorbers eliminate internal reflections in the chamber, which could cause deformation of the results of the measuring. The bilogarithmic-periodic antenna, as shown in Figure 1, measures the equipment in the chamber and operates over a wide frequency range of 30MHz - 2GHz. Concurrently, another measuring equipment is placed outside the semi-anechoic chamber. The testing of the security cameras was performed using the following techniques of measurement:

- CBL 6112 - bilogaritmic-periodic antenna,
- ESU8 (Rohde & Schwarz) - EMI test receiver which is operating in the range from 20 Hz to 8 GHz,
- EMC32 (Rohde & Schwarz) - EMC measurement software,

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- OSP 130 (Rohde & Schwarz) - switch and control unit,
- OSP 150 (Rohde & Schwarz) - switch and control unit.

IV. Process of Measurement

The CCTV used to perform the testing included an analog or IP camera. Most parts of the CCTV were moved outside the semi-anechoic chamber to avoid a large distortion of the electromagnetic interference of the cameras. Power over Ethernet (POE) adapter was placed inside and outside the semi-anechoic chamber, in order to determine its influence on the level of EMI. Similar tests under the same conditions were carried by the authors in another research publication [2].

The standard [3] requires a changing polarization (horizontal and vertical) and an antenna height (from 1m to 4m - the possibilities of testing the workplace) during the measurement. A peak detector was used to measure the interference of the cameras. The peak detector helps to evaluate the maximum level of EMI for each frequency value. Contrariwise, the quasi-peak detector evaluates several samples of interference for each frequency value within the specified frequency range. In this case, the frequency range of the measurement is set from 30MHz to 1GHz, which covers a working frequency of both cameras.

The measurement process was conducted according to standard EN 55022 ed. 3 [3], which defines the procedure for measuring a test equipment. The entire process can be summarized in the following steps.

A. *Preparing the workplace*

Selection and preparation of measuring equipment suitable to perform the measurement were first carried out. These techniques of measurement involved the preparation of bilogaritmic-periodic antenna, switching and control unit, receiver and computer with the measuring software.

B. *Configuration of EUT*

To avoid distortion during the measuring process, the device to be tested has to be properly configured for the task. In this case, the tested security camera was placed in the semi-anechoic chamber. The entire configuration is shown in Figures 1 and 2.

C. *Wiring of EUT*

The test devices must be connected in accordance with the requirements set out in the proposal. The function must be thoroughly tested to ensure that the measurement results would be relevant.

D. *Configuration changes*

CCTV always consists only of one camera (IP or analog) to avoid interference between each of them; one camera was exchanged for another. Additionally, the location of the POE adapter was also placed outside the semi-anechoic chamber.

E. *Evaluation of results*

The final step involved the processing and evaluation of measurement results.

V. Disposition of EUT

The equipment must be connected to its functional state. Standard EN 55022 requires that the testing devices are placed on an insulated (non-metallic) support. Subsequently, all cables must be routed over the rear edge of the insulated surface (in this case, it is a wooden table), ie over the edge which is farthest from the measuring antenna. The standard also requires the distance between adjacent devices to be at least of 0.1m. All surplus parts of cables, which are longer than 0.4 m must be folded.

The security camera was placed in the semi-anechoic chamber on a wooden table and the distance of measuring device from the antenna was 3m, according to standard recommendations. The IP and analog cameras were powered by the POE adapter. The effect of POE adapter on the overall level of interference was also researched during the testing. Therefore, several measurements were performed with POE adapter located inside and outside the chamber. The first variant is shown in Figures 1, 2.

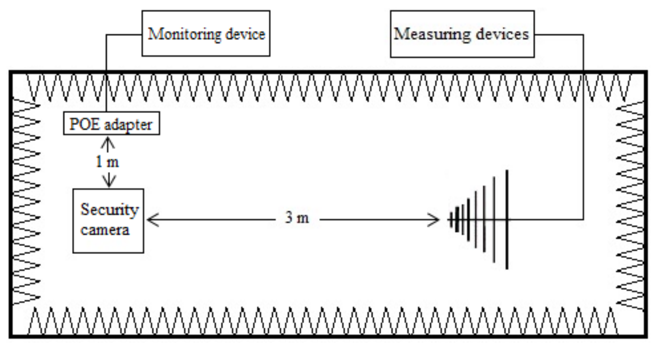

Figure 1. POE adapter placed inside the semi-anechoic chamber.

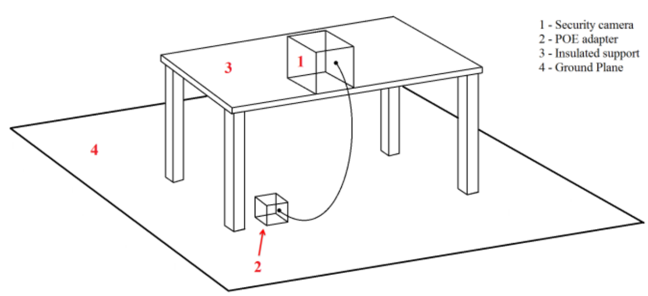

Figure 2. Disposition of EUT in the semi-anechoic chamber.

The POE adapter as shown in Figure 2, is positioned so that the effects on the measurement are minimized.

VI. Results of Measurement

This part of the paper is devoted to the presentation of results obtained through the measuring process. Measurements were performed in accordance with the requirements of EN 55022 ed. 3. The antenna changed the height and polarization during the testing to determine the conditions of the EMI in different situations. The progress of radiation was stated in a horizontal and vertical polarization of antenna for each change of the position during the testing procedure.

The x-axis always describes the frequency in Hz in the following figures and the y-axis shows the level of electromagnetic interference in dB/m. The frequency range is displayed from 30MHz to 1GHz and EMI range is displayed from 0 to EMI 80dBμV/m. The limit within which the level of EMI should not be exceeded is around the value of 41dBμV/m.

A. Analog camera

The analog camera was connected as shown in Figure 1 and Figure 2. The Hikvision camera was set in an active mode throughout the time of measurements. The camera transmitted data based on the condition of the scene into the laptop, which displayed it. This operation was carried out to verify the functionality of the device. The distance between the security camera and the antenna was 3m.

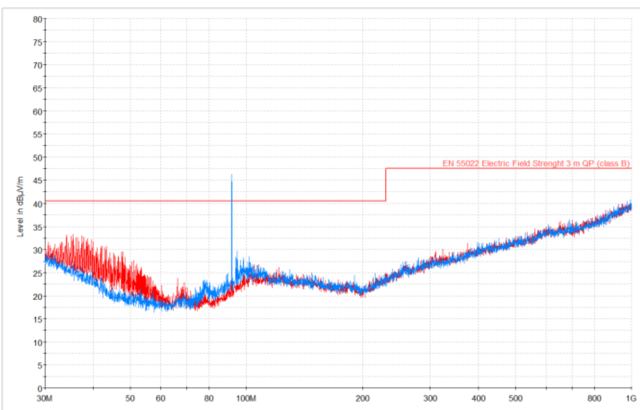

Figure 3. Waveform of EMI in horizontal and vertical polarization.

The most interesting results were reported at the location with the antenna height of 2.5 m and that is why the results presented in this entire section were measured under the same conditions. The changing of the height of the antenna detected no significant differences. The blue color depicts the horizontal polarization of antenna whiles the red shows the vertical polarization. This marking is valid for the entire section. The differences between the max and min values are given below. The maximum and minimum values of electromagnetic interference generated by the analog security camera are as follows:

a) Horizontal polarization of antenna

- maximum level: 45.987dBμV/m (91.711MHz),
- minimum level: 16.389dBμV/m (63.868MHz).

b) Vertical polarization of antenna

- maximum level: 39.938dBμV/m (995.701MHz),
- minimum level: 16.726dBμV/m (74.645MHz).

The peak which originated in the frequency point of 91.711MHz is caused both by an unattached Bayonet Neill Concelman (BNC) connector (Composite Video Blanking and Sync (CVBS) output) and twisted pair which received a radio signal (outside the semi-anechoic chamber). In other words, nothing was connected to the BNC connector, which remained free. Connecting only one connector was done for testing purposes in order to compare EMI of the coaxial cables (CVBS output, HD video output). For comparison, Figure 4 describes the process of EMI with attached CVBS output, but the HD video output was not connected to the laptop. In both cases, the free BNC connector acts as an antenna; therefore, a fluctuation arose in the waveforms of the EMI.

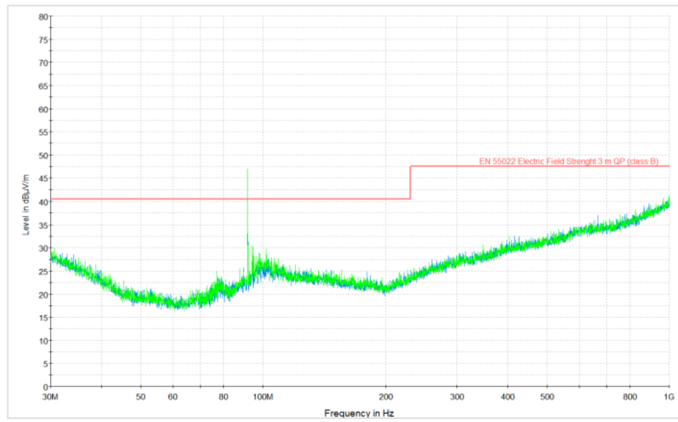

Figure 4. EMI waveform of the analog camera with the CVBS output.

In Figure 4, the waveform of interference with the connected CVBS output represented by green color is shown. The previous measurement (horizontal polarization) is also shown in the figure; however, it is largely hidden by the new green waveform. The measurement makes sense only for the horizontal polarization of the antenna because the camera did not record any significant changes in vertical polarization. The maximum and minimum values of the new measurement recorded are:

- maximum level: 47.005dBμV/m (91.711MHz),
- minimum level: 16.437dBμV/m (60.633MHz).

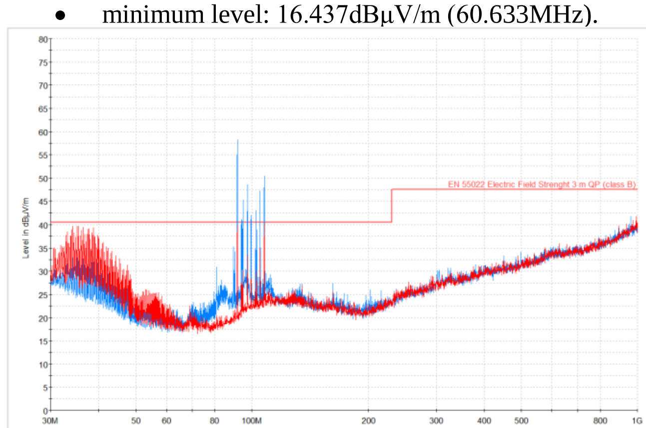

Figure 5. Waveforms of EMI with POE adapter outside the measuring chamber.

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Figure 5 shows the state of the EMI analog cameras. The POE adapter which supplies energy to the security camera is located outside the measuring chamber. The differences which resulted during the comparison of waveforms with the adapter (Figure 3), and without the adapter (Figure 5) are immediately visible. Figure 5 displays an increase of interference in the frequency range from 30 to 70MHz in the vertical polarization, and in the range from 90 to 115MHz in horizontal polarization. The maximum and minimum values for horizontal and vertical polarizations were the following:

c) Horizontal polarization of antenna

- maximum level: 58.242dBµV/m (91.711MHz),
- minimum level: 16.873dBµV/m (60.391MHz).

d) Vertical polarization of antenna

- maximum level: 41.767dBµV/m (992.719MHz),
- minimum level: 16.548dBµV/m (72.151MHz).

B. *IP camera*

The measurement procedure is the same as with the analog camera.

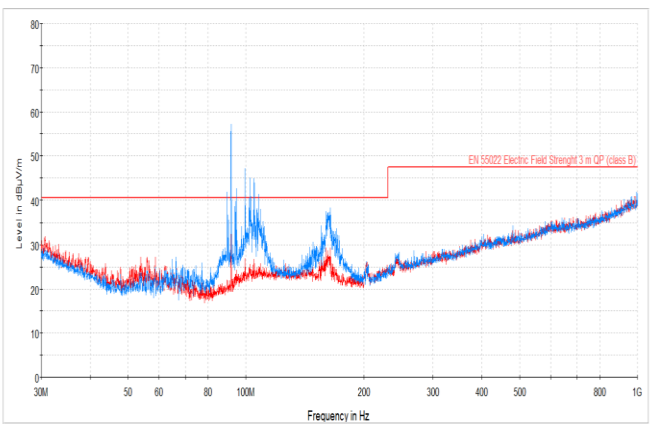

Figure 6. Waveform of EMI.

Figure 6 describes the course of electromagnetic interference generated by IP cameras, where the height of the antenna is set at 2.5m. The color-marking of waveforms is the same as in the previous cases. The undesirable influence of radio interference is especially visible in the frequency range from 50 to 250MHz. Radio frequencies were transmitted via unshielded twisted-pair cable. The influence of interference is mainly evident in the blue course of the measurement. This case was observed in analog cameras and similar waveforms can be expected in the following measurements.

a) Horizontal polarization of antenna

- maximum level: 57.539dBµV/m (91.711MHz),
- minimum level: 17.821dBµV/m (51.466MHz).

b) Vertical polarization of antenna

- maximum level: 32.444dBµV/m (91.711MHz),
- minimum level: 16.772dBµV/m (78.392MHz).

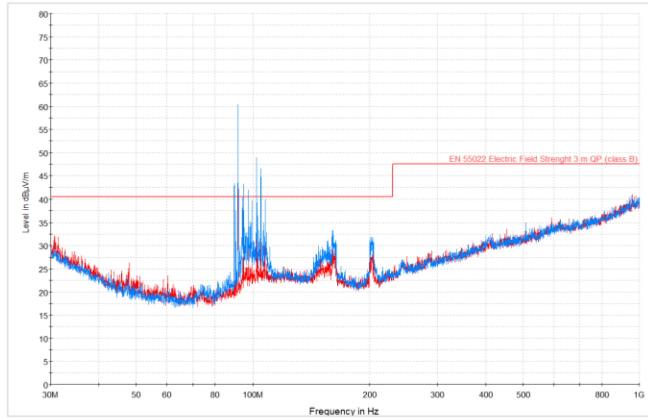

Figure 7. Waveform of EMI with POE adapter outside of semi-anechoic chamber.

Figure 7 compares the state of EMI of IP cameras with POE adapter outside of the semi-anechoic chamber. According to the figure, it is evident that changes are mainly in the blue (horizontal) waveform. The change of height of the antenna is mainly seen in the maximum values of EMI. This fact was ascertained by comparing the results of several measurements. The shape of the curve remains almost the same and the values of EMI are as follows:

c) Horizontal polarization of antenna

- maximum level: 57.132dBµV/m (91.711MHz),
- minimum level: 17.552dBµV/m (67.275MHz).

d) Vertical polarization of antenna

- maximum level: 40.880dBµV/m (980.884MHz),
- minimum level: 16.772dBµV/m (78.392MHz).

C. *Electromagnetic background*

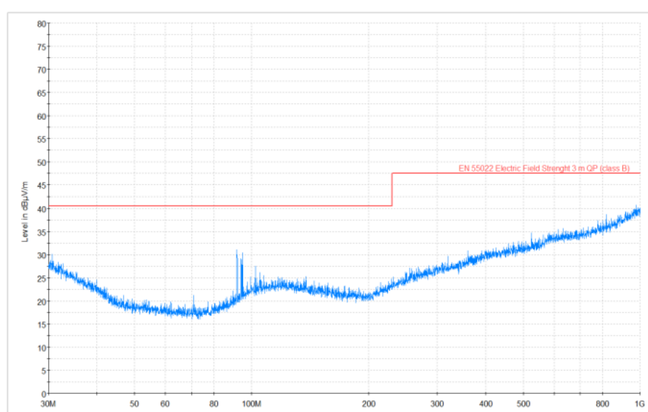

Figure 8. Electromagnetic background.

As seen in Figure 8, the electromagnetic background depicts the fluctuations in the frequency range from 80 to 100MHz, which must affect the resulting value of EMI obtained in this frequency band during the measuring. Interference in this band corresponds to radio waves. This fact must be taken into account in the analysis.

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VII. CONCLUSION AND FUTURE WORK

The paper described the state of electromagnetic interference generated by IP and analog cameras. It was observed that measurement is influenced by radio signals, which are commonly encountered in each environment. This unwanted radio interference had a significant impact on the results of the measurement because interference exceeded the desired limit of 41dBμV/m set in the standard CSN EN 55022 ed.3. This problem can be eliminated by using another transmission medium (fiber optic cable, shielded twisted pair). The use of an analog camera is better able to handle the disturbance which also is as shown in the results of the measurements. The reason may be a converter that converts digital information into analog. Conversely, IP camera generates higher interference in the larger frequency range (about 80 to 250MHz), and this fact may be exploited to acquire the transmitted information.

To ensure the required level of electromagnetic interference, it is necessary to pay attention to all parts of the system (CCTV). This is because each weakness in the system can have a congruent effect on the level of interference generated by the system or more precisely its parts.

The main purpose of this paper was to prepare a basis for further research aimed at obtaining information via electromagnetic radiation. As shown in this investigation, cameras provide a sufficient amount of data that can be analyzed in detail. The results suggest that further research should be focused on the use of IP cameras which produce more unwanted information.

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