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Electromagnetic Field Generated by Wireless Alarm Devices

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***Abstract*—Together with the rise of importance of devices employing wireless networks based on the principle of radio frequency data transfers, also the discussion on harmfulness of the electromagnetic radiation has occurred. The authors of this paper obviously cannot provide unambiguous answers to stop this discussion. On the other way, they can provide the reader of this paper with real data obtained by measurements processed inside a semi anechoic chamber that were performed at several wireless alarm peripherals. The measured values are compared to the technical and hygienic standards so the reader can form an idea of the amount of the radiated energy. Moreover, examples of waterfall diagrams of spectra generated by the devices are also listed in this paper.**

***Keywords*—Wireless Communication, Power Density, Electromagnetic Field**

I. INTRODUCTION

THE principles and mechanisms relevant to the issues of the electromagnetic field have been studied since 17th century and the first complete theory describing this phenomenon was published in 1873 by James Clerk Maxwell. Generally said, the electromagnetic field (EMF) is a physical field produced by electrically charged objects. For the purposes of communication systems, transmitting and receiving data, the most important phenomenon is the existence of the electromagnetic waves that propagate through free space, carrying energy that can be utilized at the receiver's point. Physically, the radio waves can be understood as an energy-carrying matter. Its oscillating particles are of a very low weight but they embody great momentum. The energy of the radio waves in quantized. The smallest amount of energy is represented by a photon. The photon's energy is directly proportional to a frequency it oscillates on:

$$W_f = hf\ [J] \tag{1}$$

Where $h = 6.625 \cdot 10^{-34}$ [Js] is a Planck's constant [1]. The relationship between the weight of a photon and its propagation velocity can be expressed by the well-known Einstein's equation (2). The propagation velocity of EMF is given by the permittivity and the permeability of the ambience (3).

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$$W = mc^2\ [J] \tag{2}$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \varepsilon_r \mu_0 \mu_r}}\ [m/s] \tag{3}$$

Where:
$\varepsilon_0 = 8.85 \cdot 10^{-12}$ [F/m] is the vacuum permittivity,
ε_r is the permittivity of the ambient material,
$\mu_0 = 4\pi \cdot 10^{-7}$ $[N/A^2]$ is the vacuum permeability,
μ_r is the permeability of the ambient material.

Because the EMF (radio waves respectively) is the carrier of energy, it interacts with the relevantly perceptive mass. Once the EMF is modulated, as a carrier of energy (and information) it is able to establish wireless data communication. The direct consequence of this phenomenon is a thermal action on the irradiated matter (microwave ovens) when the EMF intensity is high enough. In a free environment, the EMF intensity is usually expressed in [V/m] although the EMF consists of two components, the electrical field and the magnetic field. The intensity of electrical field is expressed in Volts per meter [V/m] while the intensity of the magnetic field is expressed in Amperes per meter [A/m]. However, in the free environment the ratio between the electric and the magnetic fields is fixed. Therefore only one unit [V/m] can be used to describe the EMF intensity correctly. The EMF intensity decreases with the distance from its radiator approximately according to the following equation:

$$E = \frac{\sqrt{30P}}{r}\ [V/m] \tag{4}$$

Where:
P is the transmitting power of the radiator in Watts,
r is the distance from the radiator in metres.

II. STANDARDIZATION

Concerning the issues on EMF, thorough technical standardization has been implemented in the past, mostly because of the problems arising from the electromagnetic compatibility of the relevant systems [2], [3], [4]. Generally, the standardization covers two large groups of issues:

- Electromagnetic compatibility of technical systems,
- Electromagnetic compatibility of biological systems.

Although the scientists usually find consensus concerning the technical systems, there are many ambiguous issues on the electromagnetic compatibility of biological systems. Although the effects of EMF on the human organism have been observed for a long time, the results of existing biophysical and biophysical research in this area are not unambiguous. The biological effects of the electromagnetic field depend on its nature, the duration of action, and the properties of the organism. Since field receptors (ie, inputs of the electromagnetic field into the organism) are not known, these effects are only assessed by non-specific reactions of the organism. [1]

In the Czech Republic, the Government Regulation 1/2008 Sb. defines requirements for work and occurrence of persons in the electromagnetic field in the frequency range 0 Hz to 300 GHz. It also specifies the limits on permissible values of induced currents, absorbed power and irradiance density as enlisted in Table I.

TABLE I
LIMITS DEFINED BY THE GR 1/2008 SB. [7]

Quantity	Employed Persons	Other Persons
Induced current density [A/m²][1)]	$\sqrt{2} \cdot 0.01$	$\sqrt{2} \cdot 002$
Areal power density [W/m²][2)]	50	10
Specific absorbed power [W/kg][3)]	0,4[4)]	0,08[5)]

1) Valid for frequencies from 300 to 107 Hz.
2) Valid for frequencies from 1 to 3 GHz.
3) Valid for frequencies from 105 to 1010 Hz.
4) If only a part of a human body is exposed, the limit is increased to 10 W/kg or 20 W/kg for hands, feet and ankles).
5) If only a part of a human body is exposed, the limit is increased to 10 W/kg or 20 W/kg for hands, feet and ankles).

III. Radio Interfaces of Safety Systems

Usually, the wireless sensors of electronic safety systems employ standardized radio bands 434 and 868 MHz. According to the standard EN 300 220 [6], the frequency band of 868.6 to 866.7 MHz is recommended for these purposes. The relevant radio bands and limits suitable for operation of the wireless sensors of electronic safety systems according to [6] are enlisted in the Table II.

For the purposes of the paper, let us assume that the wireless sensors use antennas that are close to the isotropic ones, i.e. they radiate almost equal amount of power at all directions. Then the appropriate areal power density can be calculated as follows [5]:

$$S = g\frac{P_t}{4\pi r^2}\ [W/m^2] \qquad (5)$$

Where:
g is the antenna gain (1 for isotropic antennas),
P_t is the transmitted power,
r is the distance from the transmitter.

When compared to the limits enlisted in Table I, it can be stated that the transmitting power of these devices is quite negligible.

TABLE II
SUITABLE RADIO BANDS FOR WIRELESS SAFETY SENSORS [6]

Frequency [MHz]	Effective radiated power limit [W]
433.05 – 434.04	0.01
868.0 – 868.6	0.025
868.7 – 869.2	0.025

IV. The Experiment

The experiment took place in the Laboratory of electromagnetic compatibility at the Faculty of Applied Informatics of Tomas Bata University in Zlin. The measurement was processed inside a semi anechoic chamber Frankonia SAC-3 plus by means of the following equipment:

- EMI test receiver Rohde & Schwarz ESU 8,
- EMI antenna Teseq CBL 6112.
- Controlling software Rohde & Schwarz EMC 32.

Specific construction of the chamber's ceiling improves the damping of standing waves, that may occur inside as a result of reflexitivity of the chamber's walls. The manufacturer claims that the dome shaped roof as well as its optimized absorber layout, with ferrite and partial hybrid absorber lining, allows the chamber to act as anechoic within the frequencies from 26 MHz to 18 GHz [8].

A. *Configuration*

The configuration of the experiment was as depicted in Fig. 2. The tested device was placed at the test table inside the semianechoic chamber and the receiving antenna was placed at an appropriate distance. The test receiver was set to continuously scan the narrow frequency band around the frequency of 868 MHz (or 434 MHz respectively – according to the tested device) and to record the maximum measured value (MaxHold).

MaxPeak detector was selected for this kind of measurement. During the measurement, the measured device was forced to launch alarm in order to obtain its attempt to establish radio connection between the device and its controlling exchange. Both, the vertical and the horizontal antenna polarization were used. The measurement was processed until no increase of the recorded values was observed. For each of the components, one measurement for vertical and one measurement for horizontal antenna polarization were processed separately.

This configuration has previously been used in the experiment described in [9].

B. *Results Interpretation*

The intensity of the EMF radiated by the device inside the chamber was measured. It was assumed that the manufacturer of the devices constructed its transmitting antennas in order to radiate omnidirectionally. Therefore the devices were treated as the isotropic EMF radiators. The EMF intensity was measured in the distance of 4 metres and transmitting power was calculated according to the equation (5).

Fig. 1. Frankonia SAC 3 plus

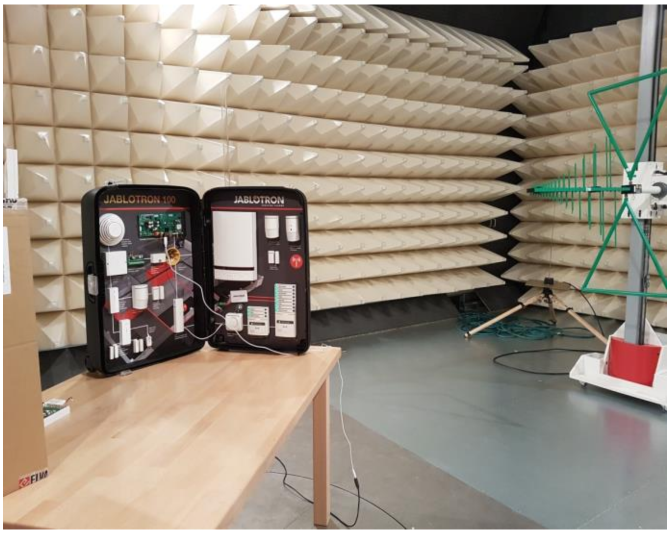

Fig. 2. Safety system Jablotron JA 100 inside the semi anechoic chamber

C. *Tested devices*

For the purposes of the experiment, the below enlisted devices were selected. All of them were provided by the manufacturer as subjects for testing and educational purposes. Primarily, these devices were indented to be tested on their operating ranges and possible vulnerability of their wireless communication. Once they were delivered to the laboratory, the intensity of EMF they transmitted was measured as well.

1) *Jablotron JA-160PC*

Jablotron JA-160PC (see Figure 3) is a wireless motion detector with embedded camera. When the alarm is launched, the detector creates a picture of the observed scene. This picture can be transmitted to the control station. The wireless connection is performed in the band of 868 MHz. The device is battery operated.

Fig. 3. Jablotron JA-160PC

2) *Jablotron JA-151M*

This is a wireless opening magnetic detector with minimized dimensions. It is a component of JA-100 Alarm system and it is intended to detection of opening of window, doors etc. of protected area. The power supply is ensured by a single lithium battery of CR2032 type. It operates in the radio band of 868 MHz.

Fig. 4. Jablotron JA-151M

3) *Jablotron JA-180B*

The JA-180B is a component of JA-100 Alarm system and it is intended to detection of glass breaking of glass surfaces of protected area by intruder. Its power supply is provided by an internal battery. It operates at the frequency of 868.1 MHz.

4) *Jablotron JA-154J*

Jablotron JA-154J is a bidirectional remote controller. It allows the user to control various devices in the framework of the alarm system. Moreover, by means of this device, the user can start an emergency alarm. The device operates in the band of 868 MHz.

Fig. 5. Jablotron JA-180B

Fig. 6. Jablotron JA-154J

Fig. 7. Jablotron JA-60P

5) *Jablotron JA-60P*

This is a PIR wireless motion detector, primarily designed for monitoring of occurrence of person's inside a guarded area. Its power supply is assured by 2 LR03 batteries with 1 year average lifetime. The operating frequency of the wireless communication is 434 MHz.

6) *Jablotron RC-11*

This is a transmitter designed in the form of a key ring. It operates on the frequency of 434 MHz and allows its user to lock or unlock the safety system as well as to start an emergency alarm.

Fig. 8. Jablotron RC-11

TABLE III
RESULTS OBTAINED BY THE EXPERIMENT

Device	Radio frequency [MHz]	Distance [m]	Measured Intensity [dBµV/m]	Transmitting power [W]
JA-160PC	868.090	4	101.2	0.00707
JA-151M	868.129	4	99.7	0.00495
JA-180B	868.089	4	100.5	0.00594
JA-154J	868.112	4	90.16	$5.54 \cdot 10^{-4}$
JA-60P	433.934	4	65.06	$1.7 \cdot 10^{-5}$
RC-11	433.947	4	77.74	$3.17 \cdot 10^{-5}$

TABLE IV
POWER DENSITIES CALCULATED FROM THE MEASURED INTENSITIES

Device	Radio frequency [MHz]	Power density [µW/m²]		Transmitting power [W]
		Distance of 1 m	Distance of 4 m	
JA-160PC	868.090	868.090	562.6	35.16
JA-151M	868.129	868.129	393.9	24.62
JA-180B	868.089	868.089	472.7	25.54
JA-154J	868.112	868.112	44.09	2.76
JA-60P	433.934	433.934	1.35	0.085
RC-11	433.947	433.947	2.52	0.16

V. RESULTS

The main results obtained by the above described experiment are enlisted in the Table III. All the final measurements were processed in the distance of 4 metres.

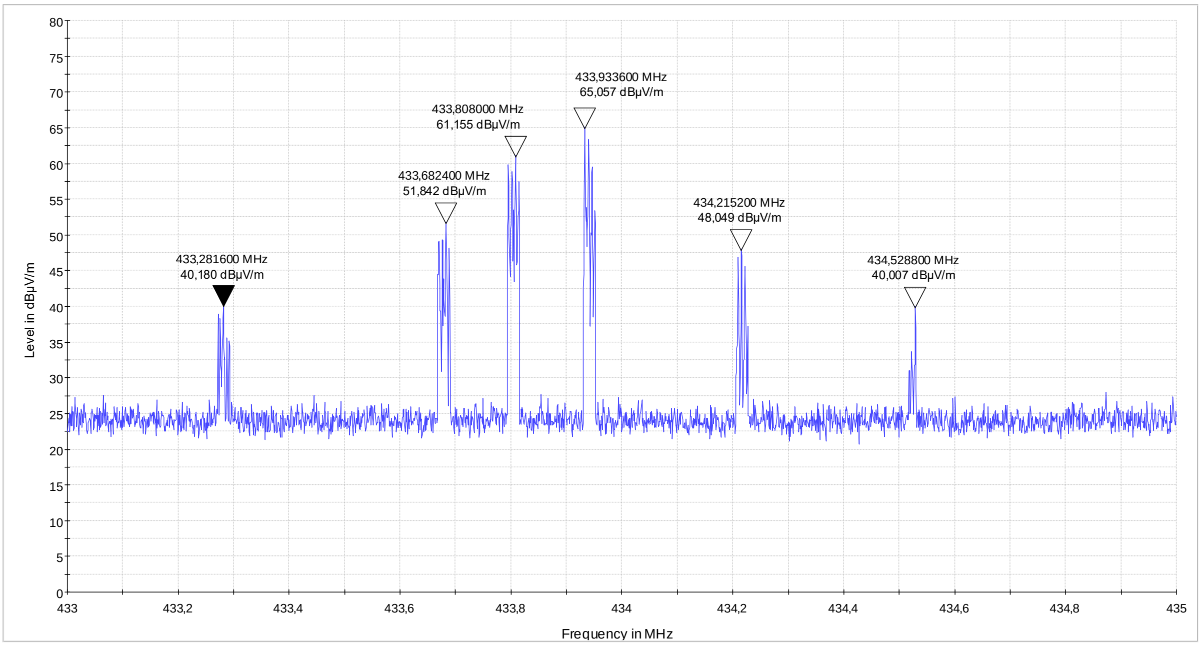

Fig. 9. Spectrum transmitted by Jablotron JA-60 P

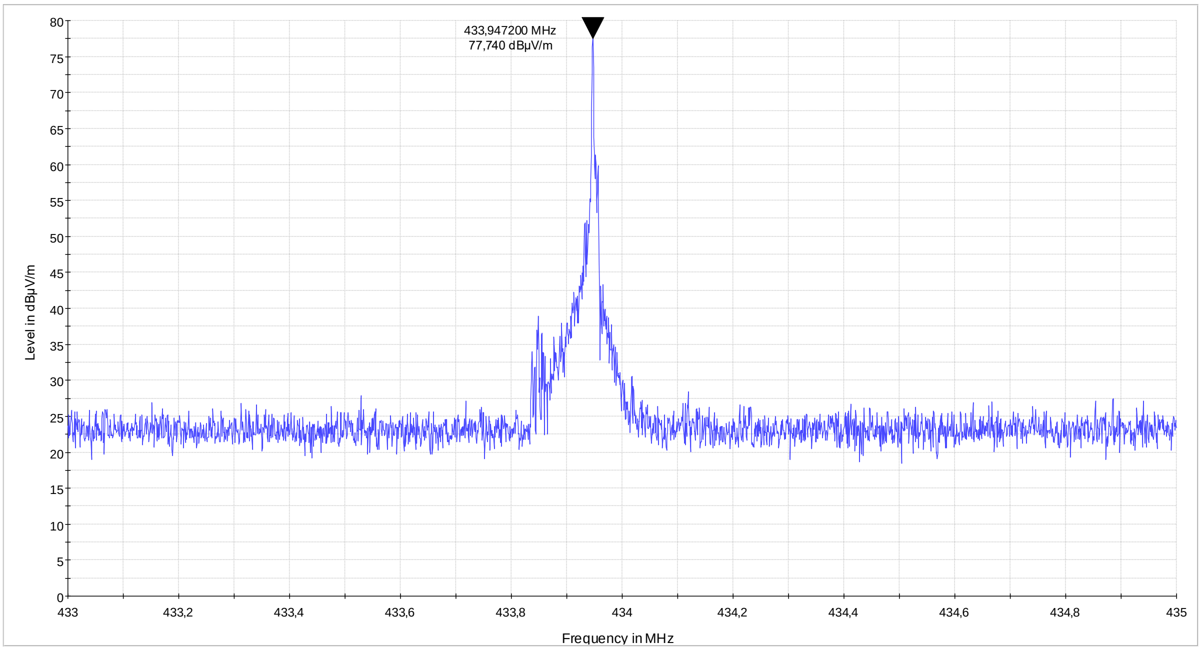

Fig. 10. Spectrum transmitted by Jablotron RC-11

According to [2] and the relevant standards, the irregularity of EVF measurement inside the semi anechoic chamber can be as high as ± 4 dB (relative to the voltage units). Due to the complexity of the problem, this uncertainty is allowed even for officially certified test laboratories. For example, if the measured intensity is 100 ± 4 dBµV/m, it means that the real value of EVF may lie somewhere between 63.096 and 158.489 mV/m, resulting in the calculated transmitting power from 2.123 to 13.4 mW. Of course, there are methods to increase the accuracy of the measurement, but they needs a lot of time and expenses in orders of thousands of Euro. Therefore the authors consider the obtained results as satisfying.

Finally, let us concern the issues on the areal power density as it is expressed in the Table I. This can be calculated by the equation (5). The calculated power densities in the distance of 1 and 4 metres from the devices are enlisted in the Table IV. It can surely be stated, that in the distance of 1 m from the device, even the short-term peak value of the transmitting power is lower than 1 mW. This is 10 000x lower value than required by the Regulation 1/2008 Sb [7].

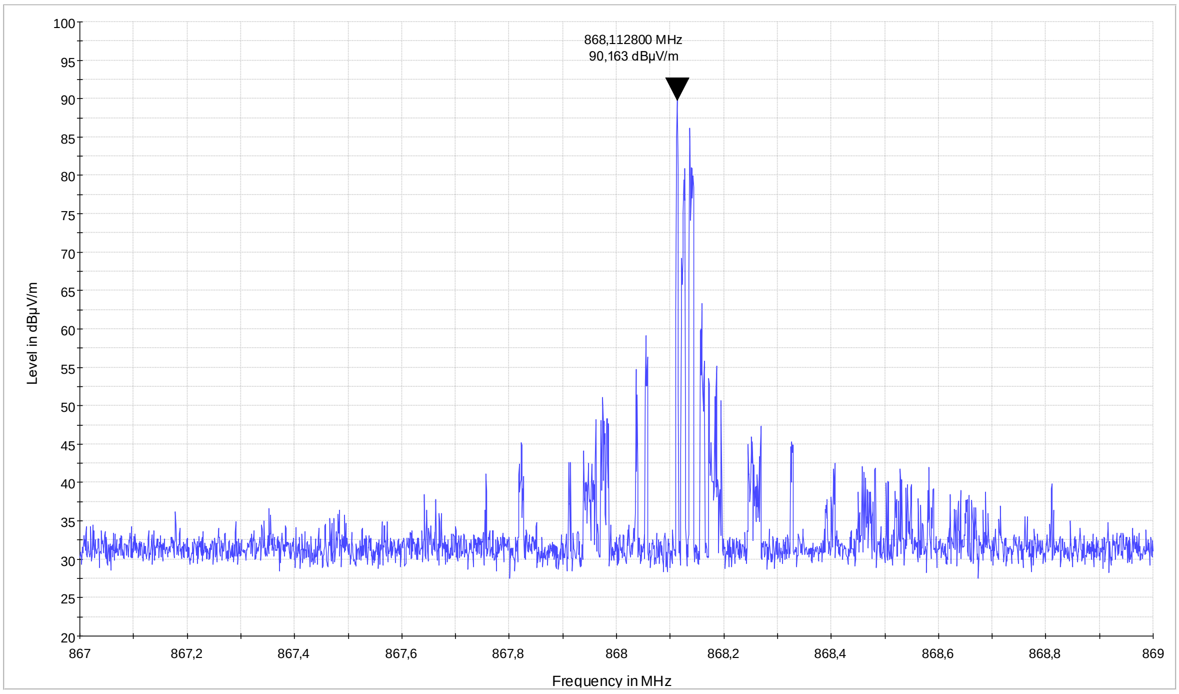

Fig. 11. Spectrum transmitted by Jablotron JA-154J

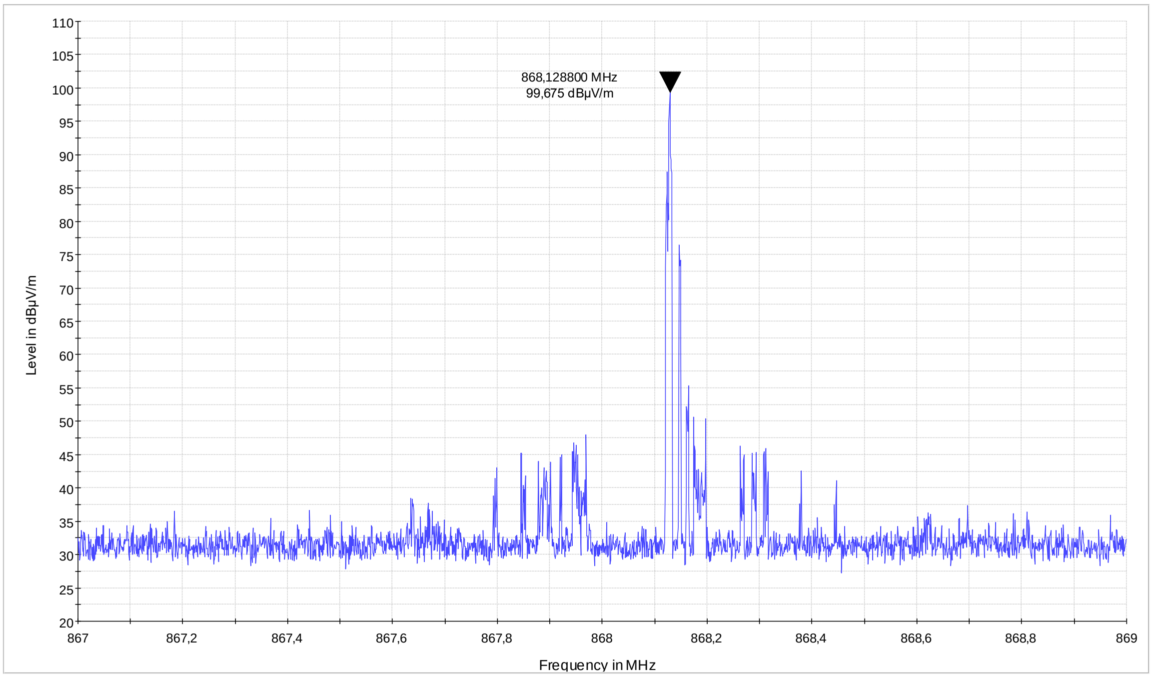

Fig. 12. Spectrum transmitted by Jablotron JA-151M

In the figures 9 to 14, there are screenshots of the measured spectra for all of the above mentioned devices. As it was mentioned above, the receiver was forced to continuously cycle through the frequency range until the maximum values were detected. Apart from the spectra, waterfall diagrams of the transmitted signals were also recorded. An example of such diagram is depicted in Fig. 15. It shows that different signs of the transmitted message generate specific spectrum. It also shows that the signs last a specific period of time.

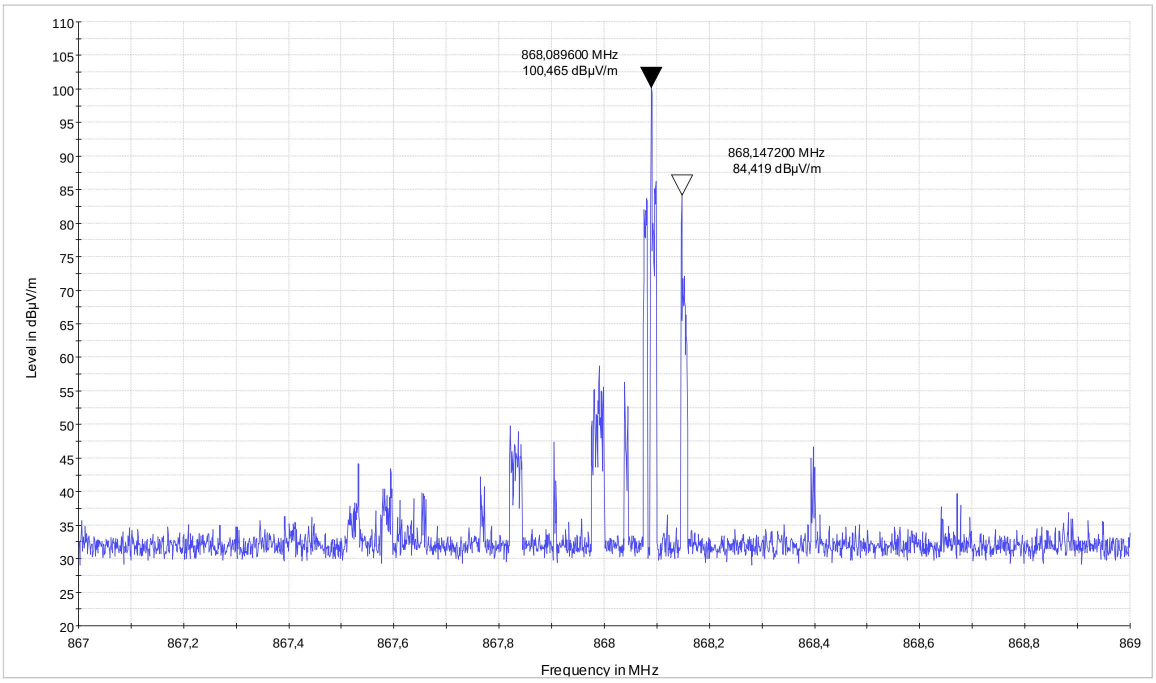

Fig. 13. Spectrum transmitted by Jablotron JA-180B

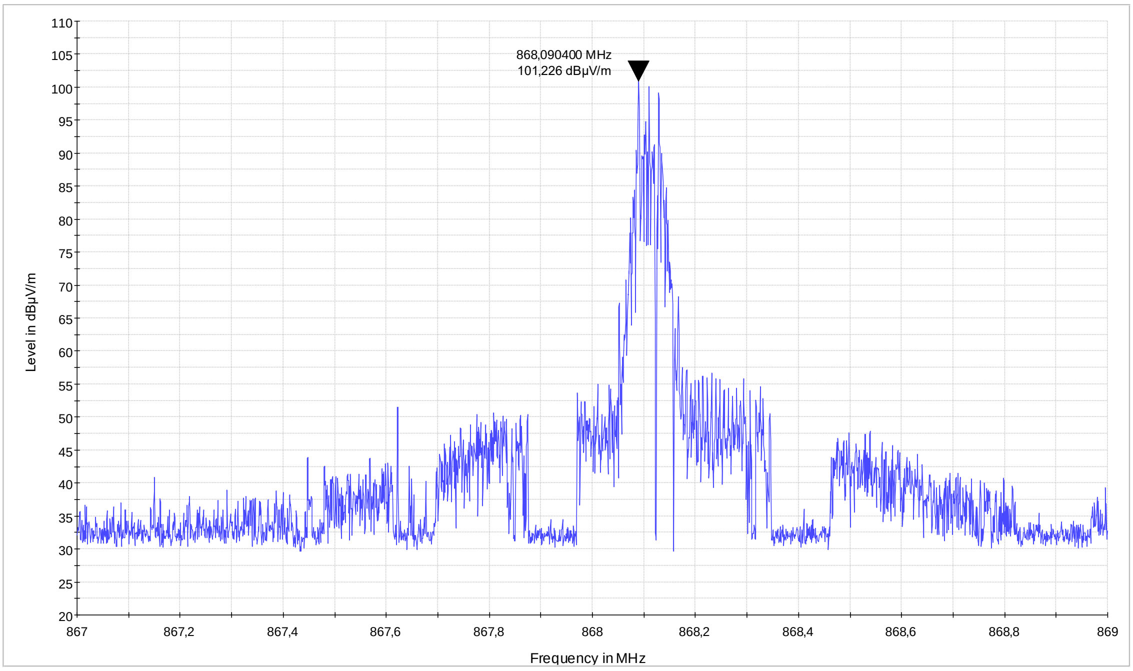

Fig. 14. Spectrum transmitted by Jablotron JA-160PC

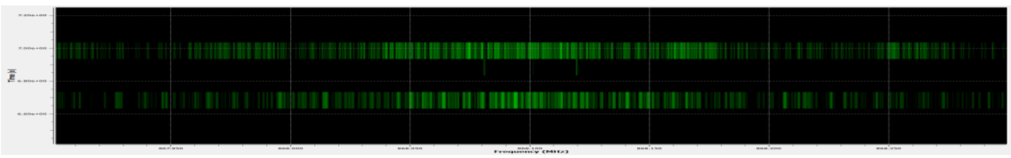

Fig. 15. Waterfall diagram – example of a piece of the message sent by a device. The x axis represents frequency in a narrow band around the nominal transmitting frequency while the y axis represents time.

VI. Conclusions

In this paper a description of the experiment consisting of measurement of the electromagnetic field intensity generated by various wireless alarm devices produced by Jablotron is provided. It was observed that the intensities of the emitted radio fields were in accordance with expectations, in other words, they were considerably low compared to the relevant hygienic limits. On the other hand, the transmitters' ranges, when used inside a building, were lower than the manufacturer declared. This indicates that when the devices were designed, there probably existed an effort to reach as low power consumption as possible.

Considering the hygienic limits, the effective radiated power generated by the devices is negligible.

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