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THE ANALYSIS OF THE IMPACT OF COMMUNICATORS ON THE HEALTH OF EMPLOYEES

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Abstract: Currently, there several contradictory epidemiological studies that address the issue of the impact of electromagnetic fields on the human health. It is problematic to prove that the exposure to the electromagnetic field causes health problems or direct health damage. The situation is all the more complicated because the effects of the electromagnetic field on human health are different for high and low frequencies. It is also necessary to note the Slovak legislation, which states that the limit and action values contained therein protect a person from the previously known effects of electromagnetic fields.
Keywords: electromagnetic field, long-term exposure, SAR, communicators

INTRODUCTION

The paper deals with the assessment of the effect of long-term exposure of humans to electromagnetic fields. The exposure is not even, as evidenced by the communicator's operating mode. The methods used have been designed with respect to technical standards, valid legislation and technical equipment available in the Slovak Republic.

ANALYSIS OF THE CURRENT STATE IN THE WORLD

The effects of electromagnetic fields are the subject of ongoing research and heated public debates. According to the World Health Organization, the electromagnetic fields of all frequencies are one of the most common and fastest growing sources of various environmental impacts. The issue also gives rise to concerns and speculations. At present, the whole population is exposed to electromagnetic fields, and the development of new technologies only increases the exposure.

The use of new technological procedures significantly improves working conditions, however, devices generating electromagnetic fields have created new problems and pose higher demands for protection of workers from their impact. The danger of electromagnetic fields and permanent magnetic and electrostatic fields is aggravated by the fact that they cannot be detected by the sensory organs of humans.

This issue is addressed by several authors in their research. T. Wessapan, in his publication "Temperature induced in human organs due to near-field and far-field electromagnetic exposure effects" deals with the biological effects of electromagnetic radiation on the human organism and its sensitive organs which are the result of absorption of the electromagnetic field.

The author also considers SAR and heat transfer in a heterogeneous human body model. In the paper "The role of electromagnetic fields in neurological disorders" M. Terzi attempted to point out the link between electromagnetic fields and human neurological disorders. Transmissions in electromagnetic channels are analyzed in a paper "Capacity of Continuous-Space Electromagnetic Channels with Lossy Transceivers" by W. Jeon. The study on SAR distribution using the modified FDTD method was performed by Wang, J. in "Study on SAR Distribution of Human Body on the Vehicle Platform Using a Modified FDTD Method".

In the paper, the author addresses the characteristics of the SAR in a human body while in the vehicle in the presence of a high-intensity intensive electromagnetic pulse (IEMP) using finite-difference time-domain method (FDTD).

Another author, who researched the impact of the electromagnetic field on the health of the population, was L. Diez in "Electromagnetic Field Assessment as a Smart City Service: The SmartSantander Use Case", where he proposed a completely new approach to monitoring the effects of wireless communication. Reducing exposure of electromagnetic radiation from WSN through transmission planning is addressed by D. Dragomir in the publication « Reducing EMF exposure from WSNs using transmission scheduling».

DESCRIPTION OF ELECTROMAGNETIC FIELD SOURCES

The subject of the research was the Quail Digital Pro7 Headset System Communicator. It is designed to improve team productivity in retail, restaurants and other work processes that require ongoing communication. Headsets enable employees to handle customers with better flexibility, make troubleshooting and search for help easier, enable fast location of inventory, expert advice, and faster service.

Figure 1. Headset communicator Quail Digital Pro 7 Headset System

The system includes wireless lightweight digital headset for up to 30 users with the option of integrating headphones with cash registers, POS systems, customer help, and passive alarm systems and a base station. The communication is limited to 6 participants at the time. Figure 1 shows the headset.

The sources of the electromagnetic field and its parameters are as follows:

1. Base station Pro7 typ Q-P7BS,
   - # operating frequency for Europe 1.88 - 1.90 GHz,
   - # DECT transmission power for Europe 250 mW,
   - # dimensions 250 x 160 x 40mm,
   - # power 100 – 240 V AC,
   - # weight 310 g.
2. Cordless headphones with microphone Pro7 typ Q-P7HS,
   - # operating frequency for Europe 1.88 - 1.90 GHz,
   - # standard Talk Lock and PTT,
   - # Lithium-ion battery 3.7 V,
   - # weight 23 g

The base station is a wireless transmitter with a DECT receiver without the need for a license. The external power supply operates at a voltage of 48 V DC. The system can be expanded to multiple bases up to a maximum of 20. In a closed communication, the network is connected by the Cat5 cable.

The typical reach of the base station is 50 meters indoors and up to 100 meters outdoors. Internal walls, staircases, partitions, especially concrete with metal fittings, building fabrics and room height may affect the range.

MEASUREMENT METHOD

We made use of methods that are based on current technical standards and relevant legislation. Measurements must be carried out in such a way as to eliminate the impact of any other sources. The operating mode of the device and its actual radiated intensity must also be assessed with regard to the time mode.

We identified two EMP sources.

» the headset - subject to our research - due to its location directly on the head

» the base station that allows the transfer of information between the headset.

The measurement was performed with a probe with a frequency range from 420 MHz to 6 GHz. The instrument has an automatic measuring range, RBW - 1 MHz, minimum display frequency Fmin - 1800 MHz, maximum display frequency Fmax - 2000 MHz. The measurements took place in close proximity to the auditory organ and in close proximity to the Q-P7BS base station. The measurements were performed in an electromagnetic compatibility laboratory in the EMC chamber at the Department of Electrical Power Engineering of the Technical University in Košice, see Figure 2.

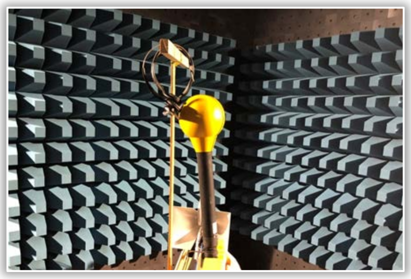

Figure 2. Measurement in EMC chamber

HEALTH PROTECTION REQUIREMENTS

Thermal effects are the most frequent manifestation of high frequency electromagnetic fields. Heat is one of the forms of energy and is given by the overall kinetic energy of the disordered movement of molecules. The higher the kinetic energy of the molecules, the more heat the substance radiates.

The absorption of electromagnetic radiation in the human body is manifested by an acceleration in the movement of the molecules of the tissue and thereby the increase in its temperature. The total amount of energy absorbed in the tissue depends on the water content of the tissue. Values of intensity and power density of electromagnetic fields which cause an overall or local rise in temperature that exceeds the thermoregulatory capabilities of the organism are perceived negatively as they have a negative effect on the human organism. Typically, the power density is 10 mW.cm-2 which is also a limit for the occurrence of the thermal effect called hyperthermia. Heat effects increase significantly with rising frequency.

Higher-frequency electromagnetic radiation penetrates into the body and causes attenuation in the tissues. The most endangered organs include eyes, the brain and the male sex organs. Warming of the eyes is associated with a high risk of their damage, as the eye lens can get rid of heat only with difficulties. Very high intensity of high frequency fields can also cause death from overheating.

For people working in the electromagnetic field (e.g. radar staff), the effect of the electromagnetic field on the eyes is manifested by eye fatigue, vision changes, reduced color sensitivity, and reduced sensitivity to the light stimulus. There is a cumulative effect (repeated irradiation and EMP below acceptable levels). The impulse array is more effective than the uninterrupted field in terms of negative effects.

EFFECTS OF HIGH FREQUENCY ELECTROMAGNETIC FIELDS

In Slovak legislation, only thermal effects of high frequency electromagnetic fields are addressed. Nevertheless, the results of recent research have shown high frequency electromagnetic fields have various effects on humans, although the results obtained by monitoring people exposed to the radio frequency electromagnetic field are often contradictory. Non-thermal effects often occur only under certain, precisely defined field parameters.

The course of the disease usually has three stages:

» At the onset of the disease comes the neurasthenic syndrome.

» The next stage is characterized by increased, sometimes decreased blood pressure and vascular problems.

» Next appears hypothalamic syndrome, cardiovascular disorders with changes in ECG, blood disorders and changes in the endocrine system.

Based on these effects, some scientists regard the electromagnetic field as a non-specific biological stressor that is detected by the nervous system. Stress of this type can be a risk factor influencing the emergence of certain stress-related diseases.

The exposure action values with regard to the electromagnetic field were set based on the frequency range used by the communication units specified in Government Order no. 209/2016 Coll., see Table 1.

Table 1. Exposure action values

Frequency band	Exposure action values	
	Intensity of the electric field E V.m^{-1}	Flow rate of equivalent plane wave S_{eq} W.m^{-2}
2 GHz - 6 GHz	140	-

The SAR_L limit values for health effects at frequencies ranging from 100 kHz to 6 GHz are shown in Table 2.

Table 2. SARL limit values for health effects at frequencies ranging from 100 kHz to 6 GHz

Health effects	SAR_L
The body's thermal load expressed as the mean SAR absorbed by the entire body of a person	0,4 W/kg
Localized heat stress in the head and torso of a person expressed as localized SAR in body	10 W/kg
Localized heat load in the limbs of a person expressed as a localized SAR in person's limbs	20 W/kg

MEASUREMENT METHODOLOGY AND RESULTS

Given the nature of the source under consideration (headset), the ideal device for assessing EMP parameters would be a phantom head intended for specialized measurements. However, such a head is not available in the SR, so we used other available methods. We used two types of measurements with corresponding probes of different shapes and different technical parameters. All measurements were made in the shielding chamber that prevented any interference.

The analyzers used the frequencies of 1800 MHz to 2 GHz. The results of the frequency-selective measurement of the electric field (E) intensity with the assessment of its impact on the employees are shown in Table 3. The measurement made use of an RMS detector that measures the intensity of Eef field. In the case of frequency-selective measurements, the following shall apply: Σ (EefP / Ea) 2 - all signals whose level is greater than 30 dB below the maximum measured level must be less than 1.

The maximum electric field intensity values were recorded for addressing impulses (recorded duration was milliseconds), these, however, did not have a significant impact on the outlined values. Nevertheless, these impulses are included in the calculated values.

Table 3 Results of the measurement of the electric field intensity - impact on employees

Measurement place	Frequency band	Measured effective value of electric field intensity	Estimated effective intensity value of the electric field	Action values according to the Decree of the Ministry of Health of the SR no. 534/2007 Coll.	$(EefP / E_a)^2$
	f V/m	Eef V/m	EefP V/m	Ea V/m	
M1	1800 ÷ 1900	1,54	2,00	140	2,00 E-03

Measurements were performed in different modes and with different number of communicators in operation. The results of the measurements of the electric field intensity as well as the frequency spectrum of the electromagnetic field are shown in Figures 3 - 8.

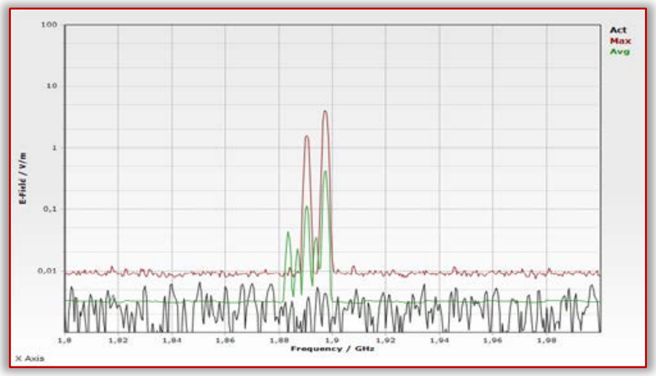

Figure 2. The communicator in the operating mode placed directly on the desk

Average value 0.47 V / m, maximum value 5.46 V / m.

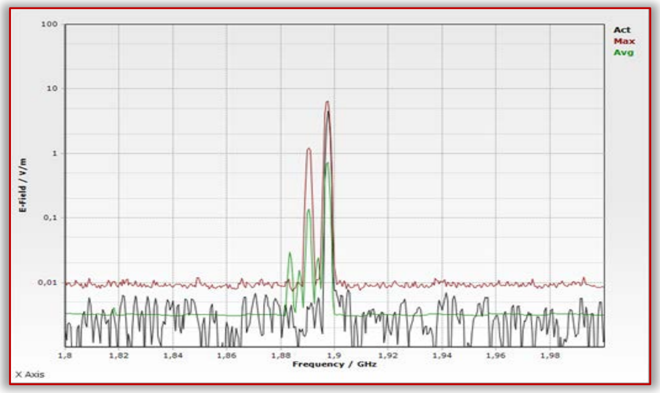

Figure 4. Communicators in standby mode hanging next to each other

Average value 0.76 V / m, maximum value 8.01V / m.

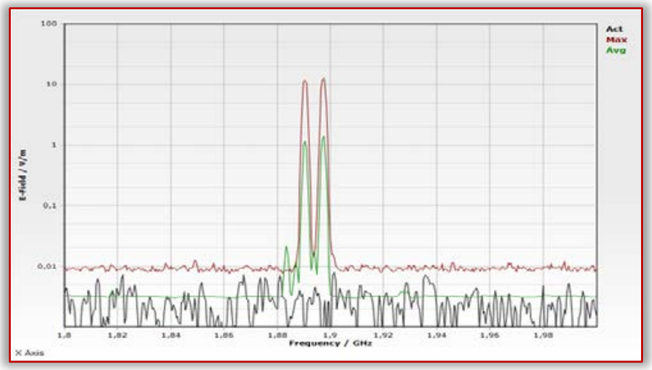

Figure 5. Measured base station in close proximity when three communicators were being used

Average value 1,53 V/m, maximum value 22,14 V/m.

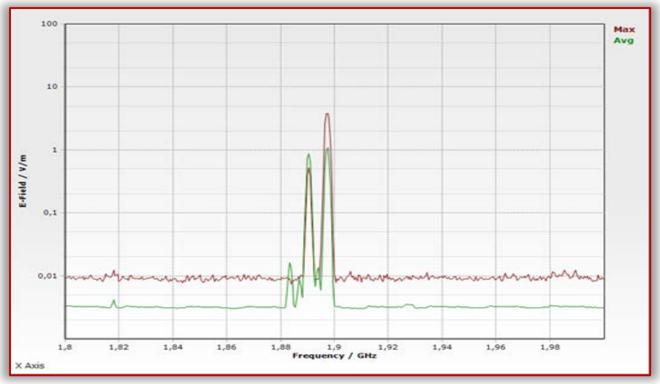

Figure 6. The communicator in operation on the head of the participant

Average value 1.54 V / m, maximum value 4.84 V / m.

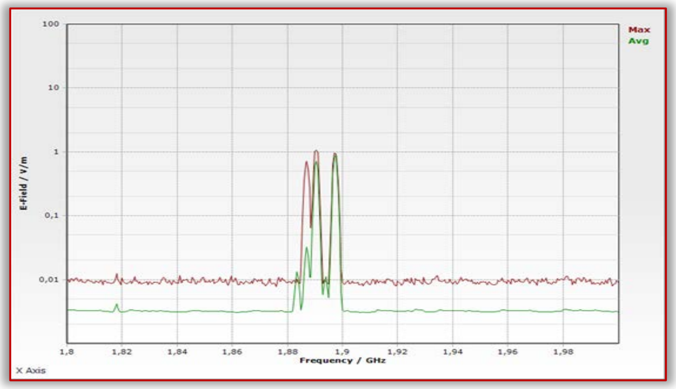

Figure 7. Measurement of 3 switched off communicators hanging next to each other

Average value 1,25 V/m, maximum value 1,94 V/m.

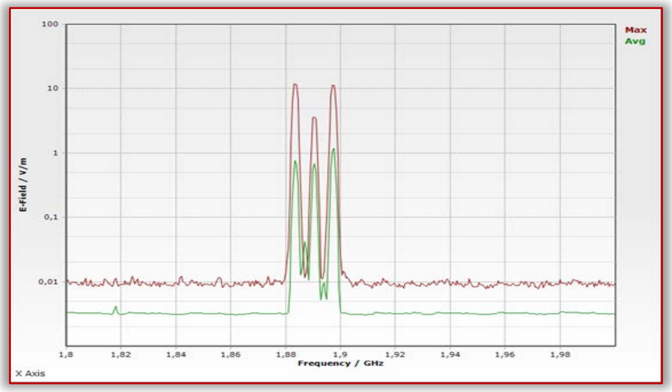

Figure 8 Measured router in close proximity of switched off communicators

Average value 1,25 V/m, maximum value 1,94 V/m.

SAR CALCULATION

In order to assess the impact of the communicator on the employee, an important value is the Specific Absorption Rate (SAR). It expresses the extent to which the body absorbs energy emitted by the high-frequency electromagnetic field. It can also be defined as the absorbed power of the weight unit of the biological organism. The SAR is usually calculated for the whole body or for a small sample of body volume, usually 1g or 10g of tissue as follows:

$$SAR = \frac{d}{dt}\frac{(\Delta W)}{(\Delta m)} = \frac{d}{dt}\frac{(\Delta W)}{(\rho \Delta V)} = \frac{\sigma E^2}{\rho}$$

where: ΔW – energy gain

Δm – weight gain in volume elements ΔV, whose specific weight is ρ,

E – the effective value of the electric field strength in the tissue

σ – electrical conductivity of the tissue

The localized heat load in the head, expressed as the localized absorbed SAR calculated based on:

» of the measured field strength E, see. tab. 3,
» the relative conductivity of human body tissues for frequencies 1800 – 1900 GHz v [Sm-1]:

Brain: σ = 0,35 Sm-1,
Skin: σ = 0,8 Sm-1,
Muscle: σ = 6,0 Sm-1,
Bone marrow: σ = 1,0 Sm-1.

in our calculations, we took into account the most unfavorable value (muscle = 6.0 Sm-1). The average weight of the human body is ρ = 1,025 kg / dm3. On the basis of the above values we calculated SAR. The results are shown in Table 4. It is obvious that the effective value of the intensity of the electric field in the tissue is smaller than at the measured point - between the communicator and the head of the participant.

Table 4. Calculated SAR

Calculated SAR	Assessed value	Limit value	Exceeding
0,014 W/kg	0,18 W/kg	10 W/kg	-

In the technical regulations the manufacturer outlines the following value: SAR = 0,056 W/kg.

CONCLUSION

Based on the results of the examination of the parameters of the electromagnetic field emitted by the communication system, we can state that the values are in accordance with the Slovak legislation. When compared to the action values, measured values are so low that the question arises whether there is a need to deal with such sources of electromagnetic field and their impact on a human beings.

Other research shows, however, that the long-term effects of EMF on humans are evident. The results are often contradictory, though. The aim of the paper is to extend knowledge on the topic of the effects of EMF on humans.

Acknowledgement

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Bibliography

[1] LUMNITZER, Ervin et al.: Metodológia komplexného hodnotenia zdravotných rizík v priemysle I . Zręcin : MUSKA - 2015. - 240 p.
[2] LUMNITZER, Ervin et al.: Metodológia komplexného hodnotenia zdravotných rizík v priemysle II. Zrecin: MUSKA, 2013. 326 s.
[3] LUMNITZER, Ervin et al.: Hodnotenie vplyvov fyzikálnych faktorov na zdravie človeka. TU, 2014.159 s.
[4] WESSAPAN, Teerapot: Temperature induced in human organs due to near-field and far-field electromagnetic exposure effects. International journal of heat and mass transfer, 2018
[5] LUMNITZER, Ervin et al.: Elektromagnetické polia v životnom a pracovnom prostredí. Objektivizácia a hodnotenie faktorov prostredia. 1. vyd - Košice : Technická univerzita - 2014. - 96 s.
[6] TERZI, Murat: The role of electromagnetic fields in neurological disorders. Journal of chemical neuroanatomy, 2016
[7] WONSEOK, Jeon: Capacity of Continuous-Space Electromagnetic Channels with Lossy Transceivers. Ieee transactions on information theory, 2018, str. 1977-1991
[8] WANG, Jian: Study on SAR Distribution of Human Body on the Vehicle Platform Using a Modified FDTD Method. Ieee transactions on electromagnetic compatibility, 2018, str. 840-848
[9] DIEZ, Luis: Electromagnetic Field Assessment as a Smart City Service: The SmartSantander Use-Case. Sensors 6, 2017
[10] DRAGOMIR, Dan: Reducing EMF exposure from WSNs using transmission scheduling. Concurrency and computation-practice & experience 23, 2017