http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 12
Number 1
March 2018
DOI: 10.12716/1001.12.01.21

Protection Against High-Frequency Radiation of Aviation Electronic Support Systems Used in Air Transport

M. Dzunda, D. Cekanova, L. Cobirka, P. Zak & P. Dzurovcin
Technical University of Kosice, Kosice, Slovakia

ABSTRACT: The aim of the article is to analyze the impact of electromagnetic radiation of aviation electronic support systems on environmental segments and a human organism. We were looking for effects of electromagnetic radiation on inhabitants and environment in the vicinity of airport radars. We accomplished measuring and found out the level of radiation harmfulness of electromagnetic radiation sources. In the conclusion we suggest to eliminate the negative impact of electromagnetic radiation on the human organism. At the same time we present the ways how workers, performing their jobs in the vicinity of strong electromagnetic radiation source, can protect themselves in compliance with legislative of the Slovak Republic. We have proposed some possibilities of protection for workers who work close to a strong source of electromagnetic radiation.

1 INTRODUCTION

Ecology is the science, the branch of biology that studies the relationships between the organisms and the environment and the relationships between living organisms themselves. The definitions of ecology generally express that the subject of studying the ecology is a living matter on different stages of organization, its external environment which consists of open Biosystems [Trnka A., Peterkova P. & Prokop P. 2006]. At the same time, studied objects of ecology may be on the different biological level. Elements of the environment are divided into biotic, abiotic and abiotic-biotic. The biotic elements include living organisms (plants, animals, humans), an abiotic part consists of the inanimate elements (air, water, rocks) and abiotic-biotic component consists of a combination of animate and inanimate components.

Electromagnetic radiation is characterized as a transfer of energy in the form of electromagnetic waves. The individual electromagnetic wave is therefore a locally formed change in the electromagnetic field.

Electromagnetic smog is increasingly being mentioned in respect of electromagnetic radiation to the environment. Electromagnetic smog is produced in a dense tangle of electromagnetic fields, mostly in densely populated areas or near sources of electromagnetic radiation, where several sources simultaneously occur.

Aviation electronic safety technology as a source of electromagnetic radiation is a potential risk [Cekan P., Hovanec M. & Sabo, J. 2016] to the surrounding ecosystem emits continuous radiation waves into the surrounding space [Vagner, J., Jencova, E. 2014]. It is therefore necessary to investigate the effects of high frequency energy radiation on the surrounding environment and look for opportunities to protect it against this radiation [Tobisova, A., Pappova, E. 2014].

2 OVERVIEW OF AIR ELECTRONIC SAFETY TECHNOLOGY

Air Traffic Services of the SR are using communication, radio navigation and radar systems to control air traffic [Gajdos, J., Socha, L. & Mihalcova, B. 2014, Socha, V. 2016]. Communication systems are operating at frequencies of 100-150 MHz. The output power of these systems is 5.0 to 20.0 W. The primary surveillance radar is operating at frequencies of 2-4 GHz. Transmitted power of these systems is 14-25 kW. The power of older types of radar is several hundred kW. Secondary radars operate at frequencies of 1030 MHz and 1090 MHz. Transmission power of a device is about 2 kW[Melnikova, L., Cibereova, J. & Korba, P. 2016].

NDB navigation systems and ADF work on the frequency kHz 200-525. Transmission power of a device is 25-50 W. VOR operates on a frequency MHz 108-112. Transmission power has a 25-100 W. DME measures the distance and works on the frequency 960-1215 MHz. Transmission power of a device is 100 W.

The ILS precision approach:

- Localizer LLZ (device frequencies: 108-112 MHz, transmission power 2W)
- GP Glide path beacon (device frequencies: 328.6 to 335.4 MHz, transmission power 2W)
- VHF marker beacons (frequency 75 MHz, transmission power 3W)

3 MEASUREMENT OF THE ELECTRIC FIELD IN VELKA IDA

Near the village Velka Ida in the place with the coordinates N48º 36'51,9 "E21 º 08 '47.14" we made measurements of the primary radar electric field (PRL).

The measuring instruments were used as follows:

- Spectrum Analyzer - Advantest R3271A, Serial No .: J001158
- Antenna - EMCO 3115 DOUBLE GUIDE RIDGE HORN, Serial No .: 4974
- Attenuator - 50Ω / 36 db
- Coaxial cable with N connector - 50Ω Coax 3m, type M17 / 75 RG-214
- Generator - 220V / 50Hz: HONDA EM30 PC

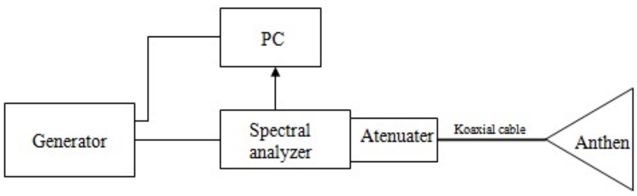

Figure 1. The connection diagram of devices during the measurement

3.1 *Measured values*

On the site we observed the field strength of six channels, and we reached the following measured values:

Table 1. The values of measurement

Frequency [GHz]	Measured Values [mV]	Intensity [V.m-1]
2,709	214,2	7,98
2,829	807,8	31,37
2,955	69,2	2,81
2,978	4398,0	179,84
3,016	699,5	28,99
3,098	741,0	31,58

The values of the electric field are in the range of 2.81 to 179.84 W / m. The measured values are the peak values of the electric field.

Allowed values of the electric field are assigned in the decree of the Slovak Republic Government No. 329 on the minimum health and safety requirements protecting workers from the risks related to exposure to electromagnetic fields. The action values are expressed in effective values for continuous exposure[Pavolová H. & Tobisová A. 2013].

Allowed values of the exposure to the electric field for the population are set out in the Decree No. 534 of the Ministry of Health of the Slovak Republic on the details of the requirements for sources of electromagnetic radiation and limits for citizens' exposure to electromagnetic radiation in the environment. The action values are expressed in effective values for continuous exposure.

We evaluated the electric field impact in order to protect workers and citizens in accordance with the Slovak Government regulations No. 329/2007 and the Ministry of Health Decree No. 534/2007.

The value of the intensity of the electromagnetic field for continuous exposure of employees in the frequency range of 2 GHz - 300 GHz is 137 V / m. The specified value for continuous exposure of the population in the same frequency range is 61 V / m[Sebescakova, I., Rozenberg, R. & Melnikova, L. 2013].

3.2 *Results of measuring*

The effective value in the measuring point is equal to the square root of the time average of the square of the field strength E (t) over the period:

$$E_{ef} = Eef = ((1 / T) \int E(t)dt)^{0,5},$$

where in T = 1/f - is the period of the oscillating parameters, and f is the frequency (s^{-1} = Hz). After substituting into the above equation we can formulate E_{ef} , as follows:

$$E_{ef} = 0{,}707.E_{šp}$$

After an analysis of how the radar works (PRL) close to Velka Ida, it can be assumed that the pulsed electromagnetic field has a pulse character with a width of 0.9 to 3.1 microseconds and a repetition period of 300-1275 Hz.

The maximum measured value of the electric field in the introduced measuring point is equal to $E_{šp}$ = 179.84 V/m. The maximum effective value of the electric field at the measuring point is equal to E_{ef} =

127.14 V/m. After comparing the measured effective values of the electric field at all frequencies with the maximum permissible action values for the exposure of employees, we have found out that the measured values do not exceed the maximum permitted levels.

If there is a simultaneous exposure to fields from several sources with different frequencies, the thermal effect applying at frequencies exceeding 100 MHz shall not exceed the action value if the followed inequality is valid:

$$\sum_{100kHz}^{1MHz}\left(E_{\mathrm{i}}/c\right)^{2}+\sum_{f<1MHz}^{300GHz}\left(E_{\mathrm{i}}/E_{L,i}\right)^{2}\leq 1$$

where E_i denotes the electric field with a frequency of "i", $E_{L,i}$ is action value of the electric field for the i-th frequency, $c = 610.10^6/f$, V/m. When measuring we found out the presence of an electric field with a frequency greater than 1.0 MHz, so the first member of an inequality on the left side equals zero. By substituting we obtain the inequality of 0.93 <1.0. By calculation, we have confirmed that the heat of an electric field in the measurement does not exceed the action value.

The maximum measured peak value of the electric field of the $E_{šp}$ = 179.84 V/m does not exceed 32 times the allowable action field intensity equal to E_L = 61 V/m.

The radiant heat exposure to an electric field, shorter than those determined for centring, or a series of short-term exposures acting during the time shorter than designed for centring doesn't exceed the action value if the exposure time " t_i "and the measured levels of fields Ei in the range from 100 kHz to 10 GHz meet the inequality:

$$\sum\left(E_i^2 t_i\right)\leq\left(6E_{L,i}{}^2\right)$$

where t_i is the time of the i-th exposure expressed in minutes. For i-th exposure during the 6 minute interval, we determined the parameters of the transmitted signal PRL. The width of the transmitted pulse PRL is 3,1 μs, repetition period of 1275 Hz. Over a period of 6 minutes t_i will be equal to 0.0237. After substituting into the relationship (4) we have received the inequality 417.40 <22326.0.

The inequality is met. We hereby confirm that the radiant heat exposure to an electric field does not exceed the action values for the field.

In the range of frequencies from 100 kHz to 300 GHz, we assessed the effect of field temperature with regard to identified action levels during the exposure to an electric field and magnetic field of the same frequency or different frequencies (according to the Decree 534/2007 Z.z.). Substituting the parameters into a relationship, we get the inequality:

2.5. 10-3<1

Radiant heat at the point of measurement does not exceed the action value because the above mentioned inequality has been met.

4 CONCLUSION

The measurement results obtained by the analysis demonstrate that the effect of the electric field in the vicinity of Velka Ida, which is in the range of 2.709 to 3.098 GHz, does not exceed the action values for exposure of workers and the citizens. Even though, it is appropriate to be protected from the high-frequency radiation [Cekan P., Korba P. & Sabo J. 2014].

The basic types of protection from non-ionizing electromagnetic radiation:

- distance,
- time,
- shielding of the workplace,
- protective work equipment

Protection methods:

- Protection by distance
  The workplace close to the electromagnetic radiation should be kept as far away from this resource as possible. The workplace should not miss signalling and warning that the one is close to the electromagnetic field.
- Protection time
  Protection time means the exposure of workers to electromagnetic fields only for a certain period of time, to avoid possible serious consequences of prolonged exposure close to the source field. Likewise, in the case of mobile phones, one of the recommendations to minimize the consequences of the radiation is to shorten the talk time to a minimum.
- Personal protective equipment
  Personal protective equipment for workers is used in cases where there is perhaps no other protection of the above. Most often it is a complete suite for the protection of the entire body (suit, helmet, gloves and boots). They may also be independent parts of clothing for individual parts of the human body. They must be made of materials that do not prevent worker's free movement.
- Protective shielding of the workplace
  Workplace protection against electromagnetic radiation is performed in a similar manner as the shielding for radiation. Protective sheets, foils and network in this case are installed in walls of a particular job. There are other ways of protecting the space from radiation such as different coatings and spraying with metal particles, window films, curtains and blinds containing metals. Protection by shielding the workplace was used in planning the construction works of a logistics center (LC) in Velka Ida. The [Džunda, M. 2010.] analyzed in details the possibility of protecting people against the radar high-frequency radiation, which is located in Velka Ida. One possible way of protection against the radar high frequency energy is to build a protective wall which would prevent the penetration of radiation into space in which people move. The protective wall, which was constructed near Velka Ida, is shown in Fig. 2.

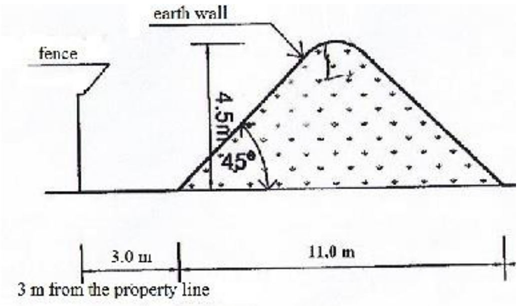

Figure 2. The protective wall constructed in Velka Ida.

The height of the protective wall is 4.5 m and is located in front of the buildings of LC on a line perpendicular to the connecting line between LC and Radar in Velka Ida. Fig. 2 clearly shows that such a protective wall provides sufficient protection against radar HF radiation near Velka Ida.

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