XVIII-th International Conference on
Electromagnetic Disturbances
Vilnius, Lithuania, 25-26 September 2008

EMD 2008

ASPECTS OF HUMAN PROTECTION FROM ELECTROMAGNETIC FIELDS

Kazimieras MACEIKA
Kazimieras.Maceika@el.vgtu.lt
Vilnius Gediminas technical university

***Summary*:** Lithuania has standards for limitation of electromagnetic fields level radiated by sources from industry frequency till microwaves. The paper makes acquaintance with the main requirements for human protection according these documents. Implementation is shown on an example of powerful radars installed in Vilnius airport.

Keywords: electromagnetic disturbances, protection from electromagnetic fields, radar.

1. Introduction

Ministry of Health Care of Republic Lithuania published normative for public health protection from electromagnetic field of various frequency bands. In normative [1] permitted values and measurement requirements of electromagnetic field in work places and residential area are described in 10 kHz-300 GHz frequencies. Calculations of intensity around powerful radiation sources are very simple and have been used many times [2]. In case of pulsed radiation it is necessary to use an average value of radiated power. The pulse duration is hundred times shorter than pulse repetition period, thus an average value of power density is hundreds times lower than a peak value of the radiation. Additionally the rotating radar antenna radiates electromagnetic field at the measurement point periodically within a very short time, which strongly depends on the width of the main lobe of antenna pattern and their scan sector. Results of calculations can be compared with permitted levels of electromagnetic radiation [1] and practical conclusions can be made before equipment establishing. Example of evaluation of radar antenna radiation intensity is shown in this paper. The found radiation is many times smaller than the permitted level and is not dangerous for population. In the last publications [3] have confirmed occurrence of various biological effects, which have been evoked by pulsed microwave radiation in humans and animals. In such exposures, e.g. from radars, the energy may reach very high values of power density in peak, at relatively low levels of power density averaged in time.

Low frequency 50 Hz fields differ from microwaves and have small energy to increase temperature of body if intensity of electric field is smaller than 1 MV/m. At this low frequencies the electric and magnetic fields act independently of one another. Any device connected to an electric outlet, even if the device is not switched on, will have an associated electric field that is proportional to the voltage of the source to which it is connected. Magnetic field depends on current which flows in circuit. Both electric and magnetic fields exist close to the lines or appliances and drops off with move away from source. Protection from fields of powerful high voltage electricity transmission lines in Lithuania is described in normative for electric field because it is constant for concrete voltage line

In 1996 the World Health Organization established the International Electromagnetic Fields project with reviewing results and conducting risk assessment for exposure to static and extremely low frequency fields [4]. Studies related to carcinogenicity of low frequency electric and magnetic fields established that they are possibly carcinogenic to humans.

Lithuanian permitted levels of electromagnetic radiation are similar to usable in European countries [5].

2. Human protection from overhead electricity lines electromagnetic fields

European states have prepared standards with limitation of electromagnetic fields level near to high voltage electricity transmitting lines. Lithuanian Ministry of Health Care prepared hygiene’s normative [6] which directs electromagnetic fields caused by industrial frequency transmitting lines if voltage is 330 kV and more. It restricts only electric field intensity and proposes these permissible values:

- inside of residence and public purpose buildings – 0,5 kV/m and in their territory -1 kV/m without time limitations,

- in urbanized territories and suburban green zones – 5 kV/m without time limitations,
- in automobile highways and country roads – 10 kV/m, if transport stays under electricity line no longer 2 h,
- in uninhabited residences, where transport can move and agriculture fields are – 15 kV/m with limited time of exposure 1 h.

The new 330 kV or more voltage electricity transmission lines must be designed at distance more than 250 m from residence buildings. Only at special cases the distance can be reduced till 20 m with permission of public health service, if electric field intensity under wires is smaller than 5 kV/m.

Fig. 1 shows levels of electric field near to high voltage 330 kV overhead power lines at 50 Hz.

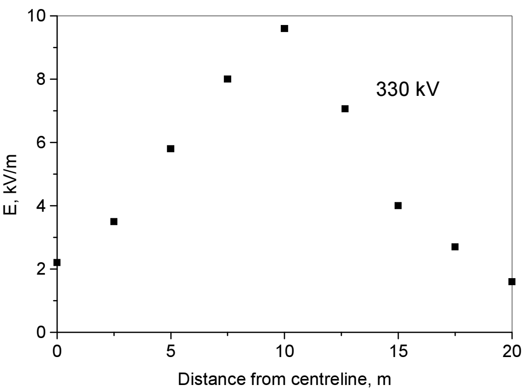

Fig.1. Dependence of electric field intensity from distance till high voltage overhead power lines

Population health is preserve from action of electricity lines due establishing of sanitary protection zones (SPZ). In the SPZ territory economy activity is forbidden or limited, in spite of plant growing or exploitation of former built buildings, if mentioned field levels are not exceed.

Technical means can be used for population protection due reducing electric field intensity by special screens and their grounding, mowing away buildings from electricity lines, planted trees and etc. Buildings attenuate electric fields considerably and their strength may be one to three orders of magnitude less inside a building than outside it. Electric fields to which people are exposed inside buildings are generally produced by internal wiring and appliances, and not by external sources.

Swedish, Russian and American specialists declare that long time non dangerous for carcinogenic risks exposure of 50 Hz magnetic field flux density not exceed 0,2-0,3 µT. Ministry of Health Care of Lithuania Republic prepared new normative for evaluation of electromagnetic fields permitted levels of occupational exposure [6]. They depend on existence time at work places. The extract from normative is taken in Table 1.

Table 1. Permitted values of industry frequency (50 Hz) electric and magnetic fields in work places on exposure duration.

Time of exposure, min	Permitted intensity of E, kV/m	Permitted H, kA/m
10	25,0	5,1
120	14,3	3,5
240	9,1	2,3
360	6,7	1,4
480	5,3	1,0
More 480	5,0	0,9

It is forbidden to work in places where intensity of electric field is greater than 25 kV/m and magnetic field than 5,1 kA/m.

3. Permitted levels of microwave electromagnetic radiation

Lithuanian hygiene's normative [1] describes permitted level of electromagnetic radiation of stationary electronic systems in living and work places in our republic. In frequencies band over 300 MHz of continuous oscillation the power flux density on 2 m above ground surface cannot be greater than 10.0 µW/cm^2. In European standard [5] the permitted level of power flux density is the same. In normative [1] the safe average level of power flux density in case of pulsed radiation is named - 20.0 µW/cm^2 because radiation heats the human body during short pulse time and the body is turning cold during a long pause between pulses. Separate description of permitted levels of electromagnetic radiation is proposed for people working places. In frequencies band 300 MHz-300 GHz the permitted flux density depends on exposition time [1]. If exposition duration is 5 min, the normative is the greatest – 1000 µW/cm^2. The minimal normative 25.0 µW/cm^2 is for workers exposition during 8 hours and more.

Up to now no one has proved that the relationship between a dose of radiation and biological effects has the same correlation function for weak field as well as for a very strong field in peak. It is necessary to underline that the scientists pointed out that pulse modulated fields could cause biological effects, although no effects appear when the radiation is continuous at the same average value of power density. A proposal [3] of safety limits for pulse-power density of EM radiation in general public has been mainly designed to protect humans against microwave auditory effects. This hearing effect is a hazard, suggest that it is reasonable to establish the power density limits of maximum peak-pulse value for general public and base the limits on these effects. Short pulses of microwave radiation produce audible sound into heads of humans and animals. The energy of microwave radiation is converted into heat and produces a small but rapid rise

of temperature. This rise of temperature generates rapid thermo elastic expansion of tissues in the head, which launches an acoustic wave of pressure. The auditory phenomenon evokes similar effects as sound exposure.
In frequency band 0,1 - 3 GHz the values of safety limits for pulse-power density have been calculated:

$$S_{peak\text{-}max} = (2{,}5\, f\,[GHz] + 6{,}7)\ kW/m^2 . \qquad (1)$$

In frequency range 3 - 10 GHz it has been found:

$$S_{peak\text{-}max} = (16{,}5\, f\,[GHz] - 35{,}3)\ kW/m^2 . \qquad (2)$$

In the case of safety limits in occupational exposures it is easy to notice that value of power density based on the auditory phenomenon is protective. In the real situation near to radar antennas the exposure conditions differ considerably from taken in laboratories to develop the auditory effects. The values of pulses vary, depending on the rotation of main lobes of antennas, and workers head is not exposed to the same value of peak-power density, but only during a short period of time.
They could be exposed to pulsed microwave radiation only during an 8 hours shift. There are designed limits for occupational exposure based on biological effects. with safety factor 1 : 10.
In frequency range 0,1 - 3 GHz the value of peak-power density that evokes the behavioral effects has been established as 500 kW/m^2. Taking into account the safety factor 1:10 one obtains $S_{peak\text{-}max}$ = 50 kW/m^2.
In frequency range 3 - 10 GHz

$$S_{peak\text{-}max} = (14{,}3\, f\,[GHz] + 7{,}1)\ kW/m^2. \qquad (3)$$

4. Calculation method of radar antenna radiated electromagnetic field

The density of radiated power of the powerful source is verified [2] at frequencies greater than 300 MHz. Figure 2 explains the situation.

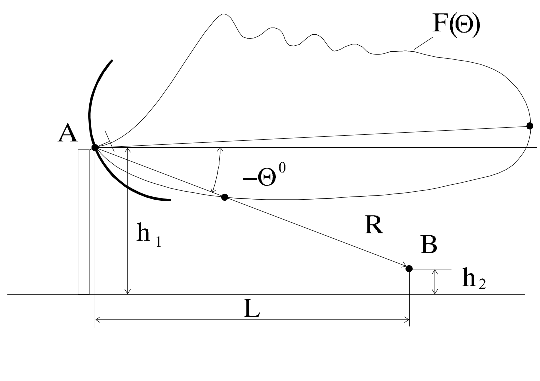

Fig.2.. Finding of antenna radiated power flux density at point B

Waves spread from the radar antenna and reach point B at level of a man's head in two ways: direct and reflected from Earth surface. The energy may reach very high values of power density in peak, but at relatively low levels of power density averaged in time. This is because the pulse duration τ of the radar radiation is many times shorter than pulse repetition T_p. Due to the rotation of the radar antenna, the point B is exposed to pulse modulated microwave radiation periodically within a very short time according to the width of a main lobe of the antenna pattern in horizontal plane. It is easy to guess that an average value of power P_{av} , averaged over pulse repetition and over a period of antenna rotation, is low:

$$P_{av} = P_{peak}\frac{\tau}{T_p}\frac{\alpha^0}{360^0}, \qquad (4)$$

in such a situation the proposed parameter to characterize the radar radiation will be average power flux density S_{av} at point B:

$$S_{av} = \frac{P_{av}}{4\pi R^2} G f^2(\theta^0)\eta(1+p^2). \qquad (5)$$

In (5) G – antenna gain in direction of maximum radiation,

f(Θ°) – antenna's pattern of directivity in vertical elevation plane,

η - efficiency factor of antenna and waveguide, less than one,

p – coefficient of electromagnetic waves reflection from ground,

R- distance AB (Fig.2) between phase centre of antenna A and observational point B.

Choosing of different values of angle Θ° permits to calculate S_{av} and to draw power density dependence on distance. Distance L can be found by:

$$L = (h_1 - h_2)/\, tg\ \Theta^o. \qquad (6)$$

As final result, dependence S_{ar} from distance L between antenna and point B can be drawn and compared with permissible level.
If P_{peak} value will put into equation (5) instead of P_{av}, the peak-power density S_{peak} will be found.

5. Results of radar antenna radiated electromagnetic field flux density

There average power flux density calculations have been made for radar in Vilnius airport. Primary radar data for calculation is taken from technical documentation:

- frequency of oscillations in radiated radio pulses - f = 2900 MHz (λ = 10,34 cm),
- peak power of transmitted impulses P_{peak} = 600 kW,
- duration of pulse τ = 1 μs.
- period of pulses repetition Tp = 1000 μs.

Characteristics of primary radar antenna AC 316 are the following:

- horizontal size of parabolic antenna D = 4,12 m,
- vertical size H = 3,3 m,
- the greatest gain of antenna G = 34,9 dB in maximum direction 3°,

- width of antenna directivity pattern in horizontal plane on 3 dB level is $\alpha°_{3dB} = 1.5°$. Side lobes are 25 dB less than the main lobe,
- antenna pattern of directivity in vertical plane has the shape $\mathrm{cosec}^2\,\theta$ up to $\Theta° = 50°$.
- rotation frequency of antenna – 0.4 Hz.

Antenna radiation investigation was made for installation height h_1=5m. Power flux density values were found at height h_2= 2 m over the ground surface. P_{peak} = 600 kW, τ = 1 μs, Tp = 1000 μs and $\alpha°_{3dB}$ = 1.5° were taken into (4) and found average power P_{av}= 2.5 W. The way of calculation of average power flux density S_{av} from distance thoroughly is described in [2]. Dependence of average power flux density on distance in case of antenna height 5 m is shown on Fig.3. Curve has a maximum for two factors. Power flux density decreases for energy dissipation in receding from radar antenna according law $1/R^2$. On another hand radiation increases with distance because in antenna's pattern of directivity in vertical plane a level of radiation is greater. Further the flux density a very fast decreases after maximum. Maximal got power flux density 0.45 $\mu W/cm^2$ at distance 115 m is smaller then the permitted level according normative - 20,0 $\mu W/cm^2$. In this case electromagnetic radiation of radar antenna is not dangerous for population.

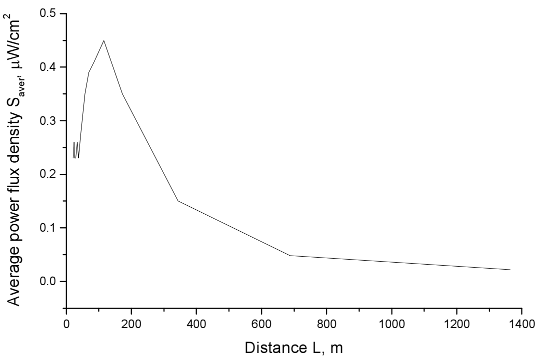

Fig.3. Average power flux density radiated by radar antenna at height 5 m from distance

It is interesting to check dangerous of acoustic effect for population from radiated pulses with peak-power value 600 kW. For frequency 2,9 GHz the $S_{peak\text{-}max}$ = 14 kW/m^2 is found from equation (1). Calculated value of radar antenna radiated peak-power flux density at distance of maximal radiation is 1.08 kW/m^2. That is many times smaller than permitted level of radiation.

6. Conclusions

1. Lithuania has confirmed normative of permitted levels of electromagnetic radiation non-dangerous for humans and animals in all frequencies band. Europe Union have the same permitted levels of radiation in frequencies band 300 MHz - 300 GHz and verifies electromagnetic field power flux density which is limited 10,0 $\mu W/cm^2$ if radiation is continuous and in case of impulse radiation - 20,0 $\mu W/cm^2$.
2. Lithuania, Russia and European countries have very strict normative with limits of electric fields level near to high voltage electricity power transmitting lines. These limitations are 0,5 kV/m in buildings and 1 kV/m in territory. Normative does not describe limitation of magnetic field, but there is known that magnetic field exposure is more dangerous than electric field and flux density must be smaller than 0,2 – 0,4 μT. Low frequency magnetic fields are possibly carcinogenic to humans
3. The evaluation method of radars antenna microwave radiation uses average value of radiated power density in calculations, which depends on two facts: radar radiates short radio pulses with long pauses between them and rotated antenna with narrow pattern of directivity in horizontal plane radiates into chosen point a short part of antenna rotation period. Result of calculation must be compared with permitted level according normative.
4. If phase centre of investigated primary radar antenna is on height 5 m, the radiated power flux density is 40 times smaller than permitted level 20.0 $\mu W/cm^2$ and is not dangerous for population. If antenna is equipped higher, the maximum of radiation intensity is further from antenna but with significant smaller amplitude.
5. The microwave auditory phenomenon has been recognized as one of the most interesting biological effects of microwave radiation. Short powerful pulses of microwave radiation produce audible sound into heads of humans and animals. The radar radiates pulse with energy 600 kW, but peak-power density 1.08 kW/m^2 is many times smaller than permitted level of pulsed radiation.

7. References

1. *Hygiene's normative HN 80:2000: Electromagnetic field in work places and residential area. Permitted values and measurement requirements in 10 kHz-300 GHz frequencies*. Ministry of Health Care of Republic Lithuania, Vilnius, 2000.
2. Maceika, K. 2008. Analysis of pulsed electromagnetic fields radiated by powerful sources, *Advances in Electrical and Electronic Engineering* 7(1-2), Zilina: 292-294. ISSN 1336-1376.
3. Kubacki, R. 2005. Military radars and assessing of exposure, *Proc. Int. Conf. on Electromagnetic Fields in the Workplace,* Warszawa: 45-47.
4. Extremely low-frequency electromagnetic fields-Who classifies the cancer risk. 2002. *Journal of Environmental Health* 65 (5) Denver, Dec. 2002: 47-48.
5. EN 50364: 2001: Limitation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 10 GHz, used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications.
6.*Hygiene's normative HN 104: 2000: Public Protection from Electric Fields caused by Electricity Lines.* Ministry of Health Care of Republic Lithuania, Vilnius.