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EVALUATION OF THE INTENSITY OF ELECTROMAGNETIC FIELDS RADIATED BY RADAR

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Abstract. A method to calculate intensity of electromagnetic fields radiated by powerful radars equipment is proposed in this paper. In such radars exposures the energy may reach very high values of power density during peaks, but relatively low levels of power density averaged over time. Calculations are made for a TA 10MTD radar according to proposed equations. It is shown that an antenna 5 m in height radiates a power flux density at the height of a man's head more than forty times smaller than the level permitted by Lithuanian law – 20.0 μW/cm^2.

Keywords: radar, microwave radiation, power flux density, permitted radiation level, public protection from electromagnetic fields, sanitary protection zone.

1. Introduction

Public health authorities require calculations of electromagnetic field intensity around radars equipment before an installed. Such evaluation takes place in spite of manufacturers' theoretical analyses and experimental measurements of the radiation issued by concrete radar. The method of evaluation is very simple and has been used many times. We make a merit of an average value of radiated power operations in calculations of antenna electromagnetic field exposure. Pulse duration is hundreds of times shorter than pulse repetition, and thus the average value of power density is hundreds of times lower than the peak value of the radiation. Additionally a rotating radar antenna radiates the EM field at the measurement point periodically within a very short time, which strongly depends on the width of the main lobe of the pattern and scan sector of the antenna. Lithuania has accredited normative defining permitted levels of electromagnetic radiation. Results of calculations can be compared to these levels and practical conclusions can be made for radar installation. An example of the radiation intensity evaluation of a Thomson radar antenna is in this paper. It is reinforced that calculated radiation is many times smaller than the permitted level and is not dangerous to the population. The real situation will become clear after the radar equipment in place and experimental tests of EM field intensity have been conducted.

2. Finding the density of radiated power

The density of the radiated power of the radar is verified at frequencies greater than 300 MHz. This density calculation method has often been used [3, 5]. Figure 1 explains the situation.

Waves spread from the radar antenna and reach point B at the level of a man's head in two ways:

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

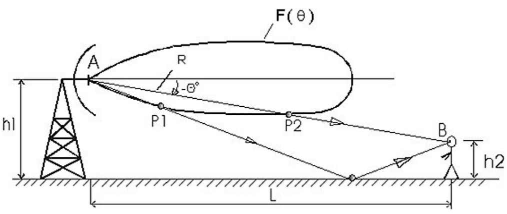

Fig 1. Finding of antenna-radiated power flux density at point B

$$P_{av} = P_{peak} \frac{\tau}{T_p} \frac{\alpha^0}{360^0}, \quad (1)$$

In such a situation, the best parameter to characterize radar radiation is average power flux density, S_{av}, at point B:

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

where G – antenna gain in direction of maximum radiation;

$f(\Theta^o)$ – antenna's pattern of directivity in vertical elevation plane (dependence of electric field intensity on angle Θ^o);

η –efficiency factor of antenna and wave-guide, less than one;

p – coefficient of electromagnetic waves reflection from ground;

R – distance AB between phase centre of antenna A and observational point B (Fig 1).

The efficiency of parabolic antennas is η<0,7. This parameter is usually involved in experimentally measured pattern of directivity (Fig 2).

Choosing different values of angle Θ^o permits one to calculate S_{av} and to draw curve of power density dependence on distance. Distances R and L can be found by:

$$R = (h_1 – h_2)/ \sin \Theta^o, \quad (3)$$
$$L = (h_1 – h_2)/ \mathrm{tg}\, \Theta^o. \quad (4)$$

The sanitary protection zone is defined in territory, where calculated average power density value exceeds permitted level. The radius of this zone can be changed and reduced by selection of antenna installation h_1 and choice of maximal radiation angle Θ^o_{max} in vertical plane. There is not flexibility because increasing of h_1 bid up a cost of the antenna installation and the rise of Θ^o_{max} worsens detection of down flying aircrafts.

3. Permitted level of electromagnetic radiation

In Lithuania hygienic normative for the electromagnetic radiation of stationary electronic systems in living and working areas describes the permitted level of radiation [1]. In frequency band over 300 MHz of continuous oscillation the power flux density is normalized and cannot be greater than 10.0 $\mu W/cm^2$. The same normative exists for the permitted electromagnetic radiation level of basic mobile telecommunication stations [2]. The European standard for the permitted level of power flux density is also 10.0 $\mu W/cm^2$ [4]. In the Lithuanian normative, the safe average level of power flux density for pulse radiation is 20.0 $\mu W/cm^2$, because radiation heats the human body during a short pulse and the body turns cold during the long pause between pulses [1]. Russia has a similar normative for evaluating the radiation of meteorological radars [5]. In case of radiated wavelength 10 cm± 15 %, permitted level of average power flux density is accredited 20.0 $\mu W/cm^2$ at 2 m above the surface of the ground.

Separate description of permitted levels of electromagnetic radiation is proposed for the working places of people. In the 300 MHz - 300 GHz band of frequencies, the permitted power flux density depends on exposition time [1]. In the case of five minutes exposition the normative is the greatest – 1000 $\mu W/cm^2$. The minimal normative – 25.0 $\mu W/cm^2$ is valid when the duration of exposure is during eight hours or more.

4. Evaluation of radiation level of radar

Power flux density calculations were made for the TA 10MTD Thomson radar which is used in Lithuania.

The primary radar data for calculation is taken from the TA 10MTD 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.

The characteristics of an AC 316 primary radar antenna 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 α^o_{3dB} = 1.5°. Side lobes are 25 dB less than the main lobe;

– antenna pattern of directivity in vertical plane is shown in figure 2 and has the shape $\mathrm{cosec}^2\, \theta$ up to Θ^o= 50°;

– antenna rotation frequency – 0.4 Hz.

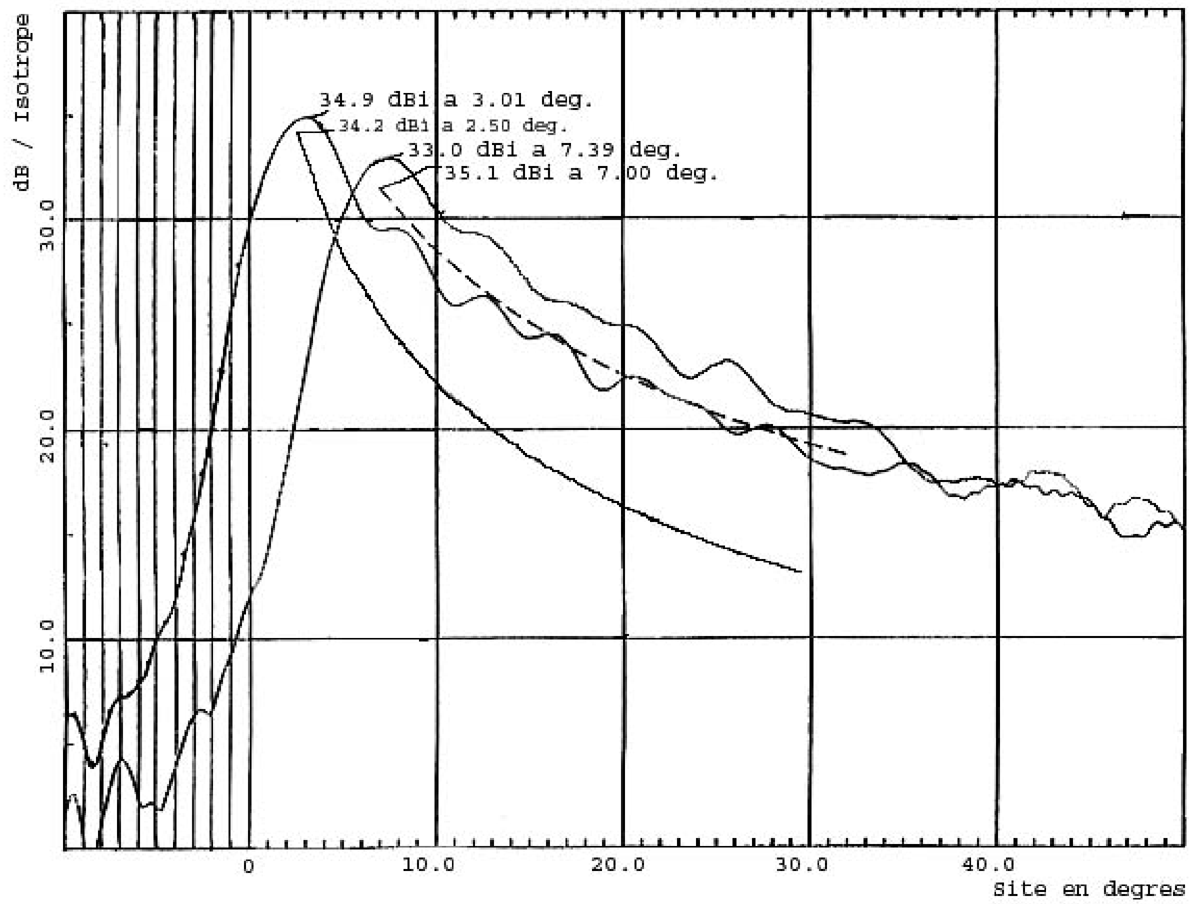

Fig 2. Pattern of directivity in the vertical plane, taken by producers of AC 316A parabolic antenna

Calculation process:
The investigation of antenna's radiation was made for two values of installation height: h_1=14 m and h_1 = 5 m. During calculations of power flux density values were found at height h_2= 2 m above surface of the ground. P_{imp} = 600 kW, τ = 1 μs, Tp = 1000 μs, and $\alpha^{o}_{3dB} = 1.5^{\circ}$ were put into (1) and found P_{aver}= 2.5 W was found. Only part of pattern directivity in vertical plane with negative values of angle Θº from -0.5º to 10º every 0.5º were used because only radiation down was analysed (Fig 2). Twenty values of -Θº and values of gain, G (Θº) in dB, were read from the pattern. In equation (2), G (Θº) will correspond $G \cdot f^{\,2}(\Theta^o)\ \eta$ set in times instead of G in dB. The concrete values of Θº were recalculated into distance L according to (4) (Fig 1). In equation (2) multiplier ($1-p^2$) corresponding to reflection of electromagnetic waves from ground (Fig 1) was inserted. According to recommendations, ($1-p^2$) = 1.5 of a frequency 2900 MHz [5]. It is necessary to note that this value is in reality smaller than 1.5, because reflected wave with direct wave adds together not essentially in phase.

The results of the calculation of average power flux density according to (2) in depending on distance are shown in figure 3.

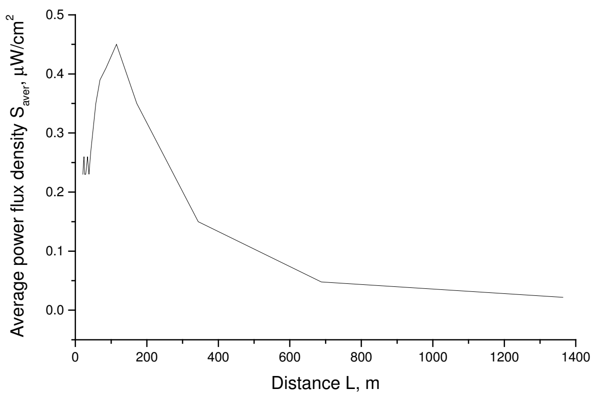

Fig 3. Dependence of average power flux density on distance, when radar antenna radiates with phase centre on h_1=5 m

The calculated curves have a maximum level due to two factors. On one hand, the power flux density decreases as the result of energy dissipation in receding from the radar according to the law 1/ $R^{\,2}$, on the other hand radiation increases with distance when radiation is greater in elevated directions according to the antenna directivity pattern in the vertical plane. Power flux density decreases very quickly after reaching the maximum.

The maximum power flux density 0.45 μW/cm^2, at a distance 115 m is many times smaller than the permitted level according to normative – 20.0 μW/cm^2. In this case absence of sanitary protection zone takes place and electromagnetic radiation of radar antenna is not dangerous for population in all area around the radar. If the antenna phase centre is higher – at 14 m – the maximum power flux density reaches only 0.06 μW/cm^2 and is farther from the antenna – at distance 500 m.

5. Conclusions

1. Method of evaluating radar antenna microwave radiation calculations uses the average value of radiated power, which is many times smaller than pulse peak power because the duration of pulses is many times shorter than the long pauses between them. Besides, a rotating antenna with a narrow pattern of directivity in the horizontal plane emits the electromagnetic field in supervisory point for a small time during the period of rotation.
2. At microwave frequencies greater than 300 MHz, the average value of radiated power flux density is used to evaluate the danger for population and is compared with the permitted density level according to normative or standards.
3. Lithuania and the European Union have the same normative for permitted levels of electromagnetic field power flux density – 10.0 μW/cm^2 in the 300 MHz – 300 GHz frequency band if radiation is continuous and 20.0 μW/cm^2 in the case of the pulse radiation.
4. An evaluation of the radiation emitted by powerful radar TA 10MTD installation in Lithuania was made. If the phase centre of the antenna is 5 m in height, the radiated power flux density is 40 times smaller than the permitted level and is not dangerous to the health of the population. In this case, a sanitary protection zone is not necessary. If the antenna is established higher, the maximum radiation intensity is at greater distance but with many times smaller amplitude.
5. In this investigation, the theoretical evaluation of electromagnetic radiation is done before the installation of the radar. The real situation will be evident after the radar antenna is mounted and experimental measurements of radiated power flux density are taken. Measuring such small levels of radiation can be impeded by interferences.

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RADIOLOKATORIŲ SPINDULIUOJAMŲ LAUKŲ INTENSYVUMO VERTINIMAS

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S a n t r a u k a

Pasiūlyta galingų radiolokatorių elektromagnetinės spinduliuotės skaičiavimo metodika. Atkreiptas dėmesys, kad skaičiavimuose reikia naudoti vidutinę jo spinduliuojamą galią. Vidutinę galią apsprendžia du faktai: radiolokatorius spinduliuoja trumpus radijo impulsus su, palyginti, ilgais tarpais tarp jų, be to besisukanti antena su siaura kryptingumo diagrama horizontalioje plokštumoje spinduliuoja į nurodytą erdvės tašką tik trumpą antenos sukimosi periodo dalį. Pagal pateiktas formules buvo atliktas įvertinamasis skaičiavimas radiolokatoriui TA 10MTD. Nustatyta, kad antena, sumontuota 5 m aukštyje, žmogaus galvos lygyje sukuria elektromagnetinės bangos galios srauto tankį, daug kartų mažesnį už Lietuvos normatyvais leistiną – 20,0 μW/cm^2 ,todėl sanitarinė apsaugos zona nesusidaro.

Reikšminiai žodžiai: radiolokatorius, mikrobangų spinduliuotė, galios srauto tankis, leistinas spinduliuotės lygis, gyventojų apsauga nuo elektromagnetinės spinduliuotės, elektromagnetinio lauko normos, sanitarinės apsaugos zonos.