ANALYSIS OF PULSED ELECTROMAGNETIC FIELDS RADIATED BY POWERFUL SOURCES

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Summary Calculation method proposed for powerful sources radiation evaluation. Taken attention that in calculations it is necessary to use average radiated power. For example in case of radars it depends on two facts: radar radiates short radio impulses 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's rotation period. Calculation is made for Thomson radar according proposed equations. It is shown that antenna in 5 m height radiates power flux density into level of man head more times smaller than permitted level according Lithuanian normative - 20,0 μW/cm^2.

1. INTRODUCTION

Public health service requires calculations of electromagnetic field intensity around powerful radiation sources before their mounting. Such evaluation takes place in spite of the manufacturers theoretical analyse and experimental measurements of every concrete equipment radiation. The method of evaluation is very simple and has been used many times. It is necessary to use an average value of radiated power in calculations of antenna electromagnetic field exposure. The pulse duration is hundred times shorter than pulse repetition, thus an average value of power density is hundreds times lower than a peak value of the radiation. Additionally the 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 pattern and scan sector of the antenna. Lithuania has accredited normative for permitted levels of electromagnetic radiation, so results of calculations can be compared with these levels and practical conclusions can be made for radar establishing. Example of evaluation of Thomson radar antenna radiation intensity is shown in this paper. The calculated radiation is many times smaller than the permitted level and is not dangerous for population. The real situation will become clear after mounting of the radar at place and experimental tests of EM field intensity.

2. CALCULATION OF RADIATED POWER DENSITY

The density of radiated power of the powerful source is verified at frequencies greater than 300 MHz. This density calculation method is known [1, 2, 5] and often has been used. Figure 1 explains the situation.

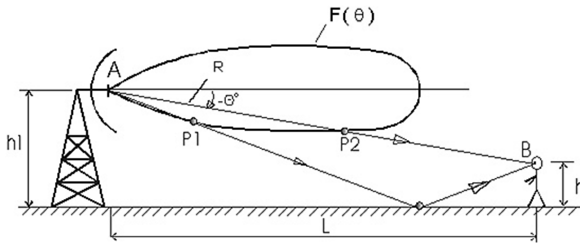

Fig. 1. Finding of antenna radiated power flux density at point B

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, 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 , thus an average value of power density is many times lower than the peak value also. Due to the rotation of the radar antenna, the point B is exposed to pulse modulated microwave radiation periodically within a very short time agreeably to the width of a main lobe of the antenna 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:

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

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

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

In (2) 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 from angle Θ^o),

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

p – coefficient of electromagnetic waves reflection from ground,

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

Efficiency of parabolic antennas is $\eta<0,7$. This parameter is involved usually in experimentally measured pattern of directivity. Choosing of different values of angle Θ^o permits to calculate S_{av} and to draw power density dependence on distance. Distance L can be found by:

$$L = (h_1 – h_2)/ tg\, \Theta^o. \qquad (3)$$

As final result, dependence S_{ar} from distance between antenna and point B can be drawn. It can be used for finding of sanitary protection zone. In this zone electromagnetic field power flux density S_{av} is a greater than permitted.

Radius of calculated sanitary zone depends on:

P_{peak} - power of radar's radiated impulse,

G - antenna gain,

α^o_{3dB}, Θ^o_{3dB} – width of antenna's pattern of directivity on level 3 dB in horizontal and vertical plane respectively,

Θ^o_{max} – angle of antenna's maximum radiation in vertical plane,

h_1 – antenna's phase centre high above ground surface.

Direction of maximum radiation Θ^o_{max} and high of antennas installation h_1 can be chosen only and they estimate sanitary protection zone radius R_{san}

Increasing of h_1 bid up a cost of antenna's installation and the rise Θ^o_{max} worsen detection of down flying aircrafts.

3. PERMITTED LEVEL OF ELECTROMAGNETIC RADIATION

Hygiene normative [3] describes permitted level of electromagnetic radiation of stationary electronic systems in living and work places in Lithuania republic. In frequencies band over 300 MHz of continuous oscillation the power flux density cannot be greater than 10.0 $\mu W/cm^2$. In European standard [4] the permitted level of power flux density is same. In Lithuanian normative [3] the safe average level of power flux density in case of pulse radiation named 20.0 $\mu W/cm^2$ because radiation heats the human body during short pulse time and the body is turning cold during a long pause between pulses. Russia has the similar normative [2] for evaluation radiation of meteorological radars. If radiated wavelength 10 cm ± 15%, the permitted level of average power flux density is accredited 20.0 $\mu W/cm^2$ on 2 m above ground surface. 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 [3]. If exposition duration is 5 min, the normative is the greatest – 1000 $\mu W/cm^2$. The minimal normative 25.0 $\mu W/cm^2$ is for workers exposition during 8 hours and more.

4. RADAR RADIATION LEVEL EVALUATION

There average power flux density calculations have been made for Thomson radar which is used in Lithuania. 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 $\alpha^o_{3dB} = 1.5^\circ$. Side lobes are 25 dB less than the main lobe,
- antenna pattern of directivity in vertical plane has the shape $cosec^2\, \theta$ up to $\Theta^o = 50^\circ$. Gain values in dependence on Θ^o are taken in Tab.1.
- rotation frequency of antenna – 0.4 Hz.

Calculation process.

Antenna's radiation investigation was made for installation height: h_1=5m and 22m. 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 $\alpha^o_{3dB} = 1.5^\circ$ were taken into (1) and found average power P_{av}= 2.5 W. Only part of pattern directivity in vertical plane with negative values of angle Θ^o from –0.5° till -10° every 0.5° were used because only radiation down was interesting. So 20 values of $-\Theta^o$ and adequate values of gain $G(\Theta^o)$ in dB were read from the pattern (Tab.1). In equation (2) $G(\Theta^o)$ will correspond $G\cdot f^2(\Theta^o)\cdot\eta$ set in times instead of G in dB. The concrete values of Θ^o were recalculated into distance L according (3) (see Fig.1). In equation (2) multiplier $(1\text{-}p^2)$ was inserted corresponding to reflection of electromagnetic waves from ground (Fig.1). According to recommendations from literature [2] $(1\text{-}p^2)$ = 1.5 on frequency 2900 MHz. It is necessary to note that this value in reality is smaller than 1.5 because reflected wave with direct wave adds together not essentially in phase.

Tab. 1. Data of radar antenna's pattern of directivity in vertical plane and average radiated power flux density dependence on distance

$-\theta°$	$Gf^2(\theta°)\eta$, dB	$Gf^2(\theta°)\eta$	L,m	S_{av}, $\mu W/cm^2$
0.5	27.6	575	113	0.0095
1	25.3	339	119	0.0088
1.5	22.9	195	126	0.0059
2	20.0	100	133	0.0041
2.5	17.9	61.7	142	0.0052
3	15.8	38	151	0.0056
3.5	13.9	24.5	162	0.0058
4	12.1	16.2	175	0.0051
4.5	10.5	11.2	190	0.0051
5	10.0	10.0	208	0.0054
5.5	8.9	7.76	229	0.0058
6	7.9	6.17	255	0.0052
6.5	7.2	5.25	286	0.006
7	7.1	5.13	327	0.0069
7.5	6.4	4.37	382	0.0079
8	5.5	3.55	457	0.0089
8.5	3.9	2.45	573	0.0092
9	5.0	3.16	763	0.0101
9.5	6.3	4.27	1145	0.0078
10	6.2	4.17	2291	0.0033

The results of calculation according (2) of average power flux density depending on distance in Tab. 1 have maximum the 0.0101 $\mu W/cm^2$ at distance 763 m. This value is many times smaller than the permitted level 20.0 $\mu W/cm^2$. So it is possible to reduce height of antenna and to win in its price. Dependence of average power flux density on distance in case of height 5 m is shown on Fig. 2. 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 sanitary protection zone absent and electromagnetic radiation of radar's antenna is not dangerous for population.

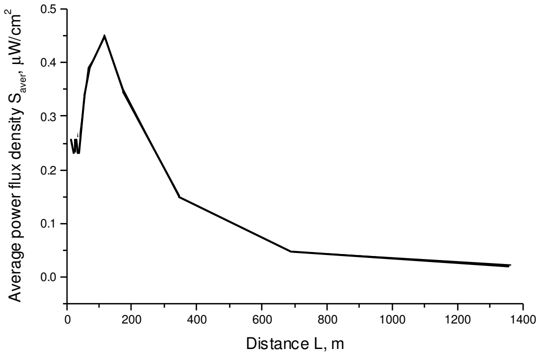

Fig. 2. Graphical presentation of the average power flux density from distance at antenna height 5 m

5. CONCLUSIONS

1. Proposed evaluation method of radars antenna's microwave radiation uses in calculations average value of radiated power density, which is compared with permitted level according normative.
2. Lithuania and Europe Union have the same normative in frequencies band 300 MHz - 300 GHz of permitted levels of electromagnetic field power flux density - 10,0 $\mu W/cm^2$ if radiation is continuous and in case of impulse radiation - 20,0 $\mu W/cm^2$.
3. If phase centre of radar antenna is on height 5 m, the radiated power flux density is 40 times smaller than permitted level and is not dangerous for population. If antenna is equipped higher, the maximum of radiation intensity is further but with many times smaller amplitude.

REFERENCES

[1] Methodical guidelines for diagnosis and normalisation of electromagnetic situation in meteorological radars places. USSR Ministry of Health Care, 1985.

[2] Maceika K. Normative of permissible electromagnetic fields level. Proc. of XI Int. Conference on Electromagnetic Disturbances, Bialystok BTU, pp.641-642.

[3] 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.

[4] Standard 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.

[5] Skolnik M.I.: Introduction to Radar Systems. McGraw-Hill, 2001.