ECOLOGICAL ASPECTS OF OPERATING RADIOLOCATION SYSTEMS

Adriana Tóthová – Milan Džunda

In this article are characterized ecological aspects of air traffic radar systems. As following are used basic concepts of ecology, environment and operating principle of radar systems. A significant portion is devoted to the issue of impact of electromagnetic radiation on environment. It shows possible effects of radiation on human health, animals and vegetation. At the end of contribution are described different options for the protection of population and living organisms against electromagnetic radiation.

K e y w o r d s: ecology, radar systems, electromagnetic radiation, microwave radiation

1 INTRODUCTION

Air transport is industry with constant evolution. This is proved by the fact, that in less than one hundred years it has gone through enormous changes in the field of safety and aviation electronic security systems.

Like any other industry, also air travel is by no means isolated from surrounding environment and is an integral part of human life. Currently, there are a lot of people which can´t imagine their lives without air transport, as it is fast and safe. One of the problems of this type of transport is its negative impact on environment. These main impacts are noise, emissions and electromagnetic radiation of radar systems.

In the article we analyze the operation of aircraft radar systems, focused on their impact on environment.

2 RADAR SYSTEMS

Radar is a radio-electronic device, whose role is to detect targets and their position in particular space by electromagnetic waves in the zone of radio frequency.

It works on the principles of reflection of electromagnetic waves from objects. Radar transmitter sends an electromagnetic signal, through antenna, into space, in the form of short pulses. A significant proportion of this energy is dissipated in the environment. If in a given direction of radiation of the signal, at a certain distance, is an object, part of the energy is reflected back and falls to the surface of antenna. Reflected signal (echo) goes to radar receiver, where it is processed and evaluated. After finding the signal, it´s possible to measure distance of the object from radar.

Based on the way how radars perform their tasks we split them to primary and secondary.

2.1 Primary radar

Primary radar operates on the principle of transmitted and reflected signals. Thanks to continuously rotating antenna it sends a signal to the environment. In case you encounter an object, part of energy is reflected and goes back to the radar. Based on the time from sending to reception of signal, primary radar can determine distance and direction of the aircraft from antenna.

Table n° 1: Different types of primary radars

Type of primary radar	Frequency [GHz]	Performance [W]
ASR 910	2,7 – 2,9	2 500
ASR E	2,7 – 3	25 000
DASR	2,7 – 2,9	2 500
Marconi S511	2,7 – 3,5	650 000
PAR 80	8 – 12	180 000
Watchman	2,7 – 3,5	58 000

Based on data from Table n° 1, we can see that primary radars operate at frequencies from 2 700 MHz to 3 500 MHz, representing a frequency zone S. Their performance may vary depending on individual factors, including: frequency and transmitter power, receiver sensitivity, time interval between pulses and their width, size, shape and material of reference object.

Primary radar is in air traffic management used for approach and landing guidance of aircraft or as complementary system of secondary radar.

2.2 Secondary radar

Secondary radar needs to work in cooperation with an object, which is provided with airborne transponder placed on board of aircraft. It means it´s composed from two parts: ground and airborne. Ground radar transmitting antenna transmits an electromagnetic signal to the aircraft and waits until the aircraft responds this request. Responder on the board of aircraft intercepts the signal and responds with its own code, which is assigned to given flight by air traffic control centre. Response of aircraft is captured by secondary radar receiving antenna, decoded on its basis and thus identifying individual aircrafts.

Table n° 2: Different types of secondary radars

Type of secondary radar	Transmitting frequency [MHz]	Receiving frequency [MHz]	Performance [W]
MSSR 1	1 030	1 090	2 000
RS 5	1 030	1 090	2 500
RSM 970	1 030	1 090	2 500

By comparing data from Tables 1 and 2 can be determined, that secondary is given much less power as primary radar. It is caused by co-operation with airborne and ground part, where is not needed such a performance as for the primary radar, which must expend much more energy to get back reflected signal.

Secondary radar consists of ground and airborne part, where each sends electromagnetic waves on different frequencies:

- for demand the signal frequency is 1030 ± 0.2 MHz;
- for respond the signal frequency is 1090 ± 0.3 MHz.

Secondary radar is one of the basic equipment in air traffic services. It operates in the frequency zone L.

2.3 Radar frequency zones

Radar systems operate over a wide zone of transmitted frequencies. Higher the frequency is, higher impact of weather conditions such as rain, snow, or others, affects them. But equally, their accuracy is greater. Since not all radars operate in the same frequency range, they should be separated into several zones.

Frequency zones A and B

Their frequency is below 300 MHz. Radars that use these zones were already in use during World War II. Today in this category we can fit radar systems for early warning. The problem is their poor accuracy because performance of radar is proportionally affected by frequency on which they work.

Frequency zone C

This zone works on frequencies from 300 MHz to 1 GHz, which is especially suitable for tracking of satellites and ballistic missiles, over long distances, but also for archaeological survey. Some weather radars work within this zone as well.

Frequency zone D

Frequency zone D is within the range 1-2 GHz. Radars operating in this range are used in air traffic management, which emit pulses with higher strain, broadband and pulsing modulation. In this case, the maximum range of these devices is limited to aircraft flying at a lower altitude, which is closely related to the geographical conditions of the country in which they are located. Frequency zone D can be also referred to the letter L.

Frequency zones E and F

These zones make together the S-zone, in which nearly all air traffic control radars work. It covers the value of 2-4 GHz and it is characterized by the use of higher power antennas to ensure maximum range.

In these zones, is impact of weather conditions higher than in zone D. On this basis are used weather radars, whose use is most effective in subtropical conditions. Likewise, there are also used radar equipments for air traffic to detect position of the aircraft and weather conditions in the neighbourhood of civilian and military airports.

Frequency zone G

It covers frequency of 4-8 GHz and is predestined for most types of radars that are used to search precipitation in temperate climates. This group includes many mobile, foreseeable, military, missile control and ground radar sets with short or medium range.

Frequency zones I and J

This group consists of frequency zones in the range of 8-12 GHz. They are used in naval, military and civil navigation radar, which includes systems used for missile guidance.

The frequency zone K

It covers frequency zone 18-40 GHz. Radar systems used in these zones provide short range, high resolution and high speed data transfer.

Frequency zones V and W

Cover a range from 40 to 300 GHz and are used in test facilities.

Based on this information we can determine that radar systems operate in the frequency range from 300 MHz to 300 GHz. This is a zone of microwave radiation, which is described in the next section.

3 MICROWAVE RADIATIONS

Is a subset of radio emission, representing the largest portion of the electromagnetic spectrum. It operates in the frequency range from 300 MHz to 300 GHz and it´s split to three zones :

1. EHF (Extremely High Frequency) covers the area from 30 to 300 GHz. It is used in astronomy for high speed data transfer.

2. SHF (Super High Frequency) this zone is used in radar systems as evidenced by applied frequency from 1 to 30 GHz.

3. UHF (Ultra High Frequency) operates in the range of 300 to 1000 MHz. It´s mostly used for transmission of television signals in a mobile communications.

Microwave radiation can be produced artificially by means of microwave generators, including special valves as magnetron, klystron and etc.

3.1 Maximum value of radiation caused by microwave radiation

All types of electromagnetic radiation have different characteristics and also various effects on the human body. In this case it is necessary to ensure that exposure does not exceed the maximum permitted value intended for staff who works with devices emitting electromagnetic radiation, but also the population, which is also irradiated by certain amount of radiation intensities.
For this reason there were developed several laws and regulations dealing with this issue. Legislative protection against exposure of microwave energy is provided by Slovak Republic Ministry of Health of Slovak Republic No. 271/2004 of 31 March 2004 as health protection against non-ionizing radiation.

3.1.1 Maximum values for continuous exposure

In radar systems it is necessary to know the maximum value of the electric field (E).

Table n° 3: Maximum value of E for continuous exposure

Frequency [Hz]	Staff E [V/m]	People E [V/m]
50	10 000	5 000
$820 – 3.10^3$	610	$2,5.10^5/f$
3.10^3 - 65.10^3	610	87
65.10^3 - 10^6	610	87
$10^6 – 10^7$	$610.10^6/f$	$87.10^3/f^{0,5}$
$10^7 – 4.10^8$	61	28
$4.10^8 – 2.10^9$	$3.10^{-3}.f^{0,5}$	$1,375.10^{-3}.f^{0,5}$
$2.10^9 – 3.10^{11}$	137	61

3.1.2 Breakpoints

To ensure more consistent protection of population and workers are also set threshold limit values that instantaneous electric field strength shall not exceed. This is known E_{hran}.

Table n° 4: Breakpoints for E_{hran} - peak

Frequency [Hz]	Staff E [V/m]	People E [V/m]
10^5	915	130
$10^5 – 10^6$	$0,438.f^{0,67}$	$0,0605.f^{0,67}$
10^6	4 226	603
$10^6 – 10^7$	$4,3514.10^5/f^{0,335}$	$56,03.f0^{0,17}$
10^7	1 952	896
$10^7 – 4.10^8$	1 952	896
4.10^8	1 952	896
$4.10^8 – 2.10^9$	$0,98.f^{0,5}$	$0,0448.f^{0,5}$
2.10^9	4 384	1 952
$2.10^9 – 3.10^{11}$	4 384	1 952

3.2 Effects of microwave radiation on human body

Biological effects of microwave radiation on human body depend on subjective and objective parameters.

Objective parameters are derived from the physical parameters of microwave radiation as used frequency range, intensity and duration of radiation.

Subjective parameters depend on the physical-chemical properties of the body such as weight, health, body water ratio, thickness of skin, fat deposits, muscle, height and etc. Only based on all these objective and subjective parameters it is possible to detect how much affects microwave radiation a human health.

Microwave radiation may affect human body in two ways, depending on the organism and the exposure conditions. The two main groups are thermal and non-thermal effects.

3.2.1 Thermal effects

If a person is exposed to intense microwave radiation, this may cause an increase of body temperature, whereupon there is a detrimental effect on the organism called Hyperthermia. This depends mainly on frequency, where relationship between increased frequency and thermal effects on the body is directly proportional. In this case, the most important factor in body is water content, because total amount of absorbed energy depends on it. Water decides on electrical properties of fibres and in addition, it is also affected by surface area which is exposed to radiation. In case amount of heat is greater than body is able to issue into the environment, may result in thermal overload authorities, and also increases the temperature of blood. Organs, particularly sensitive to temperature increase are the eyes, brain and spermatocysts.

Effects on human eyes

Since for the eye lens it is very difficult to get rid of heat, microwave radiation may cause: abnormal vision, cataract, tearing.

Effects on reproductive system

Genital changes during irradiation are at higher intensities, which lead to thermal damage of organs. This leads to degenerative process and morphological changes of these organs. This means there may be direct damage to ovum and spermatocysts, which affects fertility.

Effects on the cardiovascular system

Radio frequency fields reduce the conductivity of the coronary circulatory system. This makes changes in blood flow, causing a relaxation of blood vessels. In the case of high-frequency zones it may also cause heart rhythm disturbances.

3.2.2 Non-thermal effects

They are conditional to electrical properties of biological systems. Their effect increases with repeated exposure, relatively low intensity. It´s in the case of exposure to impulse field, where total radiated power is relatively small, but large instantaneous amplitude. These non-thermal effects mainly impact the nervous system, where they cause problems of asthenia subjective type.

Effects on the nervous system

Non-ionizing electromagnetic radiation disrupts intermolecular bonds in the body. If they impact the nervous system various problems such as headache, tiredness, exhaustion, sleep disturbances, degradation of memory, moodiness, nervousness can occur.

Despite this knowledge it is necessary to take into account that the biological effects of electromagnetic waves depend on duration of their assignment, their nature and characteristics of organism. These effects are judged mainly by nonspecific reactions of organism. Each person reacts to the activity of electromagnetic waves differently. Its adaptive, compensatory and restorative options and capabilities are different depending on him. In general, pregnant women, children and the sick are up to two degrees more sensitive to microwave radiation. This means that not all effects of electromagnetic waves have same impact on individual organisms.

3.3 Effect of microwave radiation on vegetation

Microwave radiation is not only dangerous to humans, but also to plants that react to its power more intensively. Microwaves can significantly damage the structure and development of plants. As to human even in this case means that not every plant reacts to microwave radiation the same way, but it is also affected by objective and subjective parameters.

The most common effects of microwave radiation on vegetation include: death certificates, slow growth, reducing service life, low or no germination of seeds, dry out.

3.4 Effect of microwave radiation on animals

Animals as well as people are affected by electromagnetic radiation, which can lead to changes in their behaviours, growth, disease and even death. Since they have similar body structure and the cell structure, effects of microwave radiation on them are similar.

In the case of animals, were carried out many specific experiments which have shown that microwave radiation affects their behaviour and life. In most cases basic phenomenon that occurs as an effect of microwaves to the animals rise, is body temperature. This is evidenced by the research carried out on mice that were exposed to radiation at a frequency of 2450 MHz for 5 minutes. It was shown that body temperature was increased up to 8 ˚ C. These effects depend on the specifics of organisms as well as subjective and objective parameters, impacting them.

Effects on the nervous system

Among the problems associated with the failure of the nervous system include: total disorientation, madness, probably associated with fear, lethargy, incapability to move.

Other issues that appear due to activity of microwave radiation on the organism of animals are problems with their digestive system, blood and cardiovascular systems.

Despite how microwave radiation impacts animals, they have one advantage over the man which is higher sensitivity. A human is unable, through their senses, to feel greater amount of radiation, which might threaten. This is evidenced by the fact, that human does not have specific receptors, which are primarily irritated by microwave radiation. Animals have these receptors as a sixth sense, which help them to stay out of places with high intensity of microwave radiation.

3.5 Options to protect against negative effects of microwave radiation

According to the findings from previous subsections we conclude, that microwave radiation is dangerous and its consequences can be dire. That is why it´s necessary to strictly comply with all exposure limit values designed to ensure the protection of life and health of citizens and staff working with devices emitting electromagnetic radiation. This protection can be enhanced by other methods, including: shielding of radiation source or shielding of work place, provide personal protection equipment, ensure emission reductions near the source of radiation.

3.5.1 Shielding of radiation source

It´s appropriate to ensure effective protection of the population living in the neighbourhood of radiation source. It´s not used on workplaces as it would reduce the effectiveness of radar systems. The aim of shielding is to create a barrier to the penetration of microwaves into living spaces. In order to make it correct and properly fill its purpose, it´s necessary to consider basic rules of construction, such as:

- determine the true value of the radiant energy incident on the spot;
- determine the frequency of radiation and its course;
- proper grounding;
- characteristics of microwave radiation;
- shielding of all parts;
- use appropriate shielding materials.

3.5.2 Personal protection equipment

In this case it is mainly to protect employees who work with devices emitting microwave radiation. The aim of this equipment is to provide to employee maximum protection in areas that exceed safe level of radiation. Since microwave radiation affects all parts of body, protection clothing of employees must consist of components such as: protection helmets, helmet or cape with cover, protection gloves, safety shoes and protection overalls.

In addition to this protection equipment there are still a lot of clothes that are suitable for everyday use. They are designed for people who want to protect their health from unwanted effects of microwave radiation. This includes a lot of clothes as from head scarves, sweaters to pants with effect from 40 to 60 dB.

For every protection clothe is valid that it should meet basic requirements for protection prior to the second radiation and should allow the user complete freedom of movement and comfort.

4 CONCLUSION

In this contribution we deal with issue of ecological aspects of air traffic radar systems. Radars are part of the airline's electronic security equipment and are used to control and to monitor air traffic management. They allow us to locate position of flying objects using electromagnetic radiation, which can have adverse effects on humans, animals and vegetation. From the analyses of air traffic radar systems we see they operate in the 1-4 GHz, which is the area of microwave radiation. From inscription of the effects of radiation on living organisms and fauna, we concluded, that this radiation has adverse effects on human health and life, flora and fauna. Therefore, it is needed to protect ourselves. To do this, we can use various devices such as protection clothing, shielding materials and legislative measures. Even though we did not perform laboratory measurements on the basis of analysis we assume, that the radiation of radar systems is dangerous to human, flora and fauna, especially if they are located in close neighbourhood.

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AUTHOR´S ADDRESSES

Ing. Adriana Tóthová
HSNP 154, 044 25 Vyšný Medzev
tothovaadka@gmail.com
prof. Ing. Milan Džunda, CSc.
Rampová 7, 041 12 Košice
milan.dzunda@tuke.sk