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Electromagnetic Radiation Between Two Towers Of 400 kV Transmission Line Bitola 2 – Meliti And Nearby Objects

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***Abstract*—In today's modern living and working world, man has reached a high level of technological development by inventing machines and devices that have made his life easier. There are many types of radiation that are present in our environment and that affect our health. Some of them are electromagnetic radiation. Every organism is different and therefore reacts differently to this radiation. We came to the conclusion that the electromagnetic radiation is stronger and is conditioned by the proximity of exposure from transmission lines.**

Keywords—electromagnetic radiation; measuring, standards

I. INTRODUCTION

The electromagnetic field affects humans with a certain electromagnetic radiation, which we can freely say is a certain electro smog, or electromagnetic pollution, with which we are constantly surrounded. This pollution, in fact, is any amount of radiation that is greater than natural and is almost everywhere around us. Some of it is a consequence of the radiation of the Sun and the Earth, but people are also exposed to natural radiation from cosmic rays, especially at high altitudes. On average, 80% of the annual dose of background radiation that a person receives is due to natural sources of terrestrial and cosmic radiation. Background radiation levels vary geographically due to geological differences.. Exposure in certain areas can be more than 200 times higher than the global average. The backbone of the Macedonian transmission network are 400 kV transmission lines that form a 400 kV ring consisting of three transmission lines that connect the largest energy consumption located in the northern part of the Earth, with the largest production capacities located in the southwestern region. Radiation exposure also comes from man-made sources, ranging from nuclear power generation to medical use of radiation for diagnosis or treatment. Today, the most common sources of ionizing radiation produced by humans are medical devices, including X-ray machines and computed tomography scanners. The largest amount comes from sources that are man-made. There has been a great interest in researching radiation for a long time. At that time, the emphasis was only on the impact of natural radiation. Although at that time people may not have been aware of what radiation was, and even attributed some supernatural properties to it and called it by various names, such as "demon's door", "devil's field" and the like, they were nevertheless aware of its negative impact on human health and life. Many countries and several international organizations have adopted guidelines or standards for exposure to electromagnetic fields (EMF) in occupational environments and for exposure to the general (non-professional) population. Such guidelines and standards are based on an evaluation of the established scientific literature, including an evaluation of the consistency of the findings reported. In order to preserve our health and protect the environment on which our survival directly depends, man should work on developing technology by prioritizing the reduction of harmful impacts.

II. ELECTROMAGNETIC FIELD

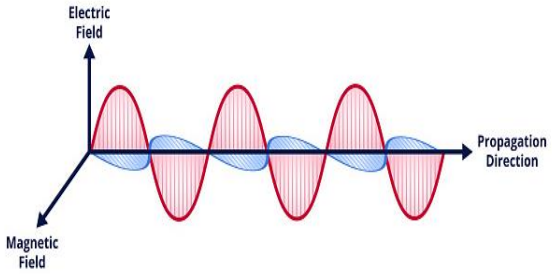

Fig. 1. Electromagnetic field [17]

Electromagnetic fields are a combination of invisible electric and magnetic fields. These fields are generated by natural phenomena such as the Earth's magnetic field, but also by human activities, most notably the use of electricity. Most artificial electromagnetic fields change their direction at regular intervals, ranging from extremely low frequencies (power lines), through medium frequencies (computer screens) to high radio frequencies (mobile phones). The term static describes fields that do not change over time (i.e., with a frequency of 0 Hz). Static magnetic fields are generated by devices that use direct current and are used in medical imaging. [13] Life on Earth has evolved in connection with and

dependent on electromagnetic frequencies in the infrared, visible, and ultraviolet spectrums - light from the Sun, as well as natural frequencies generated by the Earth. Electromagnetic radiation connects everything in the universe, forming a vast pulsating field of different frequencies, and we humans vibrate in that field. We also receive information present in this field through our senses at the cellular level, from which our brain translates it into an apparent reality. Biomagnetic fields are electrical activity that occurs in our bodies that produce magnetic fields. Heart tissue produces the strongest electrical and magnetic activity of any tissue in any other organ in our body, and its biomagnetic field extends indefinitely in front of and behind the body. The electrical activity of the heart is created by the continuous rhythmic movement of positively and negatively charged ions of sodium, potassium, chloride, calcium, and magnesium across each heart cell membrane. The magnetic field of the heart is measured at 10-3 Gauss, which is one millionth of the strength of the Earth's magnetic field and about one thousandth of the background magnetic field in an urban environment. Brain activity also produces an electromagnetic field, hundreds of times weaker than the heart's field. Each of our muscles produces a small magnetic pulse when it contracts, which it radiates into the surrounding space. The measurable biological electricity generated by the body in each of these cases results from the passage of charged ions across cell membranes and the ability of these membranes to temporarily depolarize and repolarize. All living cells and chemical processes in the human body rely on electromagnetic interactions between molecules, responsible for making and breaking chemical bonds, releasing energy from food, producing cellular energy, and transporting minerals, nutrients, hormones, neurotransmitters, and neuropeptides across cell membranes. Just as we use electromagnetic frequencies to communicate with each other via radio, the internet, or telephone, the electric and magnetic fields generated by the tissues and organs of our bodies are part of its complex and rapid internal communication system. When these electromagnetic frequencies are insufficient or disrupted, physical and mental health is impaired, and disease can occur. [12]

III. ELECTROMAGNETIC RADIATION

There has been a great interest in radiation research for a long time. At that time, the emphasis was placed only on the impact of natural radiation. Although at that time people may not have even been aware of what kind of radiation it was, and even gave it some supernatural properties and called it by various names, such as "demon's door", "devil's field" and the like, they were still aware of its negative impact on human health and life. At that time, people tried to protect themselves from the aforementioned radiation by avoiding places where there was a large amount of natural radiation They observed the relationship between animals and plants in selected places, they trusted various fortune tellers, seers and talisman records. Unfortunately, part of this tradition, due to the low technical culture, has been retained by certain classes of citizens to this day. Electromagnetic radiation is a change in the electromagnetic field as a function of time. This radiation is a carrier of electromagnetic interaction (force) and can be interpreted as a wave or as a particle, depending on the case. The particles that quantize electromagnetic radiation are photons. Any charge generates an electromagnetic field by changing its speed of motion. This information propagates through space at the speed of light, and the properties of the corresponding electromagnetic wave are directly related to the dynamics of the change in the motion of the charge. Alternatively, if we view electromagnetic radiation as an emission of particles (photons), the energy they carry is directly related to the wavelength, or frequency, of the wave. The higher the frequency, the higher the energy of the photon. The exact relationship is described by Planck's relation:

$$E = h \cdot \upsilon, \text{ where:} \quad (1)$$

E is the energy of the photon;

h is Planck's constant and

υ is the frequency of the wave.

The properties of electromagnetic radiation depend on its wavelength and as such are divided into electric, radio and microwave waves, then infrared, visible and ultraviolet light, X-rays and gamma rays. The entire range of wavelengths of electromagnetic radiation is called the electromagnetic spectrum. The effect of these waves on people varies depending on the frequency and amplitude of the signal, as well as the distance from the transmitter (base station) and the duration of exposure to these waves. [14]

IV. THE INFLUENCE OF ELECTROMAGNETIC RADIATION ON HUMANS

In the last twenty years, psychologists have defined a new category that determines the behavior of an individual in the family environment, at work, in critical situations, etc., and that is the quality of life QL (qualitz life). The quality of life has such an impact on the perception of the environment, and also helps in overcoming difficult situations, such as crises at work, illnesses. The quality of life depends on many factors and, in principle, affects the individual's subjective feeling of satisfaction.

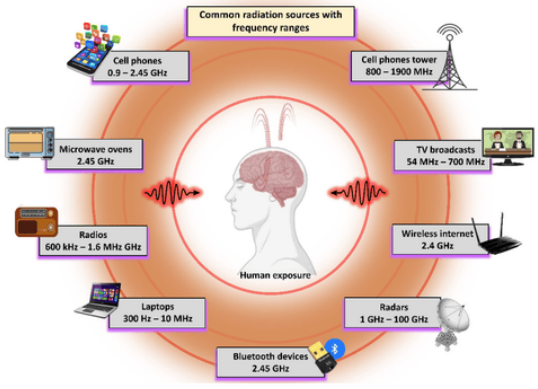

Fig. 2. Schematic representation of the influence of the electric field on humans [18]

Electromagnetic radiation, both ionizing and non-ionizing, when it comes to the quality of life of people, can be viewed from two aspects. The first is their impact on the development of human society, and the second is their impact on human health. Today's civilization widely uses electromagnetic waves and fields in a whole range of technologies. Thus, communications, radio and television, electricity, transportation, medicine, computers are based on electromagnetic fields and electromagnetic radiation. This progress has allowed people to have a high quality of life, which was unthinkable just a century ago. Penetration into space and its study are unthinkable without electromagnetic waves, as well as penetration into the world of microparticles. Their contribution to the development of modern civilization is of invaluable importance. On the other hand, the negative impact of electromagnetic radiation is that under certain conditions it causes health problems in humans (proximity to the radiation source, radiation power, wave frequency, ionization). At the same time, ionizing radiation is significantly more dangerous to human health than non-ionizing radiation. The good thing about all this is that non-ionizing radiation is in much greater use than ionizing radiation and for this reason the risk to human health is significantly reduced. If we measure the contribution of electromagnetic radiation or fields to the development and well-being of the human community and the negative effects on human health, we can conclude that the positive effects far outweigh the negative effects. In fact, the use of electromagnetic fields and waves is the basis of the development of modern civilization. As much as we do not want to admit the fact that we humans have only one and only planet to live on, unfortunately, in recent years we have become less and less aware of this truth. Especially when it comes to the pollution of our environment, where the main culprit is ourselves. In the race to achieve the highest possible profit for various businesses, we recklessly and very quickly consume non-renewable energy sources. In recent years, a large number of machines and devices have been invented, which greatly facilitate human living and working. But what is happening? Instead of people living a peaceful and safe life, we are faced with diseases that did not exist in the past or existed in a very small percentage. With the development of genetic technology, man has also caused a crisis of global proportions (the global crisis with the coronavirus COVID - 19). Where is humanity going wrong? This is a question that has direct consequences for our generations, and today's world leaders still do not have the answer or do not want to find it. [15]

V. ELECTROMAGNETIC RADIATION STANDARDS

Many countries and several international organizations have adopted guidelines or standards for exposure to electromagnetic fields (EMF) in occupational environments and for exposure to the general (non-occupational) population. Such guidelines and standards are based on an evaluation of the established scientific literature, including an evaluation of the consistency of the findings reported. Preliminary data or unproven hypotheses are often difficult to translate into recommended limits, and their use may result in the need for frequent changes in limits as research develops. Guidelines are usually based on effects observed in organisms, and laboratory effects are often difficult to interpret to derive limits for the protection of human beings. Many guidelines consider exposures of occupational groups and the general population separately, given their differences in duration of exposure and distribution of health conditions and physiological reserves. According to the International Committee on Non-Ionizing Radiation ICNIRP, whose recommendations have been implemented in European legislation, with the recommendation 1999/519/EC of 12.07.1999, the following are determined:

- basic limit values and
- reference limit values.

The basic limit values are determined on the basis of direct health effects on the human body (heating, contact currents). As physical quantities, depending on the frequency of the electromagnetic field, the following are used:

- specific absorption rate of energy SAR (Specific Absorption Rate), which is measured in W/kg;
- electromagnetic field energy density, which is expressed in W/m^2;
- contact current density, which is relevant up to 10 MHz, and is expressed in A/m^2.

Reference limit values for non-ionizing electromagnetic radiation have been established for the practical assessment of human exposure to electromagnetic fields. The following are used as measurement quantities:

- electric field strength E in V/m;
- magnetic field strength H in A/m;
- electromagnetic field energy density S in W/m^2.

Currently, international standards are set by ICNIRP, IEEE, CENELEC and other national and international committees. The first three organizations mentioned established the basis for their standards several years ago and continue to propose RF-EMF guidelines that take into account only thermal, acute and pathological effects. Unfortunately, these RF-EMF standards do little to provide protection for the general population.

In terms of international standards and likely exposure, it is imperative to recognize that the general population is not typically exposed to thermal levels in the workplace or in everyday life. The establishment of a proposed threshold level for pathological effects currently makes the assumption that compensatory or adaptive responses will occur in the body. However, we strongly disagree with this assumption. While humans very rarely receive acute exposure in everyday life, all populations in the world are daily chronically exposed to low levels of RF-EMF that can cause biological effects and standards should be set accordingly to take this into account.

The IEEE Standard for Safety Levels for Human Exposure to Radiofrequency Electromagnetic Fields,

3 kHz to 300 GHz (IEEE, 2006) aims to protect humans from identified adverse health effects from exposure to electric, magnetic, and electromagnetic fields in the frequency range 3 kHz to 300 GHz. The IEEE C95.1-2005 standard is a revision of the IEEE C95.1-1991 standard. These recommendations are expressed in terms of basic limits (BRs) and maximum permissible exposure (MPE) values. The basic restrictions are limits on exposure to electromagnetic fields based on established health effects. The maximum permissible exposure values (MPEs) are derived from the BR and are limits on external fields and induced and contact currents. These recommendations are not intended to prevent interference with medical and other devices that may be susceptible to radiofrequency (RF) fields. In general, the IEEE standard is less stringent than the ICNIRP guidelines although it is based on the same science.

IEEE C95.1-1991 provides recommendations for the prevention of adverse effects in humans exposed to electromagnetic fields in the frequency range 3 kHz to 300 GHz. The recommendations are intended to apply to exposures in controlled as well as uncontrolled environments. They are not intended to apply to intentional exposures of patients under the guidance of practitioners of the healing arts. In addition, field strengths below which induced and contact currents do not have to be measured are specified, spatial averaging and measurement distance requirements are clarified, and more precise definitions of average volume and radiated power are provided.

Electromagnetic Radiation - Human Exposure Standard 2014 regulates the performance of certain radiocommunications transmitters to protect the health and safety of persons who may be exposed to electromagnetic radiation from such transmitters.

Other standards for electromagnetic radiation are:

EN 50413 – Basic standard for measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 - 300 GHz);

EN 50492 – Basic standard for in-situ measurement of electromagnetic field strength associated with human exposure in the vicinity of base stations;

EN 50383 - Basic standard for the calculation and measurement of electromagnetic field strength and SAR associated with human exposure from radio base stations for wireless telecommunications systems 110 MHz - 40 GHz;

EN 50400 - Basic standard for demonstrating the compliance of radio transmission equipment (110 MHz - GHz) intended for use in wireless telecommunications networks with the basic restrictions on the reference levels related to the general public exposure to radio frequency electromagnetic fields when put into service;

EN 50554:2021 is a basic assessment standard related to general exposure to radiofrequency electromagnetic fields;

EN 16603-20-07:2022 is a standard relating to the electromagnetic effects of electrostatic discharges;

EN IEC 61000-4-20:2022 is a standard for testing and measurement of transverse electromagnetic wave emissions;

EN ISO 3691-2:2023 is a standard intended for noise, vibration and electromagnetic radiation emissions;

USAS C95.1-1966 10 mW/cm^2 (10 MHz to 100 GHz) based on a simple thermal model;

ANSI C95.1-1974 (permissible limits for E^2 and H^2);

ANSI C95.1-1982 (includes dosimetry);

IEEE C95.6-2002 (0-3 kHz);

IEEE C95.1-2005 (3 kHz-300 GHz);

IEEE C95.1-2345-2014 “ IEEE Standard for Military Workplaces — Strong Health Protection Regarding Personnel Exposure to Electric, Magnetic and Electromagnetic Fields, (0 -300 GHz);

IEEE C95.1-2019 "Draft Standard for Safety Levels Related to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, (0 -300 GHz);

IEEE C95.3-2002 Measurements and Calculations of Radiofrequency Electromagnetic Fields in Relation to Human Exposure to Such Fields, 100 kHz - 300 GHz;

IEEE C95.3.1-2010 Measurements and Calculations of Electric, Magnetic, and Electromagnetic Fields in Relation to Human Exposure to Such Fields, 0 Hz - 100 kHz.

The recommendations of the International Commission on Non-ionizing Radiation Protection (ICNIRP) – Guidelines for limiting exposure to time – varying electric, magnetic and electromagnetic fields up to 300 GHz) have been taken as the limit values for the electromagnetic field, whose recommendations have also been implemented in European legislation given in the CEPT recommendation ECC REC(02)04 – Measuring non ionizing electromagnetic radiation (9 KHz – 300 GHz).

Standards for electromagnetic radiation in our country are:

- ISO/IEC 14443-2:2020 - International standard for compliance with regulations on electromagnetic radiation and human exposure;
- ISO 80000-7:2008 provides names, symbols and definitions for quantities and units for light and other electromagnetic radiation. Where appropriate, conversion factors are also given.
- MKC EN 50413:2020 is a standard for measurement and calculation of human exposure to electric, magnetic and electromagnetic fields 0 Hz - 300 GHz. [16]

VI. MEASUREMENT OF ELECTROMAGNETIC RADIATION BETWEEN TWO TOWERS OF 400 KV TRANSMISSION LINE BITOLA 2 – MELITI AND NEARBY OBJECT

For the purposes of my work, I performed measurements of electromagnetic radiation between two steel lattice towers on a 400 kV transmission line near REK Bitola. I performed the measurements using the 3D EMF TESTER, Model:EMF-828 measuring device. The tester is designed to provide users with a fast, reliable and easy way to measure the levels of electromagnetic field radiation around transmission lines, electrical appliances and industrial devices. The

EMF tester is hand-held instrument designed and calibrated to measure electromagnetic field radiation over a wide range from 30 Hz to 300 Hz. This measuring instrument is intended to check the value of the magnetic induction B and the value of the magnetic field strength H. This measuring device measures the electromagnetic field along three axes (x,y,z).
I performed the measurements at 1 m, 5 m and 10 m horizontal distances from each of the poles, between the two steel lattice towers of the transmission line itself and near a house at 80 m horizontal distance from the transmission line. The distances at which the measurements were performed are at 0.6 m, 1.5 m and 2.3 m above the ground (the person) where the measurement was performed.

Fig. 3. 400 kV transmission lines and the building (house) where measurements were performed

To better present the obtained values, I used tables. The following table shows the values of electromagnetic radiation between the two 400 kV transmission lines:

Table I. Between two 400 kV towers

	0.6 m	***1.5 m***	***2.3 m***
B_x **(μT)**	*1.90*	*1.37*	*1.75*
B_y **(μT)**	*3.60*	*4.12*	*4.67*
B_z **(μT)**	*0.38*	*0.10*	*0.22*
***B* (μT)**	*4.09*	*4.34*	*4.99*

At height of 0.6 m above the ground, the total measured value is 4.09 μT. At height of 1.5 m above the ground, the total measured value is 4.34 μT. And at height of 2.3 m above the ground, the total measured value is 4.99 μT.

The following table shows a horizontal distance of 80 m from a building (house) to one pole:

Table II. At a horizontal distance of 80 m from a building (house) from one tower

	0.6 m	***1.5 m***	***2.3 m***
B_x **(μT)**	*0.01*	*0.02*	*0.01*
B_y **(μT)**	*0.23*	*0.20*	*0.21*
B_z **(μT)**	*0.04*	*0.03*	*0.04*
***B* (μT)**	*0.23*	*0.20*	*0.21*

At a height of 0.6 m above the ground, the total measured value is 0.23 μT. At a height of 1.5 m above the ground, the total measured value is 0.20 μT. And at height of 2.3 m above the ground, the total measured value is 0.21 μT.

The average value of the current through the transmission line during the measurement at that moment obtained from the Bitola 2 substation at REK Bitola was I_{sr} = 426 A

VII. CONCLUSION

For the purposes of my work, a study of electromagnetic radiation from a 400 kV transmission line was conducted, in order to assess the risk to human health. The measurements were performed with a 3D EMF TESTER device in the field of electromagnetic radiation sources, near REK Bitola.
The strength of the magnetic field depends on the distance, voltage, overhead line head and current, while electric fields depend only on the distance, voltage and overhead line head (but not on the current flow). Electric fields associated with power frequency sources exist whenever voltage is present, regardless of whether current is flowing, and have a very weak ability to penetrate bodies, much less the skin of people. Because magnetic fields exist only when current is flowing, and hence protection from these magnetic fields is difficult, they easily penetrate the human body. Since power frequency electric fields do not penetrate the body, it is assumed that any biological effect of exposure in an urban environment to power frequency fields may be the result of the magnetic component of the field or the currents that these magnetic fields induce in the body. (This topic has been the subject of debate around the world in recent years).
In recent decades, the question of the existence of a connection between power lines and carcinogenic diseases has been frequently raised. Numerous studies have been conducted on people living near power lines and people working in the electrical profession. Epidemiological studies in recent years have shown a small correlation between power lines and possible carcinogenic diseases. The same results have been reached by laboratory studies that have also shown a weak correlation, so most scientists take the position that there is no evidence that power lines cause or contribute to the occurrence of these diseases because the presented research results are insufficient and inconclusive.
The life that we all live, whether at home or at work, we could not imagine without the use of electricity. A reasonable attitude of each of us would be that when assessing the risk, there would be neither overestimation nor underestimation of the possible consequences of the impact of EM radiation. It ultimately comes down to assessing whether the harm is greater than the benefit. To solve the problem, we must not think of moving backwards and giving up on the progress we have achieved. Also, we must not "rush" forward and cause uncontrolled progress of

technique and technology, to the detriment of human health. We should seek the solution in the controlled use of devices that generate this radiation. I would like to emphasize again that this problem has been considered by various national and international institutions, but to this day, none of them has concluded that adverse effects on the health of people who are normally exposed in everyday life have been established with certainty.

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