

Specifications for Biological Effects Assessment of 5G Networks on Humans

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Abstract—In many countries, preparations are completing for the rollout of 5G networks, which are replacing the existing fourth-generation networks. Thanks to new Physical Layer (PHY) technologies and the use of new frequency bands with wider operating bandwidths in 5G systems, it is planned to increase the data transfer rate to 30 Gb/s. The frequency range (FR) in the 5G NR Standard is divided into FR1 (410 MHz to 7125 MHz) and FR2 (24250 MHz to 52600 MHz). Also, in 5G systems it is planned to use new technologies such as Massive MIMO and Beamforming with beam coordination. Recently, the scientific world and in society have been actively discussing the impact of radiation generated by these technologies on humans. The results of the study of electromagnetic radiation negative impact on humans are reflected in many international specifications, but this issue has not been finally resolved for 5G systems. This report examines these problems and specifications that are used in different countries. The base station radiation limits imposed by these specifications are intended to minimize the negative human impact of 5G systems.

I. INTRODUCTION

Nowadays preparations are completing for 5G networks rollout which represent a further development and significant expansion of the already launched fourth generation networks. In such networks physical layer (PHY) is based on MIMO (Multiple Input Multiple Output) technology, which is widely used to significantly increase spectral efficiency and energy efficiency of modern radio communication systems [1], [2], [3]. It should be mentioned that in 5G networks is planned to increase the data rate to 30 Gb/s.

One of the main features of 5G networks is the use of antenna systems based on adaptive antenna arrays using Massive MIMO (i.e. MIMO technology with a large number of antennas) and Beamforming technologies [3]. Massive MIMO and Beamforming technologies with beam coordination allow to form narrow beams towards the subscriber station to increase the data rate, which in turn results in an increase in radiated power towards the subscriber.

Recently, the scientific world and in society have been actively discussing the impact of electromagnetic fields (EMF) radiation generated by these technologies on humans [4]. In this report we consider the problem of negative impact of 5G networks radiation on humans and specifications for EMF radiation that are used in different countries to minimize the negative impact on humans in 5G frequency ranges.

II. FREQUENCY RANGES OF 5G NETWORKS AND SPECIFICATIONS FOR EMF RADIATION

Fifth generation networks use two groups of frequency ranges [2]: the first (FR1) includes frequencies from 410 MHz to 7125 MHz, the second (FR2) – from 24250 MHz to 52600 MHz. In the frequency ranges above 6 GHz it is necessary to increase the number of base stations, which leads to an increase in the total radiated power. Therefore, the use of the microwave frequency ranges, especially millimeter waves, causes alarm among the people around the world. Based on the foregoing, the problem of 5G networks radiation impact on the human body has arisen.

There are many organizations in the world, national and international, that deal with the safety of EMF radiation when exposed to humans. One of the main independent organizations involved in this activity is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP was created to study the risks to human health that may be associated with exposure to various types of non-ionizing radiation and to develop scientifically substantiated requirements for limiting the exposure to EMF on humans to ensure an acceptable level of protection of human health from known adverse effects [5], [6].

When building 5G networks, one of the main regulatory documents of the ICNIRP is the "ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)" [5]. The specifications given in this document are accepted and are basic in many countries of the world. All permissible values given in the above document are based on scientific biomedical research. These specifications are accepted and are fundamental in many countries around the world.

III. BIOLOGICAL EFFECTS ASSESSMENT AND SPECIFICATIONS OF INTERNATIONAL ORGANIZATIONS

Various scientific methods are used to assess EMF biological effects for various frequencies [7], [8]. For fields with frequencies from 100 kHz to 10 GHz, the main limits are given in terms of Specific Absorption Ratio (SAR) to prevent heat stress in the human body; and for fields with a frequencies from 10 GHz to 300 GHz, the main limits are given for the

Power Flux Density (PFD) in order to prevent increased heating on the surface or at the surface of the human body.

Methods of mathematical simulation are often used to study the effects of EMF on humans. They allow you to estimate the maximum levels of EMF exposure on the human body. It should be also mentioned that two types of regulations are used. Norms for working conditions and norms for protecting the population. Specifications designed to protect people impose more stringent requirements on EMF radiation levels.

Radiofrequency (RF) levels of modern technologies exposure to lead to a slight increase in temperature in the human body. As the frequency increases, there is less penetration into body tissues and energy absorption becomes more limited by the body surface (skin and eyes). Provided the overall exposure remains below international specifications, no public health impact is expected [6], [7], [8].

The International Telecommunication Union (ITU) is also involved in the study of EMF negative impact of on humans [7]. ITU provides some guidance for measuring radiation levels, especially in the case of newly emerging technologies. This work is chaired by the "EMC, lighting protection, EMF" working group of the telecommunication standardization sector (ITU-T). ITU-T has published many documents on the effects of EMF on the human body. These are recommendations on how to comply with the EMF limits for human exposure and how to limit such exposure. Also, ITU-T is working on the development of special software for predicting EMF levels from modern radio communication networks such as 5G.

All of this research and work is carried out in close collaboration with other international and national organizations (for example, the International Electrotechnical Commission (IEC), the Institute of Electrical and Electronic Engineers (IEEE), the World Health Organization (WHO) and others), which carry out their research tasks in the field of telecommunication and radio communication systems standardization [9], [10], [11].

IV. EXAMPLES OF RADIATION LIMITS IN DIFFERENT COUNTRIES

The history of the study of the assessment of the harm of using mobile phones to human health is approximately 20 years. Thus, it is impossible to say with certainty whether mobile phones pose a potential health risk, since this is a short period for such studies. According to the World Health Organization, no adverse health effects caused by the use of mobile communications have been identified [6], [8], [11].

International documents, such as ICNIRP Guidelines, are not legally binding in any particular country [6]. In order to come into force, these documents must be transferred to the national regulatory framework. According to the results of more than a 20-year period of using these standards, there was no medical and biological evidence of a negative impact on human health of EMF with the indicated levels.

Considering the recommendations of various international organizations, one can notice that levels of electromagnetic fields in the regulatory documents of many countries, in general, have similar values. However, many countries use their maximum permissible levels, which are significantly

different from the generally accepted ones. Table I shows radiation limits based on international specifications for mobile communication systems with frequency ranges below and above 6 GHz [9], [10].

TABLE I RADIATION LIMITS FOR MOBILE COMMUNICATION SYSTEMS WITH FREQUENCY RANGES BELOW AND ABOVE 6 GHz

Country	Power flux density ($\mu\text{W} / \text{cm}^2$) (to protect people)	
	1.8 GHz	> GHz
ICNIRP	900	900
Russia	10	10
Switzerland	9.5	9.5
Italy	10	10
China	10	10
Canada	440	1000
USA	1000	1000

Analyzing the data from Table I, it can be seen how much the specifications for non-ionizing radiation differ in different countries of the world. The mildest levels are used in the USA. The most stringent standards are used in a number of countries, for example, in Russia, China, Italy – this is $10 \mu\text{W} / \text{cm}^2$ – which is a hundred times stricter in comparison with international standards.

V. MAXIMUM PERMISSIBLE LEVELS OF EMF RADIATION IN RUSSIA AND THEIR CONTROL

In the Russian Federation, the norms for EMF radiation are regulated by the Sanitary Norms and Rules. The requirements of sanitary rules were introduced to minimize the adverse effect on human health of electromagnetic fields generated by base and mobile stations of mobile radio communication systems. Requirements for permissible levels of EMF radiation to protect people are presented in Table II [11].

TABLE II MAXIMUM PERMISSIBLE LEVELS OF EMF IN THE RANGE FROM 3 MHz TO 300 GHz TO PROTECT PEOPLE

Frequency range	3-30 MHz	30-300 MHz	0.3-300 GHz
Parameter	Electric field strength, E (V / m)		PFD ($\mu\text{W} / \text{cm}^2$)
Maximum permissible levels	10	3	10 (25^*)
* - when radiated from antennas operating in a scanning mode			

The commissioning and operation of base stations, as well as the levels of EMF radiation from them, are strictly regulated by law and monitored by authorized government bodies. The locations of base stations are planned to minimize the impact of electromagnetic fields on people during their operation. After the base station is put into operation, with an interval of 1 to 3 years, control of electromagnetic radiation level is carried out in the territory adjacent to the base station and in residential buildings.

In the Russian Federation, to control compliance with sanitary standards for radiation, there are special state regulatory bodies (Rospotrebnadzor and Roskomnadzor), which conduct measurements of EMF radiation levels, and make a conclusion whether the permissible levels are exceeded or comply with specifications.

Summing up the above, we can conclude that the issue related to the safety of EMF radiation by 5G base stations on people has not been unambiguously resolved [6], [7], [9], [10], [11]. This is evidenced by the fact that different countries use different standards for permissible levels of EMF, that is, there are disagreements and there is no consensus.

VI. CONCLUSION

Future 5G networks are designed for significant increasing in data rates, using Massive MIMO technology in millimeter frequency bands. 5G networks will additionally use Beamforming technology to more efficiently focus signals on specific subscriber devices [1], [2], [3]. These new technologies and new frequency bands alarms people around the world about the impact of such EMF radiation on humans.

Health conclusions are drawn from studies done across the entire RF spectrum, but only a few studies have been done to date on frequencies that will be used in 5G. Higher frequencies are new to mobile networks (they are now used, for example, for microwave communications and other radio services). At these higher frequencies, 5G networks will use more base stations and connected devices [1], [3], [4].

Research of biological effects caused by EMF radiation when using mobile communication systems is actively continuing. They are conducted both at the international level and at the state level around the world [6], [9], [11]. The norms introduced to protect the population lead to severe restrictions

on the permissible levels of radiation from base stations in order to minimize the negative impact of radiation on the human body. However, the analysis shows that different standards are used in different countries and there is no consensus on the specifications for EMF permissible levels [4].

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