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# AN OVERVIEW OF THE IMPROVEMENTS SUPPORTED BY ICNIRP 2020 GUIDELINES COMPARED TO THEIR PREVIOUS EDITIONS

BY

**PETRONELA-CAMELIA OPREA*, MATEI-CONSTANTIN MORUZ, MARIUS-VALERIAN PĂULEȚ and ALEXANDRU SĂLCEANU**

“Gheorghe Asachi” Technical University of Iași,
Faculty of Electrical Engineering, Iași, Romania

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**Abstract.** A highly respected authority in the field of non-ionizing radiation (NIR) is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This non-profit organization with a scientific mission is a non-state actor that is an official collaborator of both the World Health Organization (WHO) and the European Commission. The frequency spectrum of these electromagnetic radiations is very wide, starting from infrasound mechanical waves and ending with ultraviolet waves. ICNIRP first developed a comprehensive set of guidelines in 1998. These recommendations were updated in 2010. The most recent scientific progress acquired in the NIR domain, especially from the perspective of their biological effects and methods of monitoring, control and reduction, have been included in the 2020 version of the ICNIRP guidelines. This paper summarizes these improvements, insisting on the main scientific justifications that were at their base. Updates related to the importance of transparency in the development of normative acts, new thresholds, changes to restrictions, the introduction of a new frontier (6 GHz) related to the formulation of exposure restrictions, and the

*Corresponding author; *e-mail*: camelia-petronela.oprea@staff.tuiasi.ro

modification of some reference level values are discussed. Attention is given to the Specific Absorption Rate (SAR) definition.

**Keywords:** normative, directive, SAR, non-ionizing radiation, health effects.

## 1. Introduction

In recent decades, we have witnessed explosive development of applications that integrate the electromagnetic environment into everyday life (mobile phone and communication systems, broadcasting, wirelessly interconnected computer and data transfer systems, remote control and security for public and private spaces, radar detection and GPS tracking systems, household appliances, toys, etc.). For these reasons, various international and governmental organizations and national bodies have taken into account the problem of occupational exposure, but especially the uncontrolled exposure of the population to electromagnetic radiation. Since the start of the 20th century, internationally recognized organizations worldwide have carried out studies on the effects of EMFs on living beings.

National regulations and legislation are based on the recommendations of these studies. One of these is the ICNIRP, set up in 1992 and specializing in the publication of reference guidelines on exposure of the general public or occupational groups to non-ionizing radiation, which are also used as a reference in European Union legislation, including national legislation. Of particular interest are the authors who carry out numerous studies on the health effects of electromagnetic fields. For example, the authors (Thomas *et al*., 2023) developed a Z-shaped patch antenna to detect skin cancer. The antenna was implanted into human skin to detect the presence of skin cancer using SAR distribution.

Also, authors (Psenakova *et al*., 2017a) drew attention to the study where the band RF at the cochlear implant is analyzed by evaluating SAR in the multilayered structure of the skin with cochlear implant while comparing with values in guidelines. The same authors also performed the first studies involving simulation and analysis of the RF (2.4 GHz) within human tissue using a multi-layer skin and pacemaker model (Psenakova *et al*., 2017b). Thus, many developing technologies using EMF, over a wide spectrum range maintain the relationship between EMF and potentially adverse health outcomes. The general public's safety has become increasingly important and the ICNIRP Guidelines have had to be reviewed and updated to keep pace with advances in relevant scientific knowledge.

The present article by the authors aims to explain the main differences between the guidelines. In addition to explaining the various principles contained in the guidelines mentioned earlier, the goal is to assist individuals in understanding their necessity. This article presents a detailed analysis of the main differences but should not be seen as a substitute for the ICNIRP Guidelines. As

a result, all of the information in this article is derived from the ICNIRP Guidelines; that being said, the ICNIRP, in all of its forms, is the only source of information considered relevant in situations in which there is apparent or contrary proof.

In Romania, the issue of exposure to electromagnetic fields is regulated by law, and the limits recommended by ICNIRP and the Federal Communication Commission are valid. The exposure limits for the general population are 50 times lower than the limits for which there are scientific results on health effects (so called thermal effects).

## 2. Results and discussion

The ICNIRP Guidelines introduce two categories of physical quantities on which restrictions are imposed:

• *Basic restrictions*: which are directly related to biological effects;

• *Reference levels*: which are physical quantities that can be directly measured or calculated in a given circumstance and are conditional on the performance of the radiation source and the exposure conditions.

(ICNIRP, 2020) the limits for exposure to EMF range from 100 kHz to 300 GHz. This guide extends the EMFs part of the (ICNIRP, 1998) with limits ranging from 100 kHz to 10 MHz, while also incorporating (ICNIRP, 2010) guidelines with limits for low frequency.

Since the ICNIRP 1998 and 2010 Guidelines did not cover an extremely large area, it was necessary to produce the ICNIRP 2020 Guidelines in addition to the other two. The guide describes a multitude of measures to protect people who are exposed to EMFs in the average values mentioned. In any frequency range, the measure used to characterize the effects of the EMFs is the SAR, to which particular limit values have been imposed in all three guidelines. Restriction limits are updated on an ongoing basis and every so often as new adaptations are made, the guidelines are revised and adapted according to new requirements. In general, these guidelines are intended to describe limits for the dosimetry area, as well as from a biological point of view, in terms of human health in contact with EMF and the effects due to EMF on the human body.

In the vast majority of studies to date, special interest is shown in EMF exposure from several points of view, limits are regulated with regard to effects on human health, studies such as medical procedures, effects of medical devices, implantation of various metallic components inside the body, disturbance of EMFs in the human body, etc. In the case of EMF action, a detailed analysis of these phenomena is extremely important.

### 2.1. General defining elements of protection systems in ICNIRP

#### *2.1.1. Transparency*

Public understanding of the limitations they confront is the rising considerably as a result of the abundance of scientific research being conducted in this field by writers from around the world. Another aspect of the most recent ICNIRP guidelines that demonstrates their transparency is the fact that numerous projects and studies have been conducted in collaboration with the scientific community to address both the simpler and more complicated problems in the before guidelines, thus offering a comprehensive evaluation of recent and upcoming scientific advancements. However, it is also made very evident that the knowledge of specialists in the subject will continue to be necessary at specific moments in the formulation process (the most obvious and frequent instance being if a technology of any kind were found to have a negative impact on one's health).

Still, it goes without saying that the validity of the assertion itself has to be developed, investigated, and, at the very least, resolved by setting exposure limitations that can be maintained all through time and in future steps.

#### *2.1.2. A variety of fields of application*

In that they both offer information on protection against any negative effects on health, whether carried on by acute or chronic exposure, independent of age, gender, or current health, the scope of the (ICNIRP, 2020) and (ICNIRP, 1998) are highly identical.

#### *2.1.3. Adverse health effects thresholds*

Previous research papers, such as the (ICNIRP 2020) have used the claim that *"Exposure to EMF can cause adverse health effects"*. As long as exposure to EMFs stays within the bounds of the (ICNIRP, 1998) declared that *"EMF does not cause adverse health effects"* a significant body of research and literature support EMF exposure. The methodology for establishing thresholds for detrimental health consequences was greatly improved by (ICNIRP, 2020). Based on the (ICNIRP, 1998) the expert panel acknowledged that *"thermal effects make it difficult to determine thresholds for adverse health effects"*.

This acknowledgement brought to light how difficult it is to determine the lowest amount of EMF-induced health damage, hence requiring extensive research. By utilizing the gathered data (ICNIRP, 2020) improved and expanded the recommendations, guaranteeing more accurate and dependable safeguards against electromagnetic field exposure.

*2.1.4. The effect of EMF on fertility, reproduction and ultimately the fetus*

On limits on exposure (ICNIRP, 1998) and (ICNIRP, 2010) offer details on *"fertility, reproduction, or fetus"*. For conclusive evidence to the contrary (ICNIRP, 2020) treats the fetus as a member of the *"general public"* and places limits on it, even in cases where exposure to variables classified as external *"occupational"* causes harm to developmental outcomes. The conclusion of the guidelines presents the theory that, although limits are necessary, there are no negative effects of EMFs on fertility, reproduction, or the health of the fetus itself.

*2.1.5. The EMF effect of various electronic devices on cancer*

A number of academic papers have been published about cellular and molecular mechanisms that are specifically associated with cancer. This includes studies of cell proliferation, differentiation and apoptosis-related processes. Although asserts of RF EMF effects across multiple of these, no conclusive evidence of health-relevant effects has been discovered (Vijayalaxmi *et al.*, 2018).

Despite certain animal research studies have found positive benefits of RF EMF exposure on carcinogenesis, the majority of these studies have problems in their methodology or dosimetry, or their results have not been confirmed by other independent investigations. across fact, across a wide range of animal models, the great majority of studies have not shown any carcinogenic effects.

Two other recent animal studies investigating carcinogenicity in long-term exposure to mobile phone-associated RF EMF have been released for review: the first review was conducted (NTP, 2018) and the other by the (Falcioni *et al.*, 2018). Although both studies used large numbers of animals, there are still important inconsistencies and limitations that affect the usefulness of their results for a concrete setting of (ICNIRP, 2020). In addition to these, some studies have been conducted on other tumor types such as leukemia, lymphoma, uveal melanoma, pituitary gland tumors, testicular cancer, and malignant melanoma. With a few exceptions, studies have collected self reported information about mobile phone (Lerchl *et al.*, 2014).

Hardell and Carlberg (2009) report from significantly increased the risks of both acoustic neuroma and malignant brain tumors already less than five years after the start of mobile phone use. However, they are not consistent with guidelines and limitations.

Also, studies of other tumor types have not provided evidence of an increased tumor risk from mobile phone use. Only one study is available on mobile phone use in children and brain tumor risk (Aydin *et al.*, 2011). Studies of exposure to environmental RF EMF, for example from radio and television transmitters, also have not provided evidence of increased cancer risk (Hardell *et al*., 2005). Thus, the present epidemiological studies do not provide evidence of

a carcinogenic effect of exposure to RF EMF at levels encountered in the general population.

### 2.2. Changes to basic restrictions

Updates to exposure restrictions are made permanent in (ICNIRP, 2020). These updates include new restrictions added, existing restrictions from previous guidelines modified and some restrictions completely removed. The main goals of these changes are to adapt the guidelines to new technological developments, like the introduction of 5G technologies and to improve accuracy based on scientific advancements. For instance, more accurate knowledge about the relationship between the spatial average of exposure and temperature rise has led to the removal of some restrictions that were found to be ineffective in protecting against adverse health effects.

#### *2.2.1. Changes to restrictions on average whole-body exposure*

The SAR parameter serves as the basis for the whole-body exposure limits in (ICNIRP, 1998) and (ICNIRP, 2020). Exposure limits range from 100 kHz to 300 GHz according to the (ICNIRP, 2020) and from 100 kHz to 10 GHz according to the (ICNIRP, 1998). Due to these variations (ICNIRP, 2020) is amend to account for new technologies that don't raise body temperature unnecessarily. Furthermore, there has been a modification in the mean duration of exposure measurement. (ICNIRP, 2020) it will last 30 minutes instead of the previous 6 minutes. With this modification, there will be a stronger correlation between the amount of time needed to raise body or tissue temperature and the amount of time needed to conduct an efficient exposure assessment.

#### *2.2.2. Transition frequency changes for local exposure*

Limitations on SAR distribution exposure were stipulated in (ICNIRP, 1998) and power density limitations were implemented beyond 10 GHz. We refer to the frequency at which this changeover takes place as the *"transition frequency"*. Because power density can underestimate exposures at lower frequencies and SAR distribution can underestimate exposures at higher frequencies, several values are used. While there isn't a perfect transition frequency, (ICNIRP, 2020) has taken a more important stance by lowering the frequency from 10 GHz to 6 GHz, which will result in exposure evaluations that are more accurate.

#### *2.2.3. Local SAR time-averaged ($f \leqslant 6$ GHz)/ ($f \geqslant 6$ GHz)*

(ICNIRP, 2020) significantly update the reference levels for EMFs across several frequencies and body regions as compared to (ICNIRP, 1998).

(ICNIRP, 2020) saw the updating of the recommendations for EMFs in order to better protect various body regions and increase the accuracy of temperature rise assessment. Among the significant adjustments are:

1. *SAR Distribution and Spatial Averaging:* (ICNIRP, 1998) which advised averaging SAR distribution over a *"contiguous"* tissue region, (ICNIRP, 2020) suggest averaging SAR distribution over a 10 g cubic zone. The goal of this modification is to give a more accurate estimate of temperature rise. With special emphasis to the head, torso and limbs (ICNIRP, 2020) also propose distinct exposure limits for different body areas at frequencies below the transition frequency.

2. *Incident Power Density vs. Absorbed Power Density*: For values above 6 GHz, (ICNIRP, 2020) rules employ *"absorbed power density"* which takes into account body absorption more thoroughly than the *"incident power density"* mentioned in (ICNIRP, 1998). The goal of this change is to give a body exposure measurement that is more precise.

3. *Average Area of Mediation and Focus:* Compared to the 20 $cm^2$ average utilized in (ICNIRP, 1998), (ICNIRP, 2020) reduced region average of 4 $cm^2$. This modification makes sure that the acceptable exposure can not be concentrated in a small area, preventing an unwarranted rise in temperature. In addition, (ICNIRP, 2020) impose a 1 $cm^2$ limit for frequencies above 30 GHz in order to mitigate highly concentrated beams, which is especially important for developing technologies like 5G.

4. *Summary of Fundamental Limitations for EMF > 6 GHz:* By utilizing absorbed power density (ICNIRP, 2020) seted baseline limits for EMF > 6 GHz comparated with (ICNIRP, 1998). Peak exposure in the body for EMF > 6 GHz is lower in (ICNIRP, 2020) than in (ICNIRP, 1998) a 4 $cm^2$ average area was implemented. In compliance with international standards, these updates aim to ensure appropriate protection against exposure to EMF, reflecting the ongoing growth of scientific knowledge and technologies.

### *2.2.4. Nerve stimulation restrictions (100 kHz to 10 MHz)*

(ICNIRP, 2020) comprised a reassessment of the fundamental limitations delineated in (ICNIRP, 2010) were principally intended to provide protection against nerve stimulation. These limitations cover the frequency range between 100 kHz and 10 MHz, which is where thermal effects and nerve stimulation may both be possible. The basic limitations for nerve stimulation (ICNIRP, 2010) have been included in the updated (ICNIRP, 2020) along with the basic restrictions for any other possible negative health effects. A complete set of fundamental limitations covering the whole EMF range, from 100 kHz to 300 GHz, is ensured by this integration.

### 2.3. Changes in reference levels

#### *2.3.1. Additional reference levels*

In particular, reference limits for continuous whole-body exposures were developed (ICNIRP, 1998). This was especially relevant when assessing public compliance with EMF emissions from gadgets such as mobile phone base stations. These reference levels did not cover all forms of fundamental constraints, so they had limitations. By contrast, reference levels for all fundamental constraints are currently provided (ICNIRP, 2020). This all-inclusive method makes it easier to evaluate compliance with all fundamental constraints. However, difficulties in differentiating between near and far fields might still pose problems, making it impossible to apply reference levels in certain circumstances.

#### *2.3.2. Removal of reference levels*

Reference thresholds for whole-body exposure over 10 GHz in terms of power density, magnetic field (H-field) and electric field (E-field) were set in (ICNIRP, 1998). It was discovered, meanwhile, that E-field and H-field readings over around 2 GHz might not always reliably represent adherence to safety restrictions. In order to achieve a more accurate evaluation of EMF exposure, (ICNIRP, 2020) decided not to utilize E-field and H-field values for whole-body exposure over 2 GHz.

Reference values for contact currents, when a conductive object directs RF EMF toward a person through physical touch, were also included in (ICNIRP, 1998). This may cause the tissue's SAR to rise and maybe beyond the safety thresholds. While (ICNIRP, 2020) found that it is difficult to provide a universal reference level because of the various characteristics involved that cannot be simply predetermined, having a reference level for contact currents could assist prevent such over exposure.

For this reason, explicit reference levels for contact currents are no longer provided (ICNIRP, 2020). The goal of is to guarantee that occupational health and safety programs comprehend and adequately handle the possible risk that contact currents provide. The goal (ICNIRP, 2020) is to assist businesses in putting suitable safeguards in place to reduce the dangers brought on by contact currents and EMF exposure at work.

#### *2.3.3. More specification of compliance rules*

Reference levels were mainly set for EMFs (ICNIRP, 1998) with the understanding that the near-field region may also use these levels. But as knowledge about EMF exposure increased, it became clear that more reference

values were required to guarantee that the fundamental limitations in the near-field zone were followed.

Due to this, determining and evaluating EMFs in close proximity to the source became difficult. In order to tackle these issues (ICNIRP, 2020) implemented distinct reference levels that are suited for various field zones, such as the reactive near-field zone, radiative near-field zone and far-field zone. This method acknowledges the unique qualities of every field region and the requirement for personalized reference levels in order to properly comply with the fundamental constraints. Moreover, a proper estimate of EMFs depends on the correlation between reference levels and baseline restrictions. This association can be influenced by variables like the size and shape of the antenna, which highlights the significance of working with technical standards organizations to develop accurate guidelines for near and far field locations.

### *2.3.4. Differences in reference level values*

According to (ICNIRP, 1998), (ICNIRP, 2010) and (ICNIRP, 2020), these reference levels have changed over time in response to new scientific discoveries and the requirement for revised safety regulations.

Due of the paucity of research on frequencies lower than 30 MHz, (ICNIRP, 1998) established extremely cautious reference values. The safety limits were set high to ensure protection against potential risks, even though the actual health impacts were uncertain, due to the absence of adequate scientific data. The reference levels were updated with the publication (ICNIRP, 2010), especially for low frequencies down to 10 MHz. In comparison with (ICNIRP, 1998) the magnetic field reference levels were raised while the electric field reference levels were lowered.

To better reflect the most recent scientific understanding of EMFs, (ICNIRP, 2020) has updated the reference limits. Higher reference level values were found to be required in order to guarantee adherence to the fundamental constraints, even though they did not change. Reference levels rose as a result, particularly in the 100 kHz-30 MHz frequency band.

A noteworthy finding of (ICNIRP, 2020) was that reference level values for magnetic and electric fields increased steadily with decreasing frequency, beginning at 30 MHz. This emphasizes how important it is to modify reference levels in order to maintain safety requirements, taking into account the unique properties of various frequency ranges.

Additionally, by defining distinct values for exposures in the near and far field areas, (ICNIRP, 2020) brought about a significant change in the use of reference levels. This distinction ensures that people are sufficiently safeguarded against overexposure, especially in the near-field zone, by addressing potential differences in exposure levels based on the closeness to the EMF source.

## 3. Conclusions

In conclusion, the evolution of scientific understanding and the requirement to update standards to guarantee efficient and secure protection against non-ionizing radiation are reflected in the establishment of reference levels for EMFs. These updates have to be in line with what is known at the moment and offer precise instructions on how to avoid exposure to EMFs.

The thorough research provided in this paper emphasizes how vital it is to keep creating rules and recommendations to shield people from the possible health concerns connected to NIR exposure. The guidelines developed by the (ICNIRP, 1998) and (ICNIRP, 2020) show a deliberate attempt to include the most recent scientific findings and technology advancements into the regulatory framework for public health protection.

As this discussion has demonstrated, there have been substantial changes and improvements made to many aspects of exposure assessment and limitation implementation between (ICNIRP, 1998), (ICNIRP, 2010) and (ICNIRP, 2020). Every iteration of the guidelines has aimed to improve the accuracy, applicability and effectiveness of protective measures, starting from the clarification of fundamental limitations and reference levels and progressing to the inclusion of more complex factors like transparency, exposure assessments specific to a field and the influence on particular physiological processes.

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## O PREZENTARE GENERALĂ A ÎMBUNĂTĂȚĂRILOR EXPUSE ÎN GHIDUL ICNIRP 2020 COMPARAT CU EDIȚIILE ANTERIOARE

(Rezumat)

O autoritate foarte respectată în domeniul radiațiilor neionizante (NIR) este Comisia Internațională pentru Protecția împotriva Radiațiilor Neionizante (ICNIRP). Această organizație non-profit cu misiune științifică este un actor non-statal care este colaborator oficial atât al Organizației Mondiale a Sănătății (WHO), cât și al Comisiei Europene. Spectrul de frecvență al acestor radiații electromagnetice este foarte larg, pornind de la unde mecanice infrasunete și terminând cu unde ultraviolete. ICNIRP a elaborat pentru prima dată un set cuprinzător de ghiduri în anul 1998. Aceste recomandări au fost actualizate în decursul anului 2010. Cele mai recente progrese științifice dobândite în domeniul NIR, în special din perspectiva efectelor lor biologice și a metodelor de monitorizare, control și reducere, au fost incluse în versiunea 2020 a ghidurilor ICNIRP. Această lucrare rezumă aceste îmbunătățiri, insistând asupra principalelor justificări

științifice care au stat la baza lor. Se discută actualizări legate de importanța transparenței în elaborarea actelor normative, noi praguri, modificări ale restricțiilor, introducerea unei noi frontiere (6 GHz) legată de formularea restricțiilor de expunere, precum și modificarea unor valori ale nivelului de referință. O atenție deosebită este acordată definiției ratei de absorbție specifică (SAR).