VIEWPOINT

MWF Mobile & Wireless Forum

How RF Exposure Limits are Derived.

The Radio Frequency (RF) Electromagnetic Field (EMF) exposure limits in many countries are based on guidelines or standards developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[1] or the Institute of Electrical and Electronics Engineers (IEEE)[2]. While there are some differences, the limits they recommend for mobile and wireless networks and devices are essentially the same.

Based on a detailed review of the available science[3], both ICNIRP and IEEE have identified a threshold for adverse health effects of a whole body exposure of 4 W/kg. If exposed to this or higher levels over a prolonged period, the core body temperature can rise by 1 degree or more – which has been linked to adverse health effects. So while the body is quite capable of dealing with temperature fluctuations such as through normal blood circulation and sweating, the limits are designed to guard against a prolonged temperature rise where adverse health effects can occur.

Both ICNIRP and IEEE take this threshold whole body exposure value (4 W/kg) and divide it by 50, arriving at the whole body limit of 0.08 W/kg, which is relevant for emissions from base stations, radio transmitters and other such infrastructure. This reduction factor ensures that the limits are well below the levels that are required to cause adverse health effects.

In the context of localized exposure (i.e., to a part of the body as opposed to the whole body) the ICNIRP guidelines explain:

> *"Animal studies have also reported that the heating that results from radiofrequency EMF exposure may lead to the formation of cataracts in rabbits. In order for this to occur, very high local SAR levels (100–140 W kg^{-1}) at low frequencies (< 6 GHz) are needed with temperature increases of several °C maintained for several hours."*

This is also supported by the IEEE C95.1-2019 standard:

> *"[…] the limit of 10 W/kg averaged over 10 g is supported by results from animal*

---

[1] ICNIRP Guidelines For limiting exposure to electromagnetic fields (100 kHz - 300 GHz) *Health Physics* 118(5): 483–524; 2020 https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf

[2] IEEE Std C95.1™-2019 "IEEE Standard for Safety Levels With Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz" https://ieeexplore.ieee.org/document/8859679

[3] ICNIRP describes this process on its website as including "all scientific literature of good scientific quality was used to set the guidelines" and that "the literature included research searching for effects of both brief and long-term exposures to radiofrequency electromagnetic fields (RF EMF), on both immediate (e.g., pain) and delayed (e.g., cancer) health outcomes. This included evaluation of self-reported hypersensitivity to RF EMF exposure. Importantly, the research that focused on potential adverse health effects of RF EMF exposure did not make any assumptions about the mechanisms of action of the RF EMF (e.g., thermal versus non-thermal), but merely looked for any verified (substantiated) adverse health effect, and where identified, instigated protective measures regardless of mechanism." See https://www.icnirp.org/en/rf-faq/index.html

experiments…showing that this limit is 10 times below the SAR threshold for cataracts in rabbits, which is estimated to be 100 W/kg deposited in the eyeball, which is a mass of about 10 g."

IEEE used this 100 W/kg threshold level to establish localized limits for persons in 'restricted environments' (i.e., occupational limits) by applying a 10-fold reduction to 10 W/kg. For persons in 'unrestricted environment' (i.e., the public) IEEE applyed a further 5-fold reduction - or 50-fold reduction in total - to 2 W/kg for the head and torso.

ICNIRP's 1998 guidelines[4] was based on the same approach as adopted by IEEE but in the 2020 guidelines this changed, even though the SAR limits remain the same. The 2020 guidelines are now based on temperature increases in two types of tissues[5]. For Type 2 tissues such as the head, a local threshold SAR of 20 W/kg averaged over 10 g and 6 minutes is based on thermal analysis. After applying a reduction factor of 2, the occupational exposure limit is set at 10 W/kg per 10 g. For general population exposures, another factor of 5 is applied to derive a limit of 2 W/kg per 10 g. For Type 1 tissues such as limbs, the threshold SAR is doubled (i.e., 40 W/kg) but the reduction factors remain the same. Therefore, the reduction factors in the 2020 ICNIRP guidelines are 2 for the occupational local exposures and 10 for the general public local exposures. For frequencies above 6 GHz, the same thermal basis is applied to the "absorbed power density" with the limits then stated in W/m^2. In either case, the reduction factors of 2 and 10 for local exposures apply from 100 kHz to 300 GHz.

The RF exposure limits are therefore derived from a detailed review of the available science and irrespective of how the relevant limit is stated (W/kg or W/m^2) it is just a way of expressing the amount of RF energy that should not be exceeded to ensure that the identified health effects are never at risk of being realized. In any case, at whichever frequency is in question, the reduction factors applied in establishing the limits alone provide an ample safety margin[6] with independent expert groups and world health agencies agreeing that no adverse health effects have been confirmed below the ICNIRP guidelines or the IEEE exposure standard.

July 2021

---

[4] ICNIRP subsequently reconfirmed these Guidelines in 2009 and 2017.

[5] ICNIRP defines these tissue types as follows:
Type 1: all tissues in the upper arm, forearm, hand, thigh, leg, foot and auricle, and epidermal, dermal, fat, muscle and bone tissue. These tissues have a lower baseline temperature and require a higher temperature increase (+5ºC) to get to 41ºC.
Type 2: all tissues in the head, eye, abdomen, back thorax and pelvis (excluding those defined as type 1 tissue). These tissues have a higher baseline temperature and require a lower temperature increase (+2ºC) to get to 41ºC

[6] ICNIRP Guidelines also note (p3): "The degree of protection in the exposure levels is thus greater than may be suggested by considering the reduction factors, which represent only one conservative element of the guidelines. There is no evidence that additional precautionary measures will result in a benefit to the health of the population."