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TECHNICAL REPORT

EMF Radiation
from
IoT/ M2M devices

TEC 31208:2023

EMF Radiation Working Group

ISO 9001 :2015

TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
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Executive Summary

The proliferation of Machine- to- Machine (M2M)/ Internet of Things (IoT) devices having wireless (cellular/ non cellular) connectivity and wireless fixed installations around the world, has exposed the people to different sources of Radio-Frequency Electromagnetic Fields (RF-EMF). The levels of RF-EMF vary due to data traffic, quality-of-service (QoS) requirements, network coverage and capacity extension, and the introduction of new technologies. RF-EMF limits for safe human exposure of the general public and workers have been adopted world over, including India. The dominant sources of human exposure to RF-EMF are Base Station Transmitters which are typically installed on the towers as well as the devices/gadgets/mobile phones operating in close vicinity of the human body, such as handheld devices, near-field wireless and wearable devices.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) RF-EMF exposure guidelines are endorsed by World Health Organization (WHO) and constitute the current scientific consensus: *"WHO encourages the establishment of exposure limits and other control measures that provide the same or similar level of health protection for all people. It endorses the guidelines of ICNIRP and encourages Member States to adopt these international guideline"* [1].

TEC has released nineteen technical reports in M2M/ IoT domain with recommendations intended to be used in the formulation of policies/ standards (refer section 2.2). TEC has modified the standard on *Specific Absorption Rate (SAR) for Wireless Communication Devices used in close proximity to human body*[2] (TEC 13016:2023), April 2023, superseding the earlier version TEC 13016:2020. Details are available in section 5.2.

TEC has received the DoT letter No 16-04/2021/CS-II dated 27.07.2022 to study the global best practices & examine the available knowledge-based on EMF radiation from IoT/ M2M devices and submit recommendation to formulate suitable policy on this issue (refer Annexure -3). This is with reference to National Digital Communication Policy (NDCP) – 2018 work item 2.2(d) vi, *Defining policy for EMF radiation for M2M/ IoT devices.*

This document is limited to the study of EMF exposure from IoT devices only and the EMF related to mobile base station is not the part of this study.

[1] https://www.who.int/publications/i/item/9241594330
[2] https://www.tec.gov.in/standards-specifications

1. Introduction and Background

Over the past decade, the Indian telecom sector has experienced remarkable growth, especially in mobile telephony and the widespread adoption of M2M/IoT devices. According to a report by the Telecom Regulatory Authority of India (TRAI) released in February 2023[3], India currently has approximately 1.17 billion cellular connections and around 0.85 billion internet users.

To ensure the safety of the general public and workers, the Government of India has established guidelines and prescribed limits for the safe exposure of RF-Electro-magnetic field (EMF) emissions from mobile towers, mobile handsets, and other connected devices. With the rapid proliferation of IoT/M2M devices, both in India and globally, these devices are increasingly being deployed in close proximity to human bodies within buildings and homes, contributing to the creation of smart infrastructure. This study is being done in view of NDCP 2018 work item received from DoT as referred in executive summary.

Numerous studies have been conducted to assess the potential risks associated with EMF radiation on human health, focusing primarily on the radiation emitted by base stations (BS), mobile handsets, and multimedia devices. Concerns have also been raised about continuous exposure to EMF radiation emanating from IoT/ M2M devices. The EMF radiation can cause thermal and non-thermal health effects.

The Internet of Things (IoT) is a rapidly emerging technology worldwide and is being leveraged to create smart infrastructure in various sectors, including power, automotive/intelligent transport systems, safety and surveillance, remote health management, education, agriculture, aquaculture, industry 4.0, homes/buildings, and e-governance etc. Some of these verticals play a crucial role in the development of smart villages and smart cities, offering significant benefits to society, industry, and consumers.

IoT relies on a combination of technologies such as AI/ML, communication technologies (cellular and non-cellular), and cloud/edge computing etc. According to the National Digital Communication Policy (NDCP) 2018 released by the Department of Telecommunications (DoT), the aim is to establish an ecosystem for connecting 5 billion devices by 2022.

It is estimated that there will be approximately 34.7 billion IoT devices in service globally by 2028, with around 16% of them utilizing cellular technologies, as reported by the Ericsson Mobility report in November 2022[4].

[3] https://www.trai.gov.in/sites/default/files/QPIR_03022023_0.pdf
[4] https://www.ericsson.com/4ae28d/assets/local/reports-papers/mobility-report/documents/2022/ericsson-mobility-report-november-2022.pdf

It has been projected that there would be around 11.4 billion consumer IoT devices and 13.3 billion enterprise IoT devices globally by 2025[5] i.e. consumer IoT devices would account for nearly 45% of all the IoT devices.

Considering the exponential growth of IoT devices, which predominantly rely on RF technologies, there is a need to study the EMF exposure associated with these devices.

[5] https://www.rcrwireless.com/20200305/5g/iot-connections-reach-almost-25-billion-globally-2025-gsma

2. DoT/ TEC initiatives in M2M/ IoT domain

2.1. DoT Policies in M2M/ IoT Domain

DoT has released a series of policy documents/ guidelines/ circulars for the proliferation of M2M / IoT domain, as listed below:

Policy Documents:

- ***National Digital Communication Policy*** released in 2018
- ***National Telecom M2M Roadmap*** released in 2015

Guidelines and Circulars:

- ***Guidelines for Registration Process of M2M Service Providers- M2MSP and WPAN/WLAN Connectivity Providers for M2M Services***[6]released in Feb 2022.
- ***Guidelines for grant of unified license***[7] ***(Virtual Network Operators)*** released in January 2022.
- ***Guidelines for embedded SIM (e SIM)***[8] released in May 2018.
- ***Circular on 13 digit numbering scheme for SIM based Machine to Machine (M2M) devices***[9] released in December 2016.

2.1.1. National Digital Communication Policy (NDCP) 2018

NDCP 2018 was released by Department of Telecommunications in 2018. It covers many points related to IoT, Artificial Intelligence and 5G.

Extract related to IoT, 5G and other emerging technologies in NDCP is as given below:

1. **Propel India: Enabling Next Generation Technologies and Services through Investments, Innovation, Indigenous Manufacturing and IPR Generation**

2022 Goals:

a. Expand IoT ecosystem to 5 Billion connected devices by 2022
b. Creation of innovation led Start-ups in Digital Communications sector
c. Train/ Re-skill 1 Million manpower for building New Age Skills

[6]https://dot.gov.in/sites/default/files/M2MSP%20Guidelines%20.pdf?download=1
[7]https://dot.gov.in/sites/default/files/UL%20%28VNO%29%20Guidelines_0.pdf?download=1
[8] https://dot.gov.in/sites/default/files/M2M%20Guidelines.PDF?download=1
[9] https://dot.gov.in/sites/default/files/M2M%20numbering.pdf?download=1

2. **Accelerating Industry 4.0**
    a. Create a roadmap for transition to Industry 4.0 by 2020 by closely working with sector specific Industry Councils.
    b. Establish a multi-stakeholder led collaborative mechanism for coordinating transition to Industry 4.0.
    c. Developing market for IoT/ M2M connectivity services in sectors including Agriculture, Smart Cities, Intelligent Transport Networks, Multimodal Logistics, Smart Electricity Meter, Consumer Durables etc. incorporating international best practices.

3. **Ensuring a holistic and harmonized approach for harnessing Emerging Technologies**
    a. Creating a roadmap for emerging technologies and its use in the communications sector, such as 5G, Artificial Intelligence, Robotics, Internet of Things, Cloud Computing and M2M.
    b. Simplifying licensing and regulatory framework whilst ensuring appropriate security framework for IoT/ M2M/ future services and network elements incorporating international best practices.
    c. Earmarking adequate licensed and unlicensed spectrum for IoT/ M2M services.
    d. Encourage use of Open APIs for emerging technologies.
    e. Ensuring the Transition to IPv6 for all existing communications systems, equipment, networks and devices.
    f. Enabling Hi-speed internet, Internet of Things and M2M for rollout of 5G technologies and services.

        - Implementing an action plan for rollout of 5G applications and services
        - Enhancing the backhaul capacity to support the development of next-generation networks like 5G.
        - Ensuring availability of spectrum for 5G in < 1 GHz, 1-6 GHz and > 6 GHz bands
        - Reviewing industry practices with respect to traffic prioritization to provide 5G enabled applications and services.
        - Developing framework for accelerated deployment of M2M services while safeguarding security and interception for M2M devices

- ***Defining policy for EMF radiation for M2M devices, with accompanying institutional framework to coordinate government-funded and India-specific research in this regard.***

g. Facilitating and supporting deployment of innovative solutions in identified Smart Cities

4. Ensuring adequate numbering resources, by:

Allocating 13-digit numbers for all M2M mobile connections

5. Recognizing Digital Communications as the core of Smart Cities by:

a. Developing, in collaboration with Ministry of Urban Development, a Common Service Framework and Standards for Smart Cities
b. Facilitating and supporting deployment of innovative solutions in identified Smart Cities

6. Promoting research & development in Digital Communication Technologies by:

c. Creating a framework for testing and certification of new products and services

2.2. M2M/ IoT Standardization in TEC

TEC has been working in M2M/ IoT domain since 2014 and created a framework for finalizing specifications in sync with global bodies. TEC formed various multi-stakeholders working groups time to time to study the M2M/ IoT domain, with the outcome to be used in policies / standards. These working groups are having members from the related stakeholders i.e. industry, academia, R&D organisations, Standards developing organisations (SDOs), Government etc.

Nineteen Technical Reports have been released so far covering several verticals namely Power sector, Automotive, Health care, Safety & Surveillance, Smart homes, Smart cities, Smart Village & Agriculture; as well as the horizontal layer (requirements common to all the verticals) such as M2M Gateway & Architecture, Communication Technologies and IoT Security in M2M/ IoT domain.

Important outcomes of these technical reports are the part of policies/ standards. All the work done by TEC in M2M/ IoT domain is available in brief in the report on "*TEC / Initiatives in M2M / IoT domain - An overview*". All the Technical Reports are available on TEC website[10].

[10] https://www.tec.gov.in/M2M-IoT-technical-reports

It is worth mentioning that the International Telecommunication Union (ITU) has posted the following six TEC Technical Reports on its website[11] in IoT sections (2023, 2022 and 2021), recognizing as insightful technical resource for the benefit of global community:

I. Security by Design for IoT Device Manufacturers
II. Framework of National Trust Centre for M2M/IoT Devices and Applications
III. IoT/ ICT Standards for Smart Cities
IV. Emerging Communication Technologies & Use Cases in IoT Domain
V. Code of Practice for Securing Consumer Internet of Things (IoT)
VI. IoT/ ICT Enablement in Smart Village and Agriculture

[11] https://www.itu.int/cities/dt-resource-hub/iot/

3. M2M/ IoT

3.1. Machine to Machine (M2M) Communication

M2M refers to the technologies that allow wired / wireless system to communicate with devices of same ability. M2M uses a device (sensor, meter etc.) to capture an 'event' (motion, meter reading, temperature etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information.

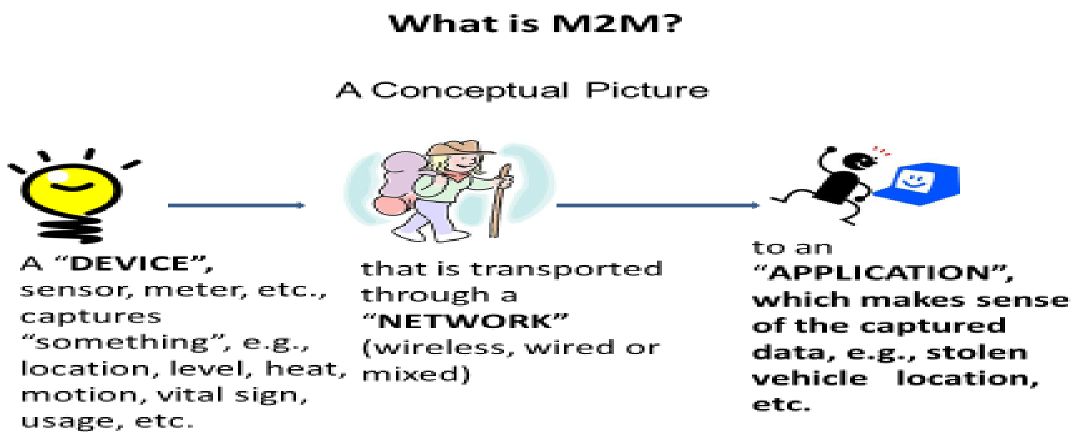


Figure 1: Machine to Machine (M2M) Communication

3.2. Internet of Things

International Telecommunication Union (ITU) has defined Internet of Things (IoT) as "***A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies***"[12].

IoT is benefitted by a number of technologies i.e., Cellular and non -cellular communication technologies, AI/ ML, Cloud computing, edge computing etc.

The IoT ecosystem comprises of devices, Gateways, Communication technologies, big data and process management, IoT platform, User interface (web, Mobile, HMI) and end to end security.

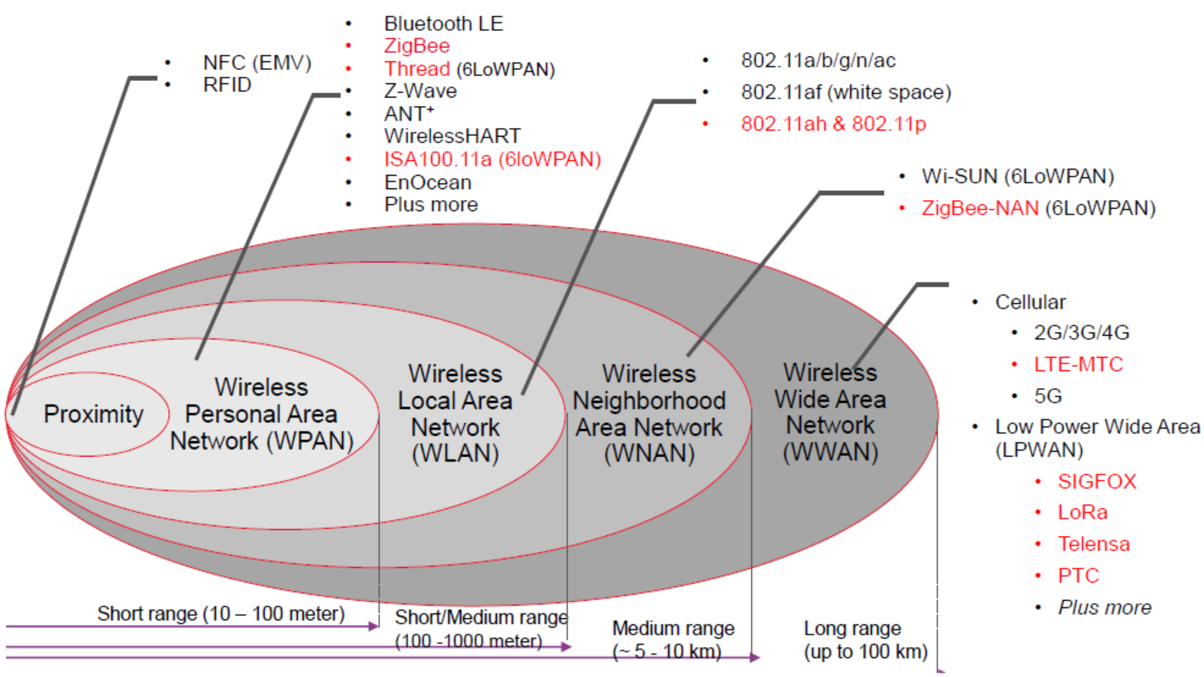
[12]ITU-T Y.2060 - Y.2060 : Overview of the Internet of things (06/2012) (https://www.itu.int/rec/T-REC-Y.2060-201206-I)

3.3. Communication Technologies

In M2M/ IoT domain, there are various types of communication technologies depending upon the coverage, power, QoS, use-case requirement etc. Communication technologies may be categorized to work in PAN/ NAN/ LAN / WAN depending upon the coverage distance.

Communication technologies for M2M / IoT domain have been studied in TEC, resulting in two technical reports, released in 2017 and 2021.

Technical Report released in 2017 on **Communication technologies in M2M/ IoT domain**[13] covered in detail the Cellular Technology (2G, 3G, 4G i.e. up to LTE 3GPP release 14), Low power wireless communication technologies (NFC, RFID, Bluetooth, ZigBee etc.), Low power wide area network technologies (LPWAN – cellular/ non-cellular), Wi-Fi [IEEE 802.11 a, b, g, n, ac (variant of Wi-Fi)], DSRC (802.11p), wire line (PLC, DSL, FTTH) etc. and the related use cases.



[Source: Keysight Technologies]

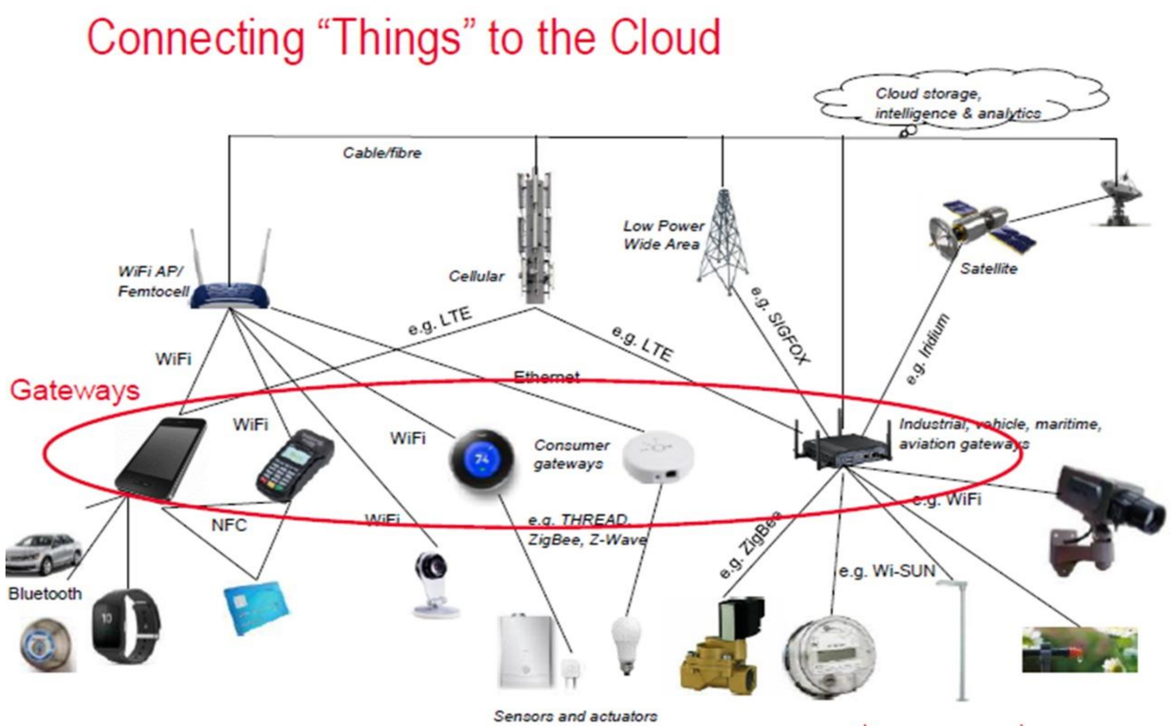
Figure 2: Communication technologies in M2M/ IoT domain

13 https://tec.gov.in/pdf/M2M/Communication%20Technologies%20in%20IoT%20domain.pdf

Due to advancement in technology, further study has been done and the Technical Report on ***Emerging Communication Technologies and Use cases in IoT domain***[14] was released in November 2021. This report covers 5G, Wi-Fi 6, WiFi 6E, WiFi HaLow, Bluetooth Mesh and some important use cases such as Intelligent transport system (Connected vehicles, C-V2X etc.), Private Industrial Network (Smart factories, Industry 4.0), Smart homes etc. **This report provides recommendations on spectrum and regulatory related aspects, which may be quite useful in the development of eco-system in India.**

IoT devices are generally working on various communication technologies as detailed above and also depicted in figure 2, which will be operating normally up to 300 GHz. The EIRP limit in various frequency range of related communication technologies are mentioned in annexure-1.

Figure 3 below illustrates the connectivity of IoT devices with the headend system/ cloud directly or through IoT Gateway on various communication technologies.



(Source: Keysight technologies)

Figure 3: Communicating things to the cloud

IoT devices are generally connected on wireless communication technologies but may be on wireline also. Some of the examples of the IoT devices may include smart camera, smart

[14] https://tec.gov.in/pdf/M2M/Emerging%20Communication%20Technologies%20&%20Use%20Cases%20in%20IoT%20domain.pdf

watch, smart meters, tracking devices etc. IoT gateways may include POS machines, smart phones, Wi- Fi routers etc. IoT devices connected on wireless communication technologies will radiate electromagnetic waves. Study regarding EMF exposure from multiple RF devices in close proximity to the human body has been covered.

3.4. IoT applications

The various applications of IoT/M2M devices are summarized in the table below:

Sr. No.	Vertical	Vertical related applications
1	Smart City	Intelligent Transport System, Waste Management, Street Light control system, Water Distribution, Smart Parking, Intelligent Buildings, Safety & Security, Air Quality Monitoring
2	Automotive/ Intelligent Transport System	Vehicle Tracking, Emergency call system (e-call: 112 adopted in India), Cellular V2X applications, Traffic Control, Navigation, Infotainment, Fleet Management, Asset Tracking, Manufacturing and Logistics.
3	Utilities	Smart Metering (electricity/ water/ gas), Smart Grid, Electric line monitoring, Gas/ Oil / Water Pipeline Monitoring, Sewage Monitoring
4	Health Care	Remote Diagnostics, Remote monitoring of patient after surgery (e-health), Medication reminders, Tele-Medicine, Wearable Health Devices, Medication reminders, e-ICU based applications.
5	Safety & Surveillance	Commercial and home security monitoring, Surveillance applications, Video analytics and sending alerts, Fire alarm, Police / Medical alert.
6	Smart Home	Security & alarm, Connected appliances, Smart Lighting System.
7	Agriculture	Smart Irrigation, Weather monitoring and forecasting, Precision Agriculture, Remote Crop Monitoring, Remote monitoring of soil quality, Smart Warehousing, Logistics and Distribution, Remotely Controlled Irrigation.

8	Livestock Farming	Animal production, Animal Tracking, remotely monitoring of the health of animals.
9	Smart Manufacturing	Proactive maintenance of machines, Shop floor monitoring, Industry automation.
10	Energy	Renewal energy sources like solar, Biomass and connecting to smart micro grid, Smart Distribution Network, Smart Metering, Smart Grid, Electric line monitoring, Gas / Oil / Water pipeline monitoring, Smart Street Lighting.
11	Education	Tele-education, e-attendance (biometric).

Table 1: IoT applications

4. Electromagnetic Field Radiations

Electromagnetic field (EMF) radiation consists of electromagnetic waves, propagating through space, carrying electromagnetic energy. It includes microwaves, infrared, (visible) light, ultraviolet, X-rays, and gamma rays. All of these waves form part of the electromagnetic spectrum.

The most common sources of exposure include TV transmission, wireless communication networks such as Cellular networks (2G, 3G, 4G, 5G), low power wireless communication technologies/ LPWAN etc. based network and devices (refer section 4.3 for communication technologies).

EMF exposure may be described in several ways like non ionizing, ionizing, SAR, power density etc as detailed below:

4.1. Non-ionizing Radiation

Non-ionizing radiation (NIR) is a generic term used to describe electromagnetic radiation that does not carry enough photon energy to ionize atoms or molecules and, as per its definition, also includes mechanical waves (infra- and ultrasound). Non-ionizing radiation is sub-grouped into frequencies or wavelength bands. As per ICNIRP, the RF-EMF up to 300 GHz is Non-ionizing in nature and health effects related to the non-ionizing radiation include tissue heating at levels above limits[15].

4.2. Ionizing Radiation

Ionizing radiation is a form of energy that acts by removing electrons from atoms and molecules of materials that include air, water, and living tissue. Ionizing radiation can travel unseen and pass through these materials. An example of ionizing radiation is that of x-rays, which can penetrate through our body and reveal pictures of our bones. The x-rays are “ionizing”, meaning that they have the unique capability to remove electrons from atoms and molecules in the matter through which they pass. Ionizing activity can alter molecules within the cells of our body, which may cause eventual harm. Intense exposures to ionizing radiation may produce skin or tissue damage. Other examples of ionizing radiation include alpha, beta, and gamma rays[16].

TRAI in its document, *Effects of Electromagnetic Field Radiation from Mobile Towers and Handsets*[17] released in 2014 has mentioned that electromagnetic (EM) emissions at frequencies

[15] https://www.icnirp.org/

[16] https://www.cdc.gov/nceh/radiation/nonionizing_radiation.html

[17] https://www.trai.gov.in/sites/default/files/EMF_Information_Paper_30.07.2014.pdf

above 1 THz are termed as ionizing radiations. Such radiations have enough potential to alter the chemical bonds of human tissue and may result in serious genetic damage on prolonged exposure. As some of the radiations can ionize atoms/molecules, they do have an adverse effect on the living organisms. They can break chemical bonds and damage vital molecules. If such damage is minor, cells may be able to repair themselves, otherwise cell death may occur. If the damage is at a higher rate, dead cells cannot be replaced quickly enough.

4.3. Radiation Energy

As per TRAI document, *Effects of Electromagnetic Field Radiation from Mobile Towers and Handsets*[18] released in 2014, there have been arguments that EMF radiation has the potential to mutate DNA and cause cancer. However, to mutate a DNA, we need a certain threshold energy (energy per photon). It takes about 12eV to ionize water (hydrogen-oxygen covalent bond). Electromagnetic radiation with photonic energy of more than 10 eV is generally considered ionizing. Visible light photons have about 2eV of energy while EM radiation photons at 300 GHz have only 1.24 meV (approx.) of energy. Hence, clearly EM radiation originating from cellular operations does not have enough energy to break chemical bonds or cause ionization. Hence diseases like cancer cannot be attributed to EM radiation from communication infrastructure.

4.4. Specific Absorption Rate (SAR)

SAR is a measure of the rate at which energy is absorbed by the human body when exposed to EMF. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg).

SAR is the time derivative of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element (*dV*) of a given mass density.

$$SAR = \frac{d}{dt}\frac{dW}{dm} = \frac{d}{dt}\frac{1}{\rho_m}\frac{dW}{dV}$$

SAR is expressed in units of watts per kilograms (W/kg).
SAR can be calculated by:

$$SAR = \frac{\sigma E^2}{\rho_m}$$

$$SAR = c\frac{dT}{dt}$$

[18] https://www.trai.gov.in/sites/default/files/EMF_Information_Paper_30.07.2014.pdf

$$SAR = \frac{j^2}{\rho_m \sigma}$$

where:

E is the rms value of the electric field strength in body tissue in V/m

σ is the conductivity of body tissue in S/m

ρ_m is the density of body tissue in kg/m^3

c is the heat capacity of body tissue in J/kg°C

$\frac{dT}{dt}$ is the time derivative of temperature in body tissue in °C/s

J is the value of the induced current density in the body tissue in A/m^2

SAR is usually averaged either over the whole body, or over a small sample volume (typically 1 g or 10 g of tissue). The value cited is then the maximum level measured in the body part studied over the stated volume or mass[19].

ICNIRP in its guideline *for limiting exposure to electromagnetic fields (100 KHz TO 300 GHz)* released in 2020 has mentioned that from a health risk perspective, the EMF power absorbed by biological tissues are largely responsible for the heating effects. Below 6 GHz, where EMF penetrate deep into tissue, SAR is measured and above 6 GHz, power density is measured (for more details refer section 6.2.)

4.5. Power Density

Above 6 GHz, where EMFs are absorbed more superficially (making depth less relevant), it is useful to describe exposure in terms of the density of absorbed power over area (W/m^2), which is referred as absorbed power density (S_{ab}).

[19] https://ieeexplore.ieee.org/document/8859679

5. National Study related to EMF

Since the last decade, huge growth in mobile telephony in India has accelerated in the development of smart infrastructure in various verticals including smart cities resulting in phenomenal rise of digital economy.

There is concern regarding the health effects of Electro-magnetic field (EMF) Radiation from wireless devices.

Several studies have been conducted all over the world to assess the effects of the exposure of human beings to RF-EMF emitted by the base stations (BS), mobile handsets, IoT/M2M devices etc., including continuous exposure to them. Concerns have also been raised that continuous exposure to EMF radiation emanating from wireless equipment devices (wireless radios, mobile handsets, IoT/M2M devices and wearable devices) can cause thermal and non-thermal health effects.

5.1. Department of Telecommunications (DoT) guidelines on EMF radiation

DoT, Ministry of Communications, Government of India has been taking due precautions and necessary actions in respect of EMF radiation emitted from mobile towers, mobile handsets and other connected devices by issuing various guidelines, taking into account the international standards /norms prescribed by ICNIRP, FCC, IEC/ IEEE etc.

DoT has adopted more stringent norms than ICNIRP for mobile handsets. Earlier DoT had adopted ICNIRP Guidelines for mobile phones, according to which the specific absorption rate (SAR) value for mobile phones was 2 Watts per Kg averaged over 10-gram tissue. Further, an Inter-Ministerial Committee was constituted by the Department of Telecommunications consisting of officers from the Department, Indian Council of Medical Research, Ministry of Health, Department of Bio-technology and Ministry of Environment and Forests to examine the effect of EMF Radiation from mobile phones and base stations. The Committee recommended that SAR level for mobile handset shall be limited to 1.6 Watt/Kg, averaged over a mass of 1 gram of human tissue. Accordingly SAR level for Mobile Handset has been revised from 2 watt per Kg averaged over a mass of 10 gram human tissue to 1.6 Watt per Kg averaged over a mass of 1 gram human tissue vide DoT office memorandum no. 18-10/2008-IP dated 17.08.2012[20]. The IMC also recommended that EMF exposure limits for base stations (for the general public) should be 1/10th of ICNIRP 1998/ ICNIRP 2020 limits.

[20]https://dot.gov.in/pdfembed/sar-office-memorandum-dated-17082012

5.2. SAR Standard released by TEC

TEC released a standard on specific absorption rate (SAR) (TEC 13016:2023) in April 2023 for Wireless Communication Devices used in close proximity to human body, which has defined the exposure limits, applicable test standard for measurement and associated separation distance for assessment of SAR exposure from IoT devices[21]. The operating frequency range is 4 MHz to 6 GHz. Details related to general public exposure is available in section 5.2.1. and for occupational exposure in section 5.2.2.

5.2.1. General Public Exposure

General Public SAR exposure limits apply when the general public may be exposed to RF sources in close proximity to their body, or when persons who are exposed as a consequence of their employment may not be fully aware of the potential for exposure or do not exercise control over their exposure.

The Tables below provide the limits, applicable test standard for measurement and associated separation distance for measurement for assessment of SAR exposure from RF devices with respect to general public exposure:

Applicability	**Region of Body**			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	✓	✓	✓	✓
Applicable SAR limits	1.6 W/kg averaged over 1 gm of tissue.	1.6 W/kg averaged over 1 gm of tissue.	4 W/kg averaged over 10 gm of tissue (refer Note 1)	0.08 W/kg
Applicable SAR standards for measurement	IEC 62209-1528	IEC 62209-1528	IEC 62209-1528	NA
Applicable SAR measurement distances	0 mm	5 mm or less	0 mm	NA

Table 2:Hand-held devices like Cellular/ Mobile/Satellite phones etc. which will be used close to the head

Note 1: Limb SAR is applicable only when the longest diagonal dimension of the device ≥ 15 cm.

[21] https://www.tec.gov.in/standards-specifications

Applicability	Region of Body			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	NA	✓	✓	✓
Applicable SAR limits	NA	1.6 W/kg averaged over 1 gm of tissue.	4 W/kg averaged over 10 gm of tissue	0.08 W/kg
Applicable SAR standards for measurement	NA	IEC 62209-1528	IEC 62209-1528	NA
Applicable SAR measurement distances	NA	25 mm or less	0 mm	NA

Table 3: Hand-held devices like tablets, phablets etc. which will be used in close proximity of 20 cm or less to the body

Applicability	Region of Body			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	NA	✓	NA	✓
Applicable SAR limits	NA	1.6 W/kg averaged over 1 gm of tissue.	NA	0.08 W/kg
Applicable SAR standards for measurement	NA	IEC 62209-1528	NA	NA
Applicable SAR measurement distances	NA	5 mm or less	NA	NA

Table 4: RF devices like Wi-Fi dongles, Mobile data cards which are expected to be used in close proximity of 20 cm or less to the body

Applicability	Region of Body			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	NA	✓	✓	✓
Applicable SAR limits	NA	1.6 W/kg averaged over 1 gm of tissue.	4 W/kg averaged over 10 gm of tissue	0.08 W/kg
Applicable SAR standards for measurement	NA	IEC 62209-1528	IEC 62209-1528	NA
Applicable SAR measurement distances	NA	5 mm or less	0 mm	NA

Table 5: IoT/RF devices expected to be worn on the body

Applicability	Region of Body			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	✓	✓	NA	✓
Applicable SAR limits	1.6 W/kg averaged over 1 gm of tissue.	1.6 W/kg averaged over 1 gm of tissue.	NA	0.08 W/kg
Applicable SAR standards for measurement	IEC 62209-1528,	IEC 62209-1528,	NA	NA
Applicable SAR measurement distances	0 mm	5 mm or less	NA	NA

Table 6: IoT/RF devices expected to be worn on the body near the head

Applicability	Region of Body			
	Localized SAR (Head)	Localized SAR (Body)	Localized SAR (Limbs and Extremities)	Whole body Average SAR
Applicable SAR	NA	✓	✓	✓
Applicable SAR limits	NA	1.6 W/kg averaged over 1 gm of tissue.	4 W/kg averaged over 10 gm of tissue	0.08 W/kg
Applicable SAR standards for measurement	NA	IEC 62209 - 1528	IEC 62209-1528	NA
Applicable SAR measurement distances	NA	25 mm or less	0 mm	NA

Table 7: IoT/RF devices expected to be used in close proximity of 20 cm or less to the body

Note 2: Bureau of Indian Standards (BIS) has adopted the international IEC 62209-3:2019 as IS/IEC62209-3[22] vide its Gazette CG-DL-E-21092021-229835 dated 17 Sept 2021.

Note 3: TEC has referred IEC 62209-1528 in its current standard on SAR (TEC 13016:2023) for testing to assess absolute SAR levels and demonstrate compliance; and the IEC 62209-3:2019 for testing to assess relative SAR levels in case of vector array SAR Measurement.

5.2.2. Occupational Exposure

Occupational/Controlled limits for SAR exposure apply when persons are exposed, as a consequence of their employment, provided these persons are fully aware of and exercise control over their exposure. Such devices include but are not limited to certain MRTS (mobile radio trucking system), HF (High Frequency), VHF (Very high Frequency) and UHF (Ultra high Frequency) radio handsets etc. To create a sense of safety from exposure, it is necessary to make the personnel aware by specific training programmer and also by use of visual advisories such as labeling, embossing, or on an equivalent electronic display.

[22] https://egazette.nic.in/WriteReadData/2021/229835.pdf

The table below provides the limits, applicable test standard for measurement and associated separation distance for measurement for assessment of SAR exposure from RF devices with respect to occupational exposure:

Applicability	Region of Body			
	Localized SAR (Head)	**Localized SAR (Body)**	**Localized SAR (Limbs and Extremities)**	**Whole body Average SAR**
Applicable SAR	Applicable if used close to the head #	Applicable if used close to the body #	Applicable if used in extremity conditions #	Applicable
Applicable SAR limits	8 W/kg averaged over 1 gm of tissue	8 W/kg averaged over 1 gm of tissue	20 W/kg averaged over 10 gm of tissue	0.4 W/kg
Applicable SAR standards for measurement	*IEC 62209-1528*	*IEC 62209-1528*	IEC 62209-1528	NA
Applicable SAR measurement distances	0 mm	0 mm or less	0 mm	NA

Table 8: Occupational Exposure Limits

- Manufacturer of the device to declare Applicable SAR **(**Head**/**Body**/**Limbs**)** as per the actual usage of the device**.**

For specific procedures and methodologies to be followed for SAR measurement for different categories of RF devices and different wireless technologies, relevant FCC KDBs and international IEC standards may be referred[23].

International specification referred in TEC SAR standard have been mentioned in brief in sections 6.3. and 6.4.

5.3. TRAI study on EMF radiation

TRAI has released Information paper on *Effects of electromagnetic field radiation from mobile towers and handsets*[24] in 2014. It elaborates various aspects of radiations emanating from mobile towers and mobile handsets including the norms prescribed by various international bodies. The paper also contains a write-up on sources of exposure, effects of EMF exposure on humans, absorption of energy from EMF and International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Important details from this paper have also been covered in section 4.

[23]https//:www.tec.gov.in/standards-specifications

[24]https://www.trai.gov.in/sites/default/files/EMF_Information_Paper_30.07.2014.pdf

6. Study of Global Standards/ Guidelines on EMF Exposure

EMF study carried out by various international organisations is as listed below-

6.1. World Health Organization (WHO)

To protect public health and in response to public concern over health effects of EMF exposure, WHO established the International EMF Project[25] to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. The objectives of this project are to facilitate the development of internationally acceptable standards for EMF exposure and to provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures. In this EMF Project, the frequency range is divided into: static (0 Hz), Extremely low frequency (ELF, > 0-300 kHz), Intermediate frequencies (IF, >300Hz to 10MHz), and Radiofrequency (RF, 10 MHz-300 GHz) fields.

6.2. International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for Limiting Exposure to Electromagnetic Fields

ICNIRP published guidelines for *Limiting Exposure to Electromagnetic Fields*[26] in March 2020, that ensure the protection of people against all established health hazards when they are exposed to radiofrequency electromagnetic fields (RF-EMF) in the range 100 kHz to 300 GHz.

The basic restrictions/ reference levels for EMF exposure mentioned in table 2, 5 and 6 of ICNIRP guidelines have been reiterated below in table 9, 10 and 11 respectively –

Exposure scenario	**Frequency range**	**Whole-body average SAR (W kg^{-1})**	**Local Head/Torso SAR (W kg^{-1})**	**Local Limb SAR (W kg^{-1})**	**Local S_{ab} (W m^{-2})**
Occupational	100 kHz to 6 GHz	0.4	10	20	NA
	>6 to 300 GHz	0.4	NA	NA	100
General public	100 kHz to 6 GHz	0.08	2	4	NA
	>6 to 300 GHz	0.08	NA	NA	20

[25] https://www.who.int/initiatives/the-international-emf-project
[26] https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf

Table 9: Basic restrictions for electromagnetic field exposure from 100 kHz to 300 GHz, for averaging intervals ≥6 min

Note:

1. "NA" signifies "not applicable"
2. Whole-body average SAR is to be averaged over 30 min.
3. S_{ab} is the absorbed power density
4. Local SAR and S_{ab} exposures are to be averaged over 6 min.
5. Local SAR is to be averaged over a 10-g cubic mass.
6. Local S_{ab} is to be averaged over a square 4-cm^2 surface area of the body. Above 30 GHz, an additional constraint is imposed, such that exposure averaged over a square 1-cm^2 surface area of the body is restricted to two times that of the 4-cm^2 restriction.

Exposure Scenario	Frequency range	Incident E-field strength; E_{inc} (Vm $^{-1}$)	Incident H-field strength; H_{inc} (A m $^{-1}$)	Incident power density; S_{inc} (W m^{-2})
Occupational	0.1-30 MHz	$660/f_M^{0.7}$	$4.9/f_M$	NA
	>30-400 MHz	61	0.16	10
	>400-2000 MHz	$3\ f_M^{0.5}$	$0.008f_M^{0.5}$	$f_M/40$
	>2-300 GHz	NA	NA	50
General Public	0.1-30 MHz	$300\ /\ f_M^{0.7}$	$2.2/\ f_M$	NA
	>30-400 MHz	27.7	0.073	2
	>400-2000 MHz	$1.375\ f_M^{0.5}$	$0.0037\ f_M^{0.5}$	$f_M/200$
	>2-300 GHz	NA	NA	10

Table 10: Reference levels for exposure, averaged over 30 min and the whole body, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Note:

1. "NA" signifies "not applicable"
2. f_M is frequency in MHz.
3. S_{inc}, E_{inc}, and H_{inc} are to be averaged over 30 min, over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values.
4. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither E_{inc} or H_{inc} exceeds the above reference level values.
5. For frequencies of >30MHz to 2 GHz: (a) within the far-field zone: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc}, does not exceed the above reference level values (only one is required); S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if either S_{inc}, or both E_{inc} and H_{inc}, does not exceed the above reference level values; and (c) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed.

6. For frequencies of >2 GHz to 300 GHz: (a) within the far-field zone: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if S_{inc} does not exceed the above reference level values; and (c) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.

Exposure Scenario	Frequency range	Incident E-field strength; E_{inc} (Vm $^{-1}$)	Incident H-field strength; H_{inc} (A m $^{-1}$)	Incident power density; S_{inc} (W m^{-2})
Occupational	0.1-30 MHz	$1504/f_M^{0.7}$	$10.8/f_M$	NA
	>30-400 MHz	139	0.36	50
	>400-2000 MHz	$3\ f_M^{0.5}$	$0.0274 f_M^{0.5}$	$0.29 f_M^{0.86}$
	>2-6 GHz	NA	NA	200
	>6 - <300 GHz	NA	NA	$275/\ f_G^{0.177}$
	300 GHz	NA	NA	100
General Public	0.1-30 MHz	$671\ /\ f_M^{0.7}$	$4.9/\ f_M$	NA
	>30-400 MHz	62	0.163	10
	>400-2000 MHz	$4.72\ f_M^{0.5}$	$0.0123 f_M^{0.43}$	$0.058 f_M^{0.86}$
	>2-6 GHz	NA	NA	40
	>6 - <300 GHz	NA	NA	$55/\ f_G^{0.177}$
	300 GHz	NA	NA	20

Table 11: Reference levels for local exposure, averaged over 6 min, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Note:

1. “NA” signifies “not applicable”
2. f_M is frequency in MHz; f_G is frequency in GHz.
3. S_{inc}, E_{inc}, and H_{inc} are to be averaged over 6 min
4. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither peak spatial E_{inc} or peak spatial H_{inc}, over the projected whole-body space, exceeds the above reference level values.
5. For frequencies of > 30 MHz to 6 GHz: (a) within the far-field zone, compliance is demonstrated if one of peak spatial S_{inc}, E_{inc} or H_{inc}, over the projected whole-body space, does not exceed the above reference level values (only one is required); Seq may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if either peak spatial S_{inc}, or both peak spatial E_{inc} and H_{inc}, over the projected

whole-body space, does not exceed the above reference level values; and (c) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance; for frequencies >2 GHz, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.

6. For frequencies of >6 GHz to 300 GHz: (a) within the far-field zone, compliance is demonstrated if S_{inc}, averaged over a square 4-cm^2 projected body surface space, does not exceed the above reference level values; S_{eq} may be substituted for S_{inc}; (b) within the radiative near-field zone, compliance is demonstrated if S_{inc}, averaged over a square 4-cm^2 projected body surface space, does not exceed the above reference level values; and (c) within the reactive near-field zone reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
7. For frequencies of >30 GHz to 300 GHz, exposure averaged over a square 1-cm^2 projected body surface space must not exceed twice that of the square 4-cm^2 restrictions.

6.3. Institute of Electrical and Electronics Engineers (IEEE)

IEEE has released following standards related to EMF exposure-

6.3.1. IEEE Std 1528.7-2020: IEEE Guide for EMF Exposure Assessment of Internet of Things (IoT) Technologies and Devices[27]

This standard provides references to the appropriate methodology for classifying Internet of Things (IoT) devices based on radio frequency (RF) exposure characteristics. It mentions that the majority of IoT devices are expected to operate at low radiated radio frequency (RF) power levels (< 20 mW). It further concluded that If the power of each IoT device is limited to 20 mW or less, then there in not much concern of exposure at distances larger than few centimeters.

This document further mentions that, aside from the applications that require body-worn usage, IoT devices are usually placed at 1 m distance or more away from persons. Since IoT devices communicate machine to machine rather than requiring human intervention, the distances from a human body are usually greater than those of personal communication devices. Even if a human operates close to an IoT device, the exposure time might be only a fraction of the averaging time of applicable guidelines (ICNIRP-2020 and IEEE Std C95.1-2019 specify a 6 min averaging time), thus reducing the potential to exceed the exposure limits of the IoT device.

It also mentions about, “How many devices need to be present and how close to a person, to potentially expose a human above the safety limits” if multiple IoT devices are grouped to form a population of devices. The table C.3 on page No. 70 of this IEEE standard has been reiterated in the table- 12.

[27]https://ieeexplore.ieee.org/document/9319817

Note: In the band 2.0 GHz to 300.0 GHz, the IEEE Std C95.1-2019 maximum whole-body exposure reference level is 10 W/m^2 (1mW/cm^2) for unrestricted environment and 50 W/m^2 (5mW/cm^2) for restricted environment. These limits can be considered to estimate the maximum number of devices that can be included over a closed surface while radiating simultaneously.

Denoting the exposure level limit, as L in mW/cm^2 and the radius of a spherical surface on which all the sources are located as R in meters, the power necessary to cause an exposure equal to the limit L is given as per the following equation.

$$P = 10L(4\pi R^2) \text{ (in W)} \qquad \text{(A.1)}$$

Above equation (A.1) considers only isotropic radiators. The number of devices to produce power density levels as function of effective isotropic radiated power (EIRP) placed over a spherical surface as per IEEE/ ICNIRP reference level is given by following equation (A.2).

$$N \geq P/\text{EIRP} \qquad \text{(A.2)}$$

Example 1: Positions of sources placed over the spherical surface (under the assumption that at distance of R (in m) from the sources the far field approximation is valid.)

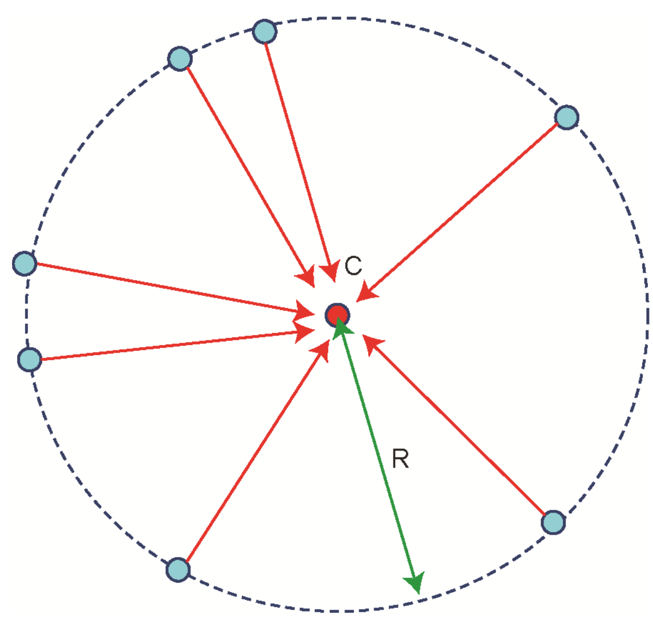


Figure 4: Position of sources over the spherical surface

EIRP (in W)	Radius=1m		Radius=0.5m		Radius=0.25m		Radius=0.125m	
	1mW/cm² (Unrestricted environment)	5mW/cm² (Restricted environment)	1mW/cm² (Unrestricted environment)	5mW/cm² (Restricted environment)	1mW/cm² (unrestricted environment)	5mW/cm² (Restricted environment)	1mW/cm² (unrestricted environment)	5mW/cm² (Restricted environment)
	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices
0.020	6283	31415	1570	7853	392	1963	98	490
0.125	1005	5026	251	1256	62	314	15	78
0.250	502	2513	125	628	31	157	7	39

Table 12: Number of devices to produce power density levels as function of effective isotropic radiated power (EIRP) placed over a spherical surface as per IEEE/ ICNIRP reference level

EIRP (in W)	Radius=1m		Radius=0.5m		Radius=0.25m		Radius=0.125m	
	0.1mW/ cm² (Unrestricted environment)	5mW/ cm² (Restricted environment)	0.1mW/ cm² (Unrestricted environment)	5mW/ cm² (Restricted environment)	0.1mW/ cm² (Unrestricted environment)	5mW/ cm² (Restricted environment)	0.1mW/ cm² (Unrestricted environment)	5mW/ cm² (Restricted environment)
	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices	Number of devices
0.006	2095	104761	523	26190	130	6547	32	1636
0.020	628	31415	157	7853	39	1963	9	490
0.125	100	5026	25	1256	6	314	1	78

Table 13: Number of devices to produce power density levels as function of effective isotropic radiated power (EIRP) placed over a spherical surface as **per Indian reference level**

Note: In India, RF-EMF exposure limits for the general public/ unrestricted environment are 1/10th of ICNIRP limits, however RF-EMF exposure limits for Occupational/ restricted environment are same as mentioned in ICNIRP. In View of this, the above table 13 has been derived as per equation A.1 for 6 mW EIRP and other power levels.

Example 2: Devices have been placed randomly inside a sphere, as shown in Figure 5, the position of each device is established per-

R = Rmax × rnd(); R > 0.05 m; Rmax ∈ {1.0, 0.5, 0.25 and 0.125} m;

$$\theta = 180.0 \times rnd()$$
$$\phi = 360.0 \times rnd()$$

where

- All angles are expressed in degrees
- rnd() is a random variable uniformly distributed in the interval [0;1]
- The observation point is at the center of the sphere
- Far field exposure is considered
- Each device is pointing toward the observation point for worst case exposure

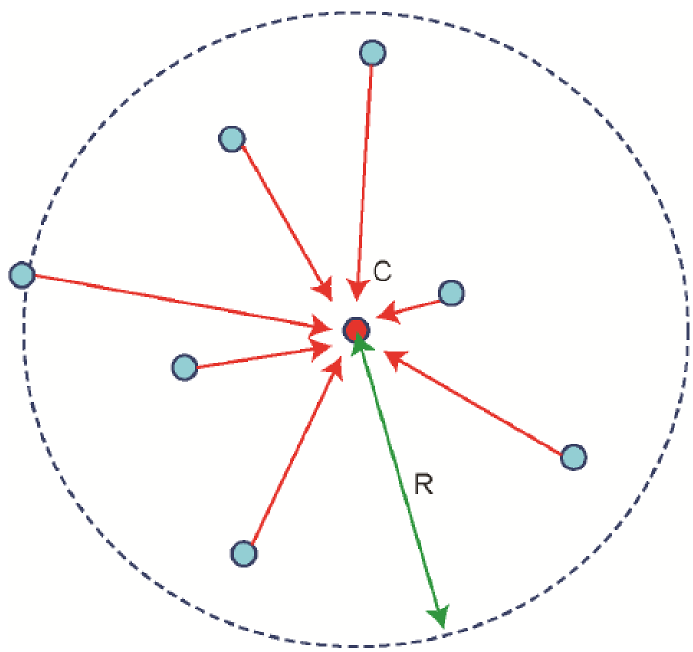


Figure 5: Position of the sources inside a spherical surface

EIRP (in W)	Radius (m)	Number of Devices for 1mW/cm² PD		Number of Devices for 5mW/cm² PD	
		Average	Standard Deviation	Average	Standard Deviation
0.02	3.0	954	133	4718	302
	1.0	317	42	1573	99
	0.5	158	21	784	47
	0.25	79	9	392	20
	0.125	39	4	197	8
0.125	3.0	163	55	763	120
	1.0	53	17	254	38
	0.5	27	8	126	19
	0.25	13	4	63	8
	0.125	6	2	31	3
0.25	3.0	88	37	388	87
	1.0	28	12	129	27
	0.5	14	6	64	13
	0.25	7	3	32	6
	0.125	3	1	16	2

Table 14: Number of devices to produce power density levels as function of their EIRP placed inside a spherical surface

Following may be concluded -

If multiple IoT devices are grouped to form a population of devices then from the table No. 14, it may be concluded that even around 79±9 devices, each emitting 20 mW EIRP simultaneously in unrestricted environment placed randomly inside the radius of 25 cm from the human body, are considered to be safe from EMF exposure and around 954 ± 133 devices, each emitting 20 mW EIRP simultaneously in unrestricted environment placed randomly inside the radius of 3 meter from the human body, are considered to be safe from EMF exposure.

In India RF-EMF exposure limits for the general public/ unrestricted environment are 1/10th of ICNIRP limits so in Indian scenario the number of devices will be reduced to $1/10^{th}$. However, RF-EMF exposure limits in India for occupational are same as mentioned in ICNIRP. In India the SAR/ EMF limits are stricter than ICNIRP/ IEEE limits for the RF devices operating in close proximity to the human body. From the details mentioned above, it may be presumed that if RF devices are SAR/ EMF complied as per Indian limit then also large number of RF devices can be occupied within a small range.

6.3.2. IEC/IEEE 62209-1528- 2020[28]- Standards on Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices

This document has listed procedures for measuring the human exposure from devices intended to be used at a position near the human head or body. It provides procedures to evaluate electromagnetic field (EMF) exposures due to radio frequency (RF) transmitting devices used next to the ear, in front of the face, mounted on the body, operating in conjunction with other RF-transmitting and non-transmitting devices or accessories (e.g. belt-clips), or embedded in garments. The applicable frequency range is from 4 MHz to 10 GHz.

6.3.2. IEEE Std C95.1™-2019[29]: IEEE Standards for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields,0 Hz to 300 GHz

This document provides exposure criteria and limit to protect against established adverse health effects in humans associated with exposure to electric, magnetic, and electromagnetic fields, induced and contact currents, and contact voltages, over the frequency range of 0 Hz to 300 GHz. The exposure limits apply to persons permitted in restricted environments and to the general public in unrestricted environments.

As per the above mentioned standard the exposure limits mentioned in table 5 to 7 of this standard have been reiterated below-

Conditions	**Persons in unrestricted environments SAR (W/kg)[a]**	**Persons permitted in restricted environments SAR (W/kg)[a]**
Whole-body exposure	0.08	0.4
Local exposure[b] (head and torso)	2	10
Local exposure[b] (limbs and pinnae)	4	20

Table 15: Dosimetric reference limits (DRLs) (100 KHz to 6 GHz)

a. SAR is averaged over 30 min for whole-body exposure and 6 min for local exposure.
b. Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).

[28]https://ieeexplore.ieee.org/document/9231298
[29] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8859679

Conditions	**Epithelial power density (W/m²)[a,b,c]**	
	Persons in unrestricted environments	**Persons permitted in restricted environments**
Body surface	20	100

Table 16: Local exposure DRLs (6 GHz to 300 GHz)

a. Epithelial power density through body surface is averaged over 6 min.
b. Averaged over any 4 cm^2 of body surface at frequencies between 6 GHz and 300 GHz (defined as area in the shape of a square at surface of the body).
c. Small exposed areas above 30 GHz: If the exposed area on the body surface is small (<1 cm^2 as defined by 3 dB contours relative to the peak exposure), the epithelial power density is allowed to exceed the DRL values of Table 6 by a factor of 2, with an averaging area of 1 cm^2 (defined as area in the shape of a square at the body surface).

Frequency range (MHz)	**Electric field strength (E)[a,b,c] (V/m)**	**Magnetic field strength (H)[a,b,c] (A/m)**	**Power density (S)[a,b,c] (W/m²)**		**Averaging time (min)**
			S_E	**S_H**	
0.1 to 1.34	614	$16.3/f_M$	1000	$100\,000/f_M^2$	30
1.34 to 30	$823.8/f_M$	$16.3/f_M$	$1800/f_M^2$	$100\,000/f_M^2$	30
30 to 100	27.5	$158.3/f_M^{1.668}$	2	$9400000\,f_M^2$	30
100 to 400	27.5	0.0729	2		30
400 to 2000	-	-	$f_M/200$		30
2000 to 300 000	-	-	10		30
Note-S_E and S_H are plane-wave-equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.					

Table 17: ERLs for whole-body exposure of persons in unrestricted environments (100 kHz to 300 GHz)

a. For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the ERLs in Table 17. For more typical non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the plane-wave-equivalent power densities or the squares of the field strengths, are compared with the ERLs in Table 17. (See notes to Table 7 through Table 11 in section 4.3.5. of this IEEE document)
b. f_m is the frequency in MHz.
c. The E, H, and S values are those rms values unperturbed by the presence of the body.

Note: ERLs for whole-body and local exposure of persons in unrestricted and restricted environments (100 kHz to 300 GHz) are mentioned in Annexure 2.

6.4. International Electrotechnical Commission (IEC)

IEC is an international standards organization that prepares and publishes international standards for all electrical, electronic and related technologies. IEC TC (Technical Committee) 106 prepare international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields. Following standards related to EMF exposure has been released by IEC –

6.4.1. IEC 62209-3-2019 Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 3: Vector measurement -based system (frequency range of 600MHz to 6GHz) [30]

This document specifies measurement protocols and test procedures for the reproducible measurement of peak spatial-average specific absorption rate (psSAR) induced inside a simplified model of a human head or body by radio-frequency (RF) transmitting devices, with a specified measurement uncertainty. This document is applicable to wireless communication devices intended to be used at a position near the human head or body at distances up to and including 200 mm. This document may be employed to evaluate SAR compliance of different types of wireless communication devices used next to the ear, in front of the face, mounted on the body, combined with other RF-transmitting or non-transmitting devices or accessories (e.g. belt-clip), or embedded in garments. The overall applicable frequency range is from 600 MHz to 6 GHz.

6.4.2. IEC 62209-1528- 2020: Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices - Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz)

This document specifies protocols and test procedures for the reproducible and repeatable measurement of the conservative exposure peak spatial average SAR (psSAR) induced inside a simplified model of the head and the body by radio-frequency (RF) transmitting devices, with a defined measurement uncertainty. The applicable frequency range is from 4 MHz to 10 GHz.

[30]https://webstore.iec.ch/publication/30773#:~:text=IEC%2062209%2D3%3A%202019%20specifies,with%20a%20specified%20measurement%20uncertainty.

TEC SAR standards also refers this standard, which has been explained in section 5.2.

6.4.3. IEC TR 62630:2010 -Guidance for evaluating exposure from multiple electromagnetic sources[31]

This document describes exposure evaluation concepts and techniques for the overall exposure level in spatial regions and occupants caused by the simultaneous exposure to multiple narrowband electromagnetic (EM) sources. It provides guidance to IEC TC 106 project teams on how to evaluate the combined exposures from multiple electromagnetic (EM) sources in the frequency range 100 kHz to 300 GHz when specific absorption rate (SAR) and equivalent power density (S) are the relevant exposure metrics, as defined by the main international guidelines recommending limits on human exposure to EM fields.

6.4.4. IEC 62479:2010- Assessment of the compliance of low-power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)[32] -

This document provides simple conformity assessment methods for low-power electronic and electrical equipment to an exposure limit relevant to electromagnetic fields. If such equipment cannot be shown to comply with the applicable EMF exposure requirements using the methods included in this standard for EMF assessment, then other standards, including IEC 62311 or other (EMF) product standards, may be used for conformity assessment.

6.4.5. IEC 62311:2019- Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz to 300 GHz)[33] -

This standard applies to electronic and electrical equipment for which no dedicated product standard or product family standard regarding human exposure to electromagnetic fields applies. This document provides assessment methods and criteria to evaluate equipment against limits on exposure of people related to electric, magnetic and electromagnetic fields. The frequency range covered is from 0 Hz to 300 GHz.

6.4.6. IEC 62209-3:2019-Body-mounted wireless communication devices - Part 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz)[34]

This Standard specifies measurement protocols and test procedures for the reproducible measurement of peak spatial-average specific absorption rate (psSAR) induced inside a simplified

[31] https://webstore.iec.ch/publication/7288
[32] https://webstore.iec.ch/publication/7081
[33] https://webstore.iec.ch/publication/33985
[34] https://webstore.iec.ch/publication/30773

model of a human head or body by radio-frequency (RF) transmitting devices, with a specified measurement uncertainty.

This document is applicable to wireless communication devices intended to be used at a position near the human head or body at distances up to and including 20 cm. This document may be used to evaluate SAR compliance of different types of wireless communication devices used next to the ear, in front of the face, mounted on the body, combined with other RF-transmitting or non-transmitting devices or accessories (e.g. belt-clip), or embedded in garments. The overall applicable frequency range is from 600 MHz to 6 GHz.

6.5. International Telecommunication Union (ITU)

ITU-T Study Group 5: *Environment, climate change and circular economy,* is responsible for studying electromagnetic fields (EMFs) produced by telecommunication devices and installations to avoid health risks. SG-5 has published a series of standards related to EMF-

6.5.1. ITU-T K.145 - Assessment and management of compliance with radio frequency electromagnetic field exposure limits for workers at radio communication sites and facilities[35]

This document provides guidance on the management of situations where RF workers/ informed workers can be exposed under controlled/occupational exposure conditions at levels higher than general population/uncontrolled exposure limits.

6.5.2. ITU-T K Suppl. 13- *Radiofrequency electromagnetic field (RF-EMF) exposure levels from mobile and portable devices during different conditions of use[36]-*

Exposure to radiofrequency electromagnetic field (RF-EMF) is different depending on the service, environment and the conditions of the use of the mobile devices. This document describes various factors that determine the level of RF-EMF exposure, as defined by the specific absorption rate (SAR) that is induced in the users of mobile and portable radio-communication devices.

The SAR level induced in the body of a person using a mobile, portable or radio-communication device can be affected by a diverse range of factors that include design aspects of the devices and their corresponding networks, personal usage patterns, how the device is held against the body and the physical characteristics of the body.

[35] https://www.itu.int/rec/T-REC-K.145/en
[36] https://www.itu.int/rec/T-REC-K.Sup13-202112-I/en

6.5.3. ITU-T K Suppl. 9 *-5G technology and human exposure to radio frequency electromagnetic fields*[37]*-*

This document mentions that the deployment of 5G and the introduction of new radio access networks in millimetre wavebands will result in the use of much higher frequency ranges and increase in the number of base stations. Massive multiple input multiple output (MIMO) antennas will allow the use of very narrow beams that will follow the user with an impact on the surrounding exposure level different from that of current systems. The number of wireless devices will dramatically increase. New technology allows for the use of more efficient systems that require lower communication signal levels.

It has been mentioned in the document that without any spectrum or technology reframing strategy, the 5G network will increase localized exposure resulting from wireless technologies, at least during the transition period. This has already been difficult in countries where exposure limits are more restrictive than those recommended by WHO, based on the ICNIRP RF-EMF exposure guidelines.

6.5.4. ITU-T K Suppl. 14- The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment[38]-

It has been mentioned in section 6.3 of this standard that EMF exposure limits that are more strict than the ICNIRP or IEEE guidelines negatively affect all potential aspects to enhance the wireless infrastructure and deployment of 5G: spectrum, technology (determining the spectral efficiency) and network topology (number of sites and sectors). The network capacity buildout (both 4G and 5G) might be severely constrained and prevent growing data traffic demand and the launching of new services on existing mobile networks being addressed. This document has given the example of simulation based study carried out in Poland about the unfavorable effects of different EMF exposure limits on network rollout.

6.6. Global System for Mobile Communications Associations (GSMA)

Some of the studies of GSMA related to EMF Exposure are as listed below-

6.6.1. 5G, the Internet of Things (IoT) and Wearable Devices- What do the new uses of wireless technologies mean for radio frequency exposure[39]

GSMA in its document, released in 2021 has mentioned that new applications, such as 5G, wireless IoT and wearable devices, are designed to comply with existing exposure limits. It may

[37] https://www.itu.int/itu-t/recommendations/rec.aspx?rec=13939
[38] https://www.itu.int/rec/T-REC-K.Sup14/en
[39]https://www.gsma.com/publicpolicy/wp-content/uploads/2021/10/GSMA_5G_IoT_and_Wearable_Devices_Oct21.pdf

be noted that for all wireless technologies, the exposure from antennas decreases rapidly with distance.

6.6.2. GSMA 5G millimeter wave safety-Electromagnetic field (EMF) health related science and research[40]

This document released by GSMA in 2022 has listed the studies of WHO, IEEE and ICNIRP related to EMF exposure and also given recommendations to policy makers based on IEC/ ICNIRP standards. It has also mentioned some of the research project carried out by Australia, France, Netherlands and the USA, on RF EMF research relevant to 5G mm Wave.

6.6.3. GSMA International EMF Exposure Guidelines, Oct 2021 (Explaining the 2020 RF-EMF exposure guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP))[41]

This document released by GSMA has explained in detail the key features of the ICNIRP guidelines on RF-EMF exposure released in 2020. GSMA has mentioned in this document guidelines relevant for exposures from mobile communications network equipment and devices operating in the frequency range 400 MHz to 300 GHz. (Refer section 6.2 for details about ICNIRP guidelines).

6.7. Federal Communications Commission (FCC), USA

FCC is an independent agency of the United States federal government that regulates communications by radio, television, wire, satellite, and cable across the United States. FCC has released a number of guiding documents on EMF exposure for the wireless networks and the connected devices.

FCC KDB 447498 D01:2015[42] *and FCC KDB 447498 D04:2021 General RF Exposure Guidance*[43], provides guidance pertaining to RF exposure requirements for mobile and portable device equipment authorizations. This document also mentioned exemption criteria for RF source based on MPE and SAR. FCC KDB 447498 D04:2021 also mentions about the SAR compliance related to body-worn accessories and transmitters implanted in the body of a user.

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[40] https://www.gsma.com/publicpolicy/wp-content/uploads/2022/11/5G-millimetre-wave-safety-v2.pdf

[41] https://www.gsma.com/publicpolicy/wp-content/uploads/2021/10/GSMA_International_EMF_Exposure_Guideline_Oct21.pdf

[42] https://apps.fcc.gov/kdb/GetAttachment.html?id=f8IQgJxTTL5y0oRi0cpAuA%3D%3D&desc=447498%20D01%20General%20RF%20Exposure%20Guidance%20v06&tracking_number=20676

[43] https://apps.fcc.gov/kdb/GetAttachment.html?id=Z0Stk%2FPOk2hqHgYJNt%2FRlQ%3D%3D&desc=447498%20D04%20Interim%20%20General%20RF%20Exposure%20Guidance%20v01&tracking_number=20676

The Limits for Maximum Permissible Exposure is mentioned in table mentioned below-

Frequency Range (MHz)	**Electrical Field Strength (V/m)**	**Magnetic Field Strength (A/m)**	**Power Density (mW/cm^2)**	**Averaging Time (min)**
0.3 – 1.34	614	1.63	*100	30
1.34 – 30	842/f	2.19/f	*180/f^2	30
30 – 300	27.5	0.073	0.2	30
300 – 1,500	-	-	f/1500	30
1,500 – 100,00	-	-	1.0	30

Table 18: Limits for Maximum Permissible Exposure (General Public/Uncontrolled)

f = Frequency in MHz; * = Plane-wave equivalent power density

The RF exposure guidelines adopted by the FCC are based on SAR and MPE limits. The basic restrictions for human exposure are defined by SAR limits. MPE limits are derived from the SAR limits, in terms of free-space field strength and power density.

6.8. Office of Communications (Ofcom), United Kingdom

Ofcom is the regulatory authority for the broadcasting, telecommunications and postal industries of the United Kingdom. Ofcom document "*Guidance on EMF Compliance and Enforcement*[44]" released in 2021, mentioned that EMF exposure should comply with the guidelines published by the ICNIRP.

[44] https://www.ofcom.org.uk/__data/assets/pdf_file/0025/214459/guidance-emf-compliance-enforcement.pdf

7. Study of Policy and Regulation on EMF exposure in various countries

7.1. Asia Pacific Region

APT published a report on *Asia-Pacific regional activities on human exposure to EMF*[45] in April 2022. Country wise national policy, regulation and guideline for EMF in Asia-Pacific region is mentioned below in brief-

7.1.1. Korea (Republic of)

The EMF exposure limits of SAR in Korea are based on international standards developed by IEEE. The regulation for EMF rating and labelling was enforced from August 1, 2014 by Ministry of Science and ICT (MSIT)[46] which states that the operators of radio stations should affix the labels for EMF strength rating in an appropriate place. The manufacturers or importers of the portable devices used in direct contact with the user's ear should affix the labels for SAR rating, and/or display the highest SAR values appropriately.

7.1.2. New Zealand

New Zealand refers ICNIRP guidelines for limiting exposures to EMF in its standard NZS 2772.1:1999, on radiofrequency field exposure. The standard also provides guidance on verification of compliance and ensures that exposures to EMF are minimized.

7.1.3. China

Though each of China's corporations has their own set of policies/ rules concerning EMFs, the Ministry of Health and Ministry of Environmental Protection have set two major policies for EMF limitations namely GB 8702-88 and GB 21288 respectively.

7.1.4. Thailand

Thailand has issued following two regulations related to EMF exposure in 2007:

- National Telecommunication and Broadcasting Commission (NTC) Notification on Health and Safety Standard for the Usage of Radio Communication Equipment.
- NTC Notification on Rules and Measures to Regulate Health and Safety form the Usage of Radio Communication Equipment.

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[45] https://www.apt.int/APTASTAP-OUTCOMES

[46] https://cdn.who.int/media/docs/default-source/radiation/emf-international-project-country-reports/wpro-region/rep.korea-20188e03dc951306424ab15966aaa638c6e9.pdf?sfvrsn=eb61d68c_5

The Basic restrictions (limits) of the regulations are based on the exposure guidelines recommended by ICNIRP for both SAR and exposure limits.

7.1.5. Vietnam

The Vietnamese Ministry of Information and Communications (MIC) released the standard TCVN 3718-1:2005 - "Management of radio frequency radiation fields hazards. Part 1: Maximum exposure levels 3 kHz to 300 GHz" on the safety of the public from EMF exposure. The regulation is based on the ICNIRP international regulation for SAR and exposure limits.

7.2. Russia

GSMA in its document *Adopting International Radio Frequency Electromagnetic Fields (RF- EMF) Exposure Guidelines: Benefits for 5G Network Deployment in Russia*[47], released in 2020 has mentioned the RF-EMF exposure limits for Russian workers and the public, set out by Sanitary and epidemiological rules and regulations (SanPIN) which are applicable across the Russian Federation.

For environmental/public RF-EMF exposures, the Russian SanPIN environmental limit of 0.1 W/m^2 is 20 to 100 times lower than the corresponding ICNIRP general public limit as mentioned in section 6.2 of this document.

7.3. Australia

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) develops standards to protect the Australian public and workers from the harmful effects of radiation while The Australian Communications and Media Authority (ACMA) regulates RF EME emissions from mobile phone base stations and other communication installations such as TV and radio antennas. ACMA also regulate the emissions from personal devices such as mobile phones, Wi-Fi routers and tablets. ACMA's regulatory arrangements require these sources of RF EME to comply with the public exposure limits in the ARPANSA RF Standard.

ARPANSA developed a new standard RPS S-1 called *Radiation Protection Standard for Limiting Exposure to Radiofrequency Fields – 100 KHz to 300 GHz*[48] based on ICNIRP 2020 guidelines. This new ARPANSA standard is designed to protect people against all known adverse health effects from exposure to RF EME, including those used in the 5G network. The Standard also includes

[47] https://www.gsma.com/publicpolicy/resources/adopting-international-rf-emf-exposure-guidelines-benefits-for-5g-network-deployment-in-russia
[48] https://www.arpansa.gov.au/sites/default/files/rps_s-1.pdf

requirements for protection of the general public and the management of risk in occupational exposure, together with additional information on measurement and assessment of compliance.

The ACMA released "Radio communications Equipment (General) Rules[49] 2021" in February 2023. Part 3 of this document mandates the Measurement methods, computational procedures, and assessment methods for the latest international EME (Electromagnetic Energy) standards-

- IEC/IEEE 62209-1528 and
- IEC/IEEE 62209-3 for up to 6GHz, and
- IEC/IEEE 63195-1 (measurement) or IEC/IEEE 63195-2 (computational) and AS/NZS 2772.2 (for Assessment) for above 6GHz.

7.4. Canada

Innovation Science and Economic Development (ISED) , Canada in its document RSS-102 — *Radio Frequency (RF) Exposure Compliance of Radio communication Apparatus*[50] (All Frequency Bands) sets out the requirements and measurement techniques used to evaluate RF exposure compliance of radio communication apparatus (Category I and II equipment) that are designed to be used within the vicinity of the human body.

Safety Code 6[51] is another document that sets out recommended safety limits for human exposure to radiofrequency electromagnetic fields (EMF) in the frequency range from 3 kHz to 300 GHz. This range covers the frequencies used by communications devices and equipment that emit radiofrequency EMF such as Wi-Fi, cell phones, smart meters, cell phone towers, etc.

Under the Safety Code 6, Supplementary Procedure SPR-002, issue 2, sets out methods for assessing compliance of equipment operating in the frequency range from 3 kHz to 10 MHz with the radio frequency (RF) exposure limits to prevent nerve stimulation and thermal effects outlined in Radio Standards Specification RSS-102, *Radio Frequency (RF) Exposure Compliance of Radio Communication Apparatus (All Frequency Bands).*

[49] https://www.legislation.gov.au/Details/F2023C00236
[50] www.ic.gc.ca/eic/site/ceb-bhst.nsf/eng/h_tt00080.html
[51] https://www.canada.ca/content/dam/hc-sc/documents/services/publications/health-risks-safety/occupational-exposure-regulations/safety-code-6-radiofrequency-exposure-guidelines/understanding-safety-code-6-eng.pdf

7.5. Comparison of SAR values

Following table illustrates the SAR values prescribed by international organizations and some countries[52]

Classification		European Union, Japan, UK, China, Australia,	USA, Canada, Korea, India	CENELEC	ICNIRP	IEEE	FCC
Normal use (W/kg)	Whole body	0.08	0.08	0.08	0.08	0.08	0.08
	Head/Torso (localized SAR)	2	1.6	2	2	2	1.6
	Limbs	4	4	4	4	4	4
Occupational user (W/kg)	Whole body	0.4	0.4	0.4	0.4	0.4	0.4
	Head/Torso (localized SAR)	10	8	10	10	10	8
	Limbs	20	20	20	20	20	20

Table 19: Comparison of SAR values

[52] https://www.rra.go.kr/en/sar/standard.do

8. Studies regarding effect of EMF Radiation on biological life forms/ human body

The biological effects of EMF exposure have been studied extensively, however, there is no conclusive evidence of adverse effect of EMF radiation on human health. Some of the studies are listed below-

8.1. World Health Organization

WHO released a fact sheet on "Electromagnetic fields radiation and public health: Base stations and wireless technologies" [53] in May 2006 wherein it has mentioned that "*Considering the very low exposure levels and research results collected, there is no convincing scientific evidence that the weak RF signals from cell phone towers and wireless networks cause adverse health effects"* and in its fact sheet on "Electromagnetic fields radiation and public health: mobile phones"[54] in October 2014 mentioned that "*to date, no adverse health effects have been established as being caused by mobile phone use*".

The WHO further explains that, "the power falls off rapidly with increasing distance from the handset. A person using a mobile phone 30-40 cm away from their body – for example when text messaging, accessing the Internet, or using a "hands free" device – will therefore have a much lower exposure to radiofrequency fields than someone holding the handset against their head".

The main conclusion from the WHO reviews is that EMF exposures below the limits recommended in the ICNIRP international guidelines do not appear to have any known consequence on health[55].

WHO in its study on "Radiation: 5G mobile networks and health" [56] mentions that as the frequency increases, there is less penetration into the body tissues and absorption of the energy becomes more confined to the surface of the body (skin and eye). Provided that the overall exposure remains below international guidelines, no consequences for public health are anticipated.

[53] https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/non-ionizing/base-stations-wireless-technologies
[54] https://www.who.int/news-room/fact-sheets/detail/electromagnetic-fields-and-public-health-mobile-phones
[55] https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/protection-norms
[56] https://www.who.int/news-room/questions-and-answers/item/radiation-5g-mobile-networks-and-health

8.2. United States Food and Drug Administration

The study on **children and teens and cell phones**[57] by U.S. food and drug administration has mentioned that the current scientific evidence does not show a danger to any users of cell phones from RF exposure, including children and teenagers**.** It further mentions that a large epidemiological study of the effects of cell phones in young adults aged between 10 and 24 was completed across 14 countries in Europe (the MOBI-KIDS study). The case-controlled study was conducted "to evaluate whether wireless phone use (and particularly resulting exposure to radiofrequency (RF) and extremely low frequency (ELF) electromagnetic fields (EMF) increases risk of brain tumours in young people". The study concluded that there was no evidence of a link between cell phone use and brain tumors in young people[58].

8.3. Centers for Disease Control and Prevention (CDC), USA

CDC[59] has mentioned that communication technologies used in wearable devices typically use low-powered radiofrequency (RF) transmitters to send and receive data from smart phones or the Internet**.** RF transmitters in wearable devices operate at extremely low power levels and normally send signals in streams or brief bursts (pulses) for a short period of time**.** As a result, wearable devices expose the user to very small levels of RF radiation over time**.**

8.4. Health Protection Agency (HPA), United Kingdom

HPA published a report of independent advisory group on Non Ionizing Radiation[60] in 2012, which mentions that although a substantial amount of research has been conducted in this area, there is no convincing evidence that RF field exposure below prescribed guideline levels causes effects in adults or children.

8.5. Health Council of the Netherlands

A report on *Influence of radiofrequency telecommunication signals on children's brains*[61] published by Health Council of the Netherlands in 2011 mentions that the available data do not indicate any effects on the development of the brain or on health if children are exposed to radio

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[57] https://www.fda.gov/radiation-emitting-products/cell-phones/children-and-teens-and-cell-phones
[58]https://reader.elsevier.com/reader/sd/pii/S0160412021006942?token=8A4F1D2BCBCF32571682FBA398635121CC0B17BB6BA3F0ED77E7638FACDD599F49A7B366DBE108511A6A47B1481BF0C3&originRegion=eu-west-1&originCreation=20221208020030
[59] https://www.cdc.gov/nceh/radiation/wearable.html
[60]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/333080/RCE-20_Health_Effects_RF_Electromagnetic_fields.pdf
[61] https://www.gov.pl/attachment/c60a0be9-725d-4554-99ca-0bf2f5a985c3

frequency electromagnetic fields such as those generated by mobile telephones, mobile telecommunications antennas or Wi-Fi facilities.

9. Criteria for exclusion from assessment

9.1. Based on TEC/ FCC KDB standards

9.1.1. For single RF sources

Following steps may be applied for single portable RF sources for RF exposure test exemptions. (If device is not exempted then the device should be tested for SAR compliance)-

9.1.1.1. 6 mW exemption limits for single RF source: - As mentioned in the table 25, Annexure- 4 (referred from TEC 13016:2023 / FCC KDB 447498 D01:2015), a single RF source is exempted if the available maximum time-averaged power is not more than 6 mW, regardless of the separation distance. The 6 mW blanket exemption limit is applicable even at a separation distances less than 0.5 cm. This exemption applies to all operating configurations and exposure conditions, for the frequency range 4 MHz to 6 GHz, regardless of fixed, mobile, or portable device exposure conditions.

9.1.1.2. Threshold power values-

a. **For 100 MHz to 6 GHz and test separation distances ≤ 50 mm,** the 1-g and 10-g SAR test exclusion thresholds are determined by the following:

$$\frac{(max.power\ of\ channel\ (Pmax), including\ tune{-}up\ tolerance, mW)}{(min.test\ separation\ distance, mm)} \times \sqrt{f(GHz)} \leq 3.0 \text{ (for 1-g SAR)}$$

$$\frac{(max.power\ of\ channel\ (Pmax), including\ tune{-}up\ tolerance, mW)}{(min.test\ separation\ distance, mm)} \times \sqrt{f(GHz)} \leq 7.5 \text{ (for 10-g extremity SAR)}$$

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm, and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

b. **For 100 MHz to 6 GHz and test separation distances > 50 mm**, the 1-g and 10-g SAR test exclusion thresholds are determined by the following:

i) For 100 MHz to 1500 MHz
{[Power allowed at numeric threshold for 50 mm in step a)]+ [(test separation distance – 50 mm) × (f(MHz)/150)]} mW

ii) For > 1500 MHz and ≤ 6 GHz
{[Power allowed at numeric threshold for 50 mm in step a)]+ [(test separation distance – 50 mm) × 10]} mW

c. For frequencies below 100 MHz, the following may be considered for SAR test exclusion:

i) For test separation distances > 50 mm and < 200 mm, the power threshold at the corresponding test separation distance at 100 MHz in step b) is multiplied by [1 + log(100/f(MHz))]

ii) For test separation distances ≤ 50 mm, the power threshold determined by the equation in

((c). i) above for 50 mm and 100 MHz is multiplied by ½

Some approximate exclusion threshold numerical values at selected frequencies and distances (As per TEC 13016:2023 / FCC KDB 447498 D01:2015 RF exemption limit) is mentioned in table 25 of Annexure- 4.

9.1.1.3. SAR-based Exemption: A more comprehensive exemption, considering a variable power threshold that depends on separation distance and power. This exemption is applicable to the frequency range between 100 MHz and 6 GHz, with test separation distance of up to 20 cm between the user and the device, and for all RF sources in fixed, mobile, and portable device exposure conditions.

Accordingly, a RF source is considered an RF exempt device if its available maximum time-averaged power or its effective radiated power (ERP), whichever is greater, are below a specified threshold. This exemption threshold was derived based on general population 1-g SAR requirements and is detailed in Annexure 4. Approximate SAR Test Exclusion Power Thresholds at selected frequencies and test separation distances are illustrated in table 25 of Annexure 4.

The SAR-based thresholds are derived based on the frequency, power, and separation distance of the RF source.

Note 1: ***FCC has released FCC KDB 447498 D04 v01, 2021*** as an interim document. This document has described the SAR based exemption as well as MPE based exemption. In SAR based exemption, it has prescribed the exemption limit of 1mW (refer table 26, Annexure-4). MPE based exemption has been described below:

MPE-based Exemption criteria: - It is an alternative to the SAR-based exemption, which has provided a much wider frequency range, from 300 kHz to 100 GHz, applicable for separation distances greater or equal to λ/2π, where λ is the free-space operating wavelength in meters. The MPE-based test exemption condition is in terms of ERP. For this case, a RF source is an RF exempt device if its ERP (watts) is no more than a threshold value as mentioned in table 27, Annexure- 5.

Note 2: As the power density limits in India have not been defined for the IoT devices working in close proximity i.e at a distance of not more than 20 cm (working on the frequency above >6GHz) therefore MPE based test exemption condition as detailed above are not directly applicable in existing Indian scenario.

(process for evaluation of SAR measurement is illustrated in the flowchart shown in annexure 7.)

Note 3:- New document FCC KDB 447498 D01 v07 is expected to be published in near future, which may be further studied. At present TEC is following the FCC KDB 447498 D01:2015 as detailed in point No. 9.1.1.1, 9.1.1.2 and 9.1.1.3 above.

9.1.2. For Multiple/Simultaneous Transmission RF sources:

Following steps may be applied for multiple/simultaneous RF sources for RF exposure test exemptions. (If device is not exempted then the device should be tested for SAR compliance)-

9.1.2.1. 6 mW exemption for multiple source: -

As mentioned in 9.1.1.1, the 6mW exemption intended for single transmitters may also be applied to simultaneous transmission conditions, within the same host device, if the aggregate maximum EIRP of all transmitting antennas is ≤ 6 mW in the same time-averaging period.
(referred from TEC 13016:2023 / FCC KDB 447498 D01: 2015))

Note: ***FCC has released FCC KDB 447498 D04 v01, 2021*** as an interim document. It has prescribed the exemption limit of 1mW. This document has described the SAR based exemption as well as MPE based exemption for multiple/simultaneous Transmission RF sources. The details are as given below:

i) Simultaneous Transmission with both SAR-based and MPE-Based Test Exemptions

A device with multiple RF sources transmitting simultaneously will be considered an *RF exempt device* if the condition of formula below is satisfied-

$$\sum_{i=1}^{a} \frac{Pi}{Pth,i} + \sum_{j=1}^{b} \frac{ERPj}{ERPth,j} + \sum_{k=1}^{c} \frac{Evaluated\ k}{Exposure\ Limit\ k} \leq 1 \quad \text{(A.3)}$$

(It has been described in detail in Annexure-6)

When simultaneous transmission SAR-based test exemptions, or when the SAR to peak location separation ratio (SPLSR) test exemption cannot be applied, SAR measurements must be performed at the maximum output power required for the applicable simultaneous transmission scenarios. (for detailed information refer annexure 6 or refer KDB 447498 D04: 2021) ii.) **Test Exemption Based on the SAR to Peak Location Separation Ratio**

When the ERP-based condition in the previous points 1 and 2 above does not apply, a test exemption may still be applicable based on the SAR to peak location separation ratio (SPLSR) procedure.

The simultaneously transmitting antennas in each operating mode and exposure condition combination must be considered one pair at a time to determine the SPLSR that qualifies for the additional test exemption.

This ratio is defined as SPLSR = $(SAR1 + SAR2)^{1.5}/R_i$, where SAR1 and SAR2 are the highest reported SAR or estimated SAR values for the two sources in the pair i, and R_i is their distance in millimeters.

When SPLSR ≤ 0.04, for all antenna pairs in the configuration, then the device qualifies for 1-g SAR test exemption.

When SPLSR ≤ 0.10, for all antenna pairs in the configuration, then the device qualifies for 10-g SAR test exemption.

If any antenna pair does not qualify for simultaneous transmission SAR test exemption, then the device must be tested for SAR compliance. (for detailed information refer KDB 447498 D04:2021)

9.1.2.2. Evaluation by SAR measurement or computation if steps mentioned in point No. 9.1.2.1, 9.1.2.1.i and 9.1.2.1.ii. above are not met

This process is illustrated in the flowchart shown in annexure 7.

9.2. Based on IEC/ IEEE standards (IEEE Std 1528.7™-2020[62])

9.2.1. For single RF sources:

Following steps may be applied for single portable RF sources for RF Exposure Test Exemptions. (If device is not exempted then the device should be tested for SAR compliance)-

9.2.1.1. If the IoT device meets low-power exclusion principle as per IEC 62479:2010 (refer annexure 9) then exposure assessment is not required.

9.2.1.2. For separation distances less than 20 cm.

[62] https://ieeexplore.ieee.org/document/9319817

i. if operating frequency <= 6 GHZ then SAR evaluation is applicable, as per appropriate existing assessment standard (IEC 62209-3:2019, IEC/IEEE 62704-1:2017, IEC/IEEE 62704-4, IEEE Std 1528-2013) and is limited to 10 GHz in IEC/IEEE 62209-1528.

ii. If operating frequency is 6 GHz to 300 GHz then power density evaluation is applicable, as per appropriate assessment standard (IEC/IEEE 63195-1, IEC/IEEE 63195-2)

iii . If the device transmits at frequencies (<= 6 GHz) where SAR assessment is required and simultaneously transmits at frequencies (from 6 GHz to 300 GHz) where power density assessment is required, then combined assessment of simultaneous exposure to multiple frequencies is applicable as per appropriate standard IEC 63195-1, IEC 63195-2, ICNIRP-2020, IEEE Std C95.1-2019, IEC TR 62630:2010, or FCC 19-126.

9.2.1.3. For separation distances greater than 20 cm and operating frequencies from 100 kHz to 300 GHz then electric field strength or magnetic field strength or incident plane-wave power density assessment is applicable, as per standard IEC 62232:2017.

9.2.1.4. If no existing product standard is applicable, then perform assessment as per IEC 62311:2019.

This process is illustrated in the flowchart shown in annexure 8, figure 7.

9.2.2. For multiple RF sources:

Following steps may be applied for multiple RF sources for RF Exposure Test Exemptions. (If device is not exempted then the device should be tested for SAR compliance)-

9.2.2.1. If the combined total power of the device meets the low-power exclusion principle as per IEC 62479:2010 (refer annexure 9) then assessment is not required.

9.2.2.2. For separation distances less than 20 cm-

a. if operating frequencies <= 6 GH_Z then SAR assessment is required,
   i. if SAR patterns overlap
      - For single system with multiple radios: assessment as per IEC/IEEE 62209-1528.
      - For multiple devices operating in close proximity: development of guidance or specific standards is required

ii. if SAR pattern do not overlap:
- SAR evaluation is applicable for frequency range up to 6 GHz, as per existing appropriate assessment standard (IEC 62209-3:2019, IEC/IEEE 62704-1:2017, IEC/IEEE 62704-4, IEEE Std 1528-2013, IEC/IEEE 62209-1528).

b. If operating frequency is 6 GHz to 300 GHz then power density assessment is required,

i. If incident power density patterns overlap
- Individual devices: experimental assessment per IEC/IEEE 63195-1, or numerical assessment per IEC/IEEE 63195-2.
- Multiple devices operating in close proximity: development of guidance or specific standards remains needed.

ii. If incident power density patterns do not overlap

- Power density evaluation is applicable, the frequency range for assessment is limited to 6 GHz to 300 GHz by assessment standard (IEC/IEEE 63195-1, IEC/IEEE 63195-2).

c. If there is a mix of frequencies above and below 6 GHz: SAR assessment for frequencies less than or equal to 6 GHz, and power density assessment for frequencies above 6 GHz; combined simultaneous exposure to multiple frequencies as per appropriate standards (ICNIRP-2020, IEEE Std C95.1-2019, IEC TR 62630:2010, or FCC 19-126).

9.2.2.3. For separation distances greater than 20 cm and operating frequencies from 100 kHz to 300 GHz: assessment of electric field strength or magnetic field strength or incident plane-wave power density is required, using IEC 62232:2017.

This process is illustrated in the flowchart shown in Annexure-8, figure 8

Note: As SAR as well as power density limits in India are different from those of IEC/ IEEE therefore, above test exemptions as detailed in section 9.2. are not directly applicable in Indian scenario.

10. Summary & Recommendations

10.1. Summary

Introduction and background has been covered in section 1. DoT/ TEC initiatives in M2M/ IoT domain and brief about the technology has been mentioned in Section 2 and 3 respectively. Basic terms and definitions related to electromagnetic field radiations have been described in section 4.

Study of existing policies, standards, guidelines and regulations related to EMF exposure/ SAR from RF devices in India have been covered in section 5 and similar global study have been detailed in section 6 and 7. As per the details available in section 6 and 7, USA, Korea, Canada and India are having the SAR (localized SAR) limits as 1.6 W/Kg averaged over 1 gm of tissues. FCC also recommends the same. Countries namely European Union, Japan, UK, China, Australia are having SAR (localized SAR) limits as 2 W/ Kg averaged over 10 gm of tissues, based on the guidelines from ICNIRP, IEEE/ IEC, CENELEC.

Study related to effects of EMF Radiation on biological life forms/ human body have been described in section 8, which concluded that if the EMF exposures are below the limits recommended in the ICNIRP guidelines then it does not have any known consequence on health.

Criteria for exclusion from assessment based on TEC/ FCC KDB standards and IEC/ IEEE standards (IEEE Std 1528.7™-2020) for single as well as multiple RF devices have been described in brief in section 9.1 and 9.2 respectively. If device is not exempted, then it should be tested for SAR/ EMF compliance.

10.2. Recommendations

1. DoT adopted SAR (localized SAR) limits i.e. 1.6 W/Kg averaged over 1 gm of tissues for the RF devices (IoT devices) operating in close proximity to human body may continue to be followed. (Refer section 5.2.).
2. The criteria for exclusion from assessment for the IoT devices with single/ multiple RF sources, based on TEC Standard/ FCC KDB, may be followed. (Refer section 9.1.)
3. For devices used in close proximity to human body (<= 20 cm) operating above 6 GHz band (Such as Wi Fi 6E, Wi- Fi 7, 5G etc.), power density limits for compliance to EMF exposure are applicable as available in FCC/ IEEE/ ICNIRP guidelines. The same need to be studied and a standard may be prepared by Radio division, TEC for assessing compliance.
4. The devices which are not exempted from RF exposure testing as per Point No. 2 above for testing and evaluation, shall be subjected to the SAR or Power Density evaluation as the case may be.

5. SAR/ EMF limits in India are stringent than ICNIRP/ IEEE limits for the RF devices operating in close proximity to the human body (refer table -19). As per the theoretical calculation from the section 6.3.1 of this document, it may be presumed that if RF devices are SAR/ EMF complied as per Indian limit then large number of RF devices can be occupied within a small range.

Important informatory guidelines

1. IEEE standard 1528.7-2020 mentions that majority of Internet of Things (IoT) devices are expected to operate at low radiated radio frequency (RF) power levels (< 20 mW). Thus, IEEE has recommended that If the power of each IoT device is limited to 20 mW or less, then it is hard to conceive an exposure of concern at distances larger than few centimeters (refer section 6.3).

2. For devices with power level less than 20 mW and operating at a distance more than 20 cm from human body then there is no need to evaluate the RF exposure from such IoT devices. It is mentioned here that, exempted power limit as prescribed in India is 6 mW for the devices in close proximity to human body. (refer Table -25, Annexure- 4).

3. IoT devices are usually placed at a distance of around one meter or more from human-being except wearable devices. Since IoT devices generally do not need human intervention, so the distance from the human-body is usually greater than those of personal communication devices. Even if a human operates close to an IoT device, the exposure time might be only a fraction of the averaging time as per the applicable guidelines in ICNIRP-2020 and IEEE Std C95.1-2019, which specify 6 minutes averaging time. Hence the possibility to exceed the exposure limits from the IoT device to the human-body is largely reduced.

From this it can be inferred that in Indian scenario, human-body exposed to multiple IoT devices will be safe, if individual IoT devices are RF complied and operating at significant distance away from human body.

11. List of Annexures

Annexure-1: Standard and EIRP limit in various frequency range of related communication technologies

Frequency Range & Relevant Standard for EMF exposure from IoT/M2M devices operating in non-cellular / delicensed frequency band as per WPC NFAP /GSR

Frequency Bands	CE standard	FCC standard	WPC GSR	Communication Technologies	EIRP Limits as per WPC GSR
2402 to 2480 MHz	ETSI EN 300 328 V2.1.1 (2016-11)	FCC 15.247 Part C	45E dated 28.01.2005	BLE,BT,WiFi, Zigbee, Z Wave, ANT , ANT +	1W (30dBm)- Max Output Power 4W (36dBm)- Max EIRP
2400 2483.MHz	ETSI EN 300 328 V2.1.1 (2016-11)	FCC 15.247 Part C	45E dated 28.01.2005	BLE,BT,WiFi, Zigbee, Z Wave, ANT , ANT +	1W (30dBm)- Max Output Power 4W (36dBm)- Max EIRP
5150 to 5250 MHz	ETSI EN 301 893 V2.1.1 (2017-05)	FCC 14.401 Part E	1048E dated 22.10.2018	WIFI, Point to Point RLAN Devices	1W (30dBm)- Max Output Power
5250 to 5350 MHz	ETSI EN 301 893 V2.1.1 (2017-05)	FCC 14.401 Part E	1048E dated 22.10.2018	WIFI, Point to Point RLAN Devices	250mW (24dBm)- Max Output Power
5470 to 5725 MHz	ETSI EN 301 893 V2.1.1 (2017-05)	FCC 14.401 Part E	1048E dated 22.10.2018	WIFI, Point to Point RLAN Devices	250mW (24dBm)- Max Output Power
5725 to 5875 MHz	ETSI EN 300 440 V2.2.1 (2018-07) ETSI EN 302 502 V1.2.1 (2008-07)	FCC 14.401 Part E	1048E dated 22.10.2018	WIFI, Point to Point RLAN Devices	1W (30dBm)- Max Output Power
76 to 77 GHz	ETSI EN 301 091-2 V2.1.1 (2017-01	FCC 15.256	GSR 699 E dated 16.09.2015	Radar Systems	5W (37dBm)
13.553 to 13.567 MHz	ETSI EN 300 330-2 V2.1.1 (2017-02	FCC 15.225	GSR 884 E dated 04.11.2010	NFC, RFID	42 dB µA/m or 93.5 dB µV/m at 10 meters
50 to 200 KHz	ETSI EN 300 330 V2.1.1		GSR 90E dated 10.02.2009	RF Wireless transceivers	50-59.750 KHz- 72dB µA/m or 123.5 dB µV/m at 10 meters 59.750-60.250 KHz 42 dB µA/m or 93.5 dB µV/m at 10 meters

					60.250-70KHz- 69dB µA/m or 120.5 dB µV/m at 10 meters 70-119KHz- 42 dB µA/m or 93.5 dB µV/m at 10 meters 119-135KHz -66 dB µA/m or 117.5 dB µV/m at 10 meters 135-140KHz- 42 dB µA/m or 93.5 dB µV/m at 10 meters 140-148.5KHz- 37.7 dB µA/m or 89.2 dB µV/m at 10 meters 148.5-200KHz -30 dB µA/m or 81.5 dB µV/m at 10 meters
24.05 to 24.5GHz	ETSI EN 302858	FCC 15.247	GSR 1047E dated 18.10.2018	Transport and traffic Telematics	24.05-24.075 GHz -100 mW EIRP 24.075-24.15 GHz- 100mW EIRP 24.15-24.25-GHz – 100 mW EIRP for Ground based Vehicular Radars Only 24.15-24.25GHz- 0.1 mW EIRP 24.25-24.495 GHz- -11dBm EIRP 24.25-24.5 GHz -20dBm EIRP for forward facing radars, 16dBm for rear facing radars 24.495-24.5 GHz- -8dBm EIRP for
865 to 868 MHz (LoRa frequency range for US is 902 to 928 MHz)	ETSI EN 300 220-2 V3.1.1	FCC 15.249	GSR 564E dated 30.07.2008	RFID, LoRa, Sigfox, RF Mesh	1W (30dBm)- Max Output Power 4W (36dBm)- Max EIRP
9-50 KHz			GSR 83 E dated 11.02.2014	Very Low Power RF Devices	Max Radiated Power/ Field Strength Limits 72dB µA/m or 123.5 dB µV/m at 10 meters
402-405 MHz			GSR 673E dated 20.09.2019	Very Low power remote cardiac monitoring RF wireless medical devices	25 µW- Max EIRP
302-351 KHz			GSR 697E dated 16.09.2015	Very Low Power RF Devices for Inductive	-15 dB µA/m at 10 meters Field Strength

				Power Applications	

Table 20: Frequency Range & Relevant Standard for EMF exposure from IoT/M2M devices operating in non-cellular / delicensed frequency band as per WPC NFAP/ GSR

Note1: For more information about standards pertaining to various communication technologies for testing purpose, refer TEC Annexure to ER[63], prepared under MTCTE framework.

Note2: In cellular communication, power control mechanism and discontinuous transmission in mobile communication systems contribute to a lower time-averaged output power than the maximum UE power. It has been mentioned in IEEE document *Actual Output Power Levels of User Equipment in 5G Commercial Networks and Implications on Realistic RF EMF Exposure Assessment*[64], a multinational study conducted in Global System for Mobile (GSM) communication based 2G networks, the mean time-averaged output power of UE was reported to be 50% and 25% of the collected power samples, of the maximum time-averaged power in in rural and urban areas, respectively. Output power levels of UE in 3G and 4G networks were found to be significantly lower than the actual output power levels reported for 2G networks. Output power levels were varying between less than 1% to 2% of the maximum UE power depending upon the environments. In 5G, the time-averaged power samples were found to be less than 8% of the maximum while the mean value was less than 2%.

[63] https://www.mtcte.tec.gov.in/annexures
[64] https://ieeexplore.ieee.org/document/9252895

Annexure-2: Exposure limits for persons in restricted and unrestricted environments as per IEEE Std C95.1™-2019

As per the IEEE Std C95.1™-2019[65] IEEE Standards for *Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, the exposure limits mentioned in table 8 to 11 of this standard have been reiterated below-

Frequency range (MHz)	**Electric field strength (E)[a,b,c] (V/m)**	**Magnetic field strength (H)[a,b,c] (A/m)**	**Power density (S)[a,b,c] (W/m^2)**		**Averaging time (min)**
			S_E	**S_H**	
0.1 to 1.0	1842	$16.3/f_M$	9000	$100\,000/ f_M^{2}$	30
1.0 to 30	$1842/ f_M$	$16.3/f_M$	$9000/ f_M^{2}$	$100\,000/ f_M^{2}$	30
30 to 100	61.4	$16.3/f_M$	10	$100\,000/ f_M^{2}$	30
100 to 400	61.4	0.729	10		30
400 to 2000	-	-	$f_M /40$		30
2000 to 300 000	-	-	50		30
NOTE-S_E and S_H are plane-wave-equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.					

Table 21: Exposure Reference Level (ERLs) for whole-body exposure of persons permitted in restricted environments (100 kHz to 300 GHz)

a. For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the ERLs in Table 21. For more typical non uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the plane-wave-equivalent power densities or the squares of the field strengths, are compared with the ERLs in Table 21. (See notes to Table 7 through Table 11 in section 4.3.5. of this IEEE document)

b. f_M is the frequency in MHz.
c. The E, H, and S values are those rms values unperturbed by the presence of the body.

[65] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8859679

Frequency range (MHz)	**Electric field strength (E)[a,b,c,d] (V/m)**	**Magnetic field strength (H)[a,b,c,d] (A/m)**	**Power density (S)[a,b,c,d] (W/m²)**	
			S_E	**S_H**
0.1 to 1.34	1373	$36.4/f_M$	5000	$500\,000/ f_M{}^{2}$
1.34 to 30	$1842/f_M$	$36.4/f_M$	$9000/ f_M{}^{2}$	$500\,000/ f_M{}^{2}$
30 to 100	61.4	$353/ f_M{}^{1.668}$	2	$47000000\ f_M{}^{3.336}$
100 to 400	$21.2 \times f_M{}^{0.232}$	$0.0562 \times f_M{}^{0.232}$	$1.19 \times f_M{}^{0.463}$	
400 to 2000	-	-	$1.19 \times f_M{}^{0.463}$	
2000 to 6000	-	-	40	
NOTE 1-Below 6 GHz, portable devices are typically tested for DRL compliance (e.g., SAR), for which distinct limits for head and torso, pinnae and limbs are defined. NOTE 2— S_E and S_H are plane-wave-equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.				

Table 22: Local exposure ERLs (100 kHz to 6 GHz)-Persons in unrestricted environments Frequency range (MHz)

a. Determined in air at the location of the body surface.
b. Spatial and temporal peaks averaged over 6 min.
c. f_M is the frequency in MHz.
d. The E, H and S values are those rms values unperturbed by the presence of the body.

Frequency range (MHz)	Electric field strength (E)[a,b,c,d] (V/m)	Magnetic field strength (H)[a,b,c,d] (A/m)	Power density (S)[a,b,c,d] (W/m²)	
			S_E	S_H
0.1 to 1.34	4119	$36.4/f_M$	45000	$500\,000/ f_M{}^{2}$
1.34 to 30	$4119/f_M$	$36.4/f_M$	$45000/ f_M{}^{2}$	$500\,000/ f_M{}^{2}$
30 to 100	137.3	$36.4/f_M$	50	$500\,000/ f_M{}^{2}$
100 to 400	$47.3\text{x}\ f_M{}^{0.232}$	$0.125\text{x}\ f_M{}^{0.232}$	$5.93\text{x}\ f_M{}^{0.463}$	
400 to 2000	-	-	$5.93\text{x}\ f_M{}^{0.463}$	
2000 to 6000	-	-	200	
NOTE 1-Below 6 GHz, portable devices are typically tested for DRL compliance (e.g., SAR), for which distinct limits for head and torso, pinnae and limbs are defined. NOTE 2— S_E and S_H are plane-wave-equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.				

Table 23: Local exposure ERLs (100 kHz to 6 GHz)-Persons permitted in restricted environments

a. Determined in air at the location of the body surface.

b. Spatial and temporal peaks averaged over 6 min.
c. f_M is the frequency in MHz.
d. The E, H and S values are those rms values unperturbed by the presence of the body.

Frequency	Persons in unrestricted environments Incident Power Density (W/m^2)[a,b,c,d,e]	Persons in restricted environments Incident Power Density (W/m^2)[a,b,c,d,e]
6 GHz	40	200
6 GHz to 300 GHz	$55f_G^{-0.177}$	$274.8\ f_G^{-0.177}$
300 GHz	20	100

Table 24: Local exposure ERLs (6GHz to 300 GHz)

a. Incident power density is averaged over 6 min for local exposure.
b. Averaged over any 4 cm^2 of body surface for 6 GHz to 300 GHz (area defined as surface of the body in the shape of a square).
c. Small exposed areas above 30 GHz: If the exposed area on body surface is small (<1 cm^2 as defined by -3 dB contours relative to the peak exposure), the incident power density is allowed to exceed the ERL values of Table 11 by a factor of 2, with an averaging area of 1 cm^2 (defined as area in the shape of a square at surface of the body).
d. Assessed in air at the location of the body, but the body is absent during assessment.
e. f_G is the frequency in GHz.

Annexure-3: DoT letter to study the global best practices on EMF radiation from IoT/M2M devices

16-04/2021/CS-II

I/3052168/2022

Government of India
Ministry of Communication
Department of Telecommunication
(Carrier Service Cell)
*****

No. 16-04/2021/CS-II **Date: ~~26~~27.07.2022**

To,

Sr. DDG & Head,
Telecom Engineer Center, DOT
Khurshid Lal Bhawan, Janpath, New Delhi

Subject: Provision 2.2(d)vi of NDCP-2018 related to EMF radiation policy for M2M devices.

Sir,

This has reference to minutes of the meeting (**copy attached**) held on the provision 2.2 (d) vi of NDCP-2018 "Defining policy for EMF radiation for M2M devices, with accompanying institutional framework to coordinate government-funded and India-specific research in this regard" held on 30-05-2022 in room no. 1006, Sanchar Bhawan, under the chairmanship of DDG (CS).

2. As decided and agreed in the meeting, the provision 2.2 (d) vi of NDCP-2018 of NDCP is being referred to TEC with request to direct the concerned division/ officer under TEC to study the best global practices & examine the available knowledge-base on this issue and submit its recommendations/ outcome within three months to enable DoT to formulate suitable policy for EMF radiation from M2M devices. It is also requested that inputs from the concerned Study Group dealing with *"Human exposure to electromagnetic fields (EMFs) due to digital technologies"* may be factored in while giving the recommendations.

This has the approval of DDG(CS).

Encl: As above.

(Arvind Kumar Tripathi)
Director (CS-II)
Tele. No. 23372628

Annexure-4: SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances

SAR-based Exemption as per TEC 13016:2023 / FCC KDB 447498 D01: This method shall only be used at separation distances from up to 20 cm and at frequencies from 100 MHz to 6 GHz and less than 100 MHz. P_{th} is given by tables below –

MHz	5	10	15	20	25	mm
150	39	77	116	155	194	SAR Test Exclusion Threshold (mW)
300	27	55	82	110	137	
450	22	45	67	89	112	
835	16	33	49	66	82	
900	16	32	47	63	79	
1500	12	24	37	49	61	
1900	11	22	33	44	54	
2450	10	19	29	38	48	
3600	8	16	24	32	40	
5200	7	13	20	26	33	
5400	6	13	19	26	32	
5800	6	12	19	25	31	

MHz	30	35	40	45	50	mm
150	232	271	310	349	387	SAR Test Exclusion Threshold (mW)
300	164	192	219	246	274	
450	134	157	179	201	224	
835	98	115	131	148	164	
900	95	111	126	142	158	
1500	73	86	98	110	122	
1900	65	76	87	98	109	
2450	57	67	77	86	96	
3600	47	55	63	71	79	
5200	39	46	53	59	66	
5400	39	45	52	58	65	
5800	37	44	50	56	62	

MHz	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	mm
100	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	mW
150	387	397	407	417	427	437	447	457	467	477	487	497	507	457	527	
300	274	294	314	334	354	374	394	414	434	454	474	494	514	534	554	
450	224	254	284	314	344	374	404	434	464	494	524	554	584	614	644	
835	164	220	275	331	387	442	498	554	609	665	721	776	832	888	943	
900	158	218	278	338	398	458	518	578	638	698	758	818	878	938	998	
1500	122	222	322	422	522	622	722	822	922	1022	1122	1222	1322	1422	1522	
1900	109	209	309	409	509	609	709	809	909	1009	1109	1209	1309	1409	1509	

2450	96	196	296	396	496	596	696	796	896	996	1096	1196	1296	1396	1496
3600	79	179	279	379	479	579	679	779	879	979	1079	1179	1279	1379	1479
5200	66	166	266	366	466	566	666	766	866	966	1066	1166	1266	1366	1466
5400	65	165	265	365	465	565	665	765	865	965	1065	1165	1265	1365	1465
5800	62	162	262	362	462	562	662	762	862	962	1062	1162	1262	1362	1462

MHz	<50	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	mm
100	237	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	
50	308	617	625	634	643	651	660	669	677	686	695	703	712	721	729	738	
10	474	948	961	975	988	1001	1015	1028	1041	1055	1068	1081	1095	1108	1121	1135	
1	711	1422	1442	1462	1482	1502	1522	1542	1562	1582	1602	1622	1642	1662	1682	1702	mW
0.1	948	1896	1923	1949	1976	2003	2029	2056	2083	2109	2136	2163	2189	2216	2243	2269	
0.05	1019	2039	2067	2096	2125	2153	2182	2211	2239	2268	2297	2325	2354	2383	2411	2440	
0.01	1185	2370	2403	2437	2470	2503	2537	2570	2603	2637	2670	2703	2737	2770	2803	2837	

Table 25: SAR Test Exclusion Threshold (mW)

Note: 10-g Extremity SAR Test Exclusion Power Thresholds are 2.5 times higher than the 1-g SAR Test Exclusion Thresholds indicated above. These thresholds do not apply, by extrapolation or other means, to occupational exposure limits.

SAR-based Exemption as per FCC KDB 447498 D04: This method shall only be used at separation distances from 0.5 cm to 40 cm and at frequencies from 0.3 GHz to 6 GHz (inclusive). Power Threshold (P_{th})is given by below formula –

$$P_{th}(mW) = \begin{cases} ERP_{20cm}\left(\frac{d}{20\ cm}\right)^{x} & d \leq 20\ cm \\ ERP_{20cm} & 20\ cm \leq d \leq 40\ cm \end{cases}$$

where,

$$x = -log_{10}\left(\frac{60}{ERP_{20cm}\sqrt{f}}\right)$$

and f is in GHz, d is the separation distance (cm), and ERP_{20cm} is as per above formula

The example values shown in Table 26 below are for illustration purpose only-

	Distance (mm)										
		5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Frequency (MHz)	**300**	39	65	88	110	129	148	166	184	201	217
	450	22	44	67	89	112	135	158	180	203	226
	835	9	25	44	66	90	116	145	175	207	240
	1900	3	12	26	44	66	92	122	157	195	236
	2450	3	10	22	38	59	83	111	143	179	219
	3600	2	8	18	32	49	71	96	125	158	195
	5800	1	6	14	25	40	58	80	106	136	169

Table 26: Power Thresholds (mW)

Annexure-5: MPE-based effective radiated power (ERP) thresholds

MPE-based Exemption: As per FCC KDB 447498 D04, General frequency and separation-distance dependent MPE-based effective radiated power (ERP) thresholds are mentioned in below table to support an exemption from further evaluation from 300 kHz through 100 GHz. –

RF Source Frequency			Minimum Distance			Threshold ERP
f_L MHz		f_H MHz	$\lambda_L / 2\pi$		$\lambda_H / 2\pi$	W
0.3	-	1.34	159 m	-	35.6 m	1,920 R^2
1.34	-	30	35.6 m	-	1.6 m	3,450 R^2/f^2
30	-	300	1.6 m	-	159 mm	3.83 R^2
300	-	1,500	159 mm	-	31.8 mm	0.0128 R^2f
1,500	-	100,000	31.8 mm	-	0.5 mm	19.2 R^2

Table 27: Thresholds for single RF sources subject to routine environmental evaluation

Note: Subscripts L and H are low and high; λ is wavelength

The table applies to any RF source (i.e., single fixed, mobile, and portable transmitters) and specifies power and distance criteria for each of the five frequency ranges used for the MPE limits.

For mobile devices that are not exempt as per above table at distances from 20 cm to 40 cm and in 0.3 GHz to 6 GHz, evaluation of compliance with the exposure limits as defined by FCC is necessary if the ERP of the device is greater than ERP_{20cm} in Formula below-

$$Pth(mW) = ERP_{20cm}(mW) = \begin{cases} 2040f & 0.3GHz \leq f < 1.5GHz \\ 3060 & 1.5GHz \leq f \leq 6GHz \end{cases}$$

Annexure-6: Simultaneous Transmission with both SAR-based and MPE-Based Test Exemptions

Either SAR-based or MPE-based exemption may be considered for test exemption for fixed, mobile, or portable device exposure conditions; therefore, the contributions from each exemption in conjunction with the measured SAR (*Evaluatedk*) shall be used to determine exemption for simultaneous transmission according to Formula

$$\sum_{i=1}^{a} \frac{Pi}{P\text{th},i} + \sum_{j=1}^{b} \frac{ERPj}{ERP\text{th},j} + \sum_{k=1}^{c} \frac{Evaluatedk}{Exposure\ Limitk} \leq 1 \qquad \text{(A.4)}$$

a	Number of fixed, mobile, or portable RF sources claiming exemption using the formula for P_{th} mentioned in Annexure- 4, including existing Exempt transmitters and those being added.
b	number of fixed, mobile, or portable RF sources claiming exemption using the Table 27, Annexure-5 formula for Threshold ERP, including existing exempt transmitters and those being added.
c	Number of existing fixed, mobile, or portable RF sources with known evaluation for the specified minimum distance.
P_i	The available maximum time-averaged power or the ERP, whichever is greater, for fixed, mobile, or portable RF source i at a distance Between 0.5 cm and 40 cm (inclusive).
$P_{th,i}$	The exemption threshold power (P_{th}) according to the Annexure- 4 formula for fixed, mobile, or portable RF source i.
ERP_j	The available maximum time-averaged power or the ERP, whichever is greater, of fixed, mobile, or portable RF source j.
$ERP_{th,j}$	Exemption threshold ERP for fixed, mobile, or portable RF source j, at a distance of at least λ/2π, according to the applicable Table 27, Annexure-5 formula at the location in question.
$Evaluated_k$	The maximum reported SAR or MPE of fixed, mobile, or portable RF source k either in the device or at the transmitter site from an existing evaluation.
$Exposure\ Limit_k$	Either the general population/uncontrolled maximum permissible exposure (MPE) or specific absorption rate (SAR) limit for each fixed, mobile, or portable sources, as applicable

The sum of the ratios of the applicable terms for SAR-based, MPE-based and measured SAR or MPE shall be less than 1, to determine simultaneous transmission exposure compliance.

Annexure-7: Flow chart to Establish Compliance with Exposure Limits for a Single RF Source as per FCC guidelines

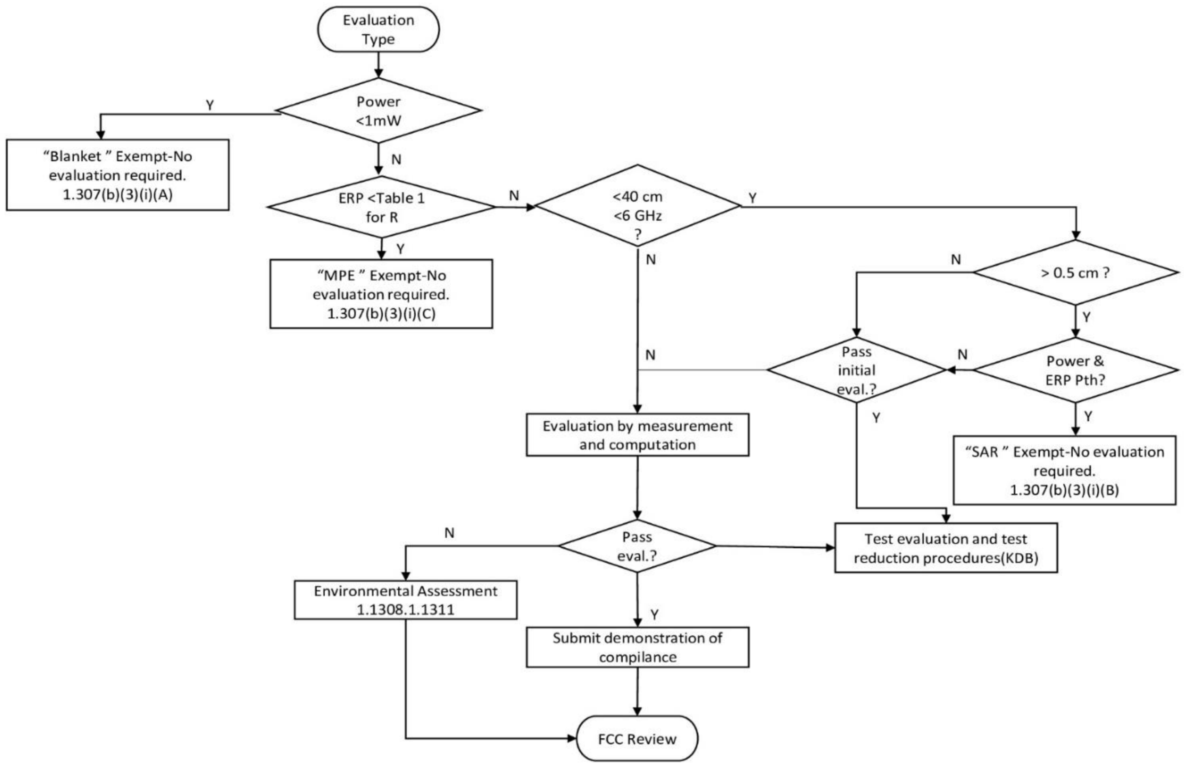

Figure 6: General Sequence for Determination of Procedure (exemption or evaluation) to Establish Compliance with Exposure Limits for a Single RF Source

Annexure-8: Flow chart for assessment of single IoT devices/ single RF sources and population of IoT devices as per IEEE Std 1528.7-2020

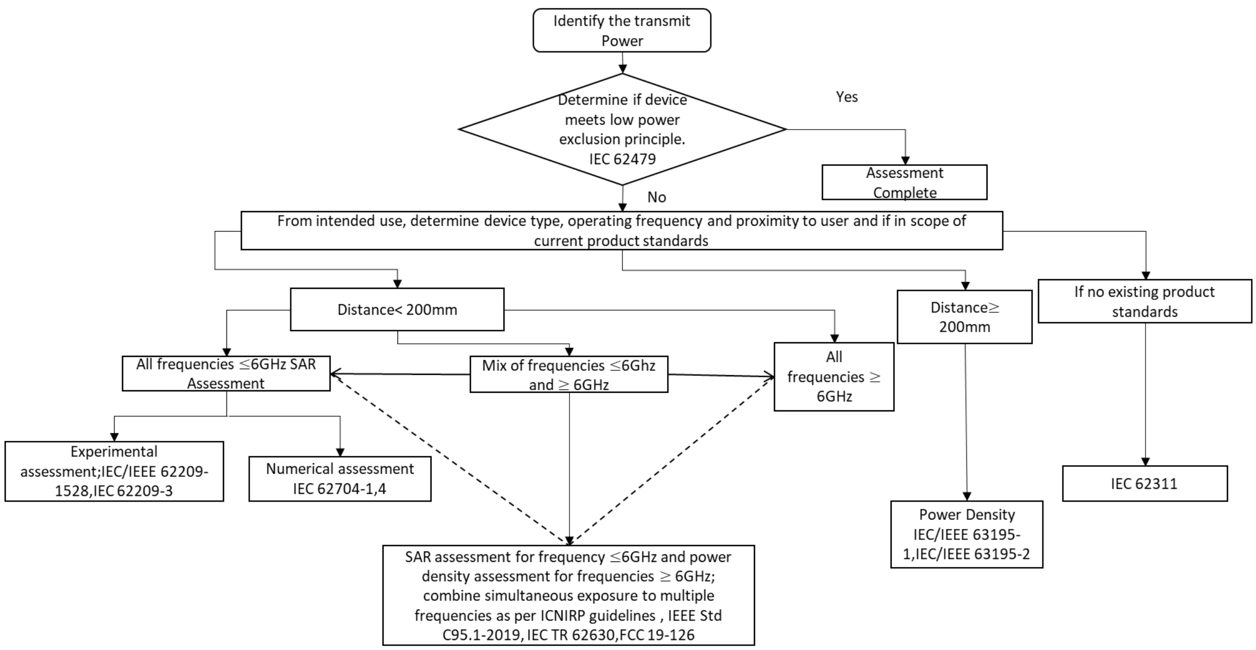

Figure 7:Exposure assessment path for single IoT devices/ single RF sources as per IEEE Std 1528.7-2020

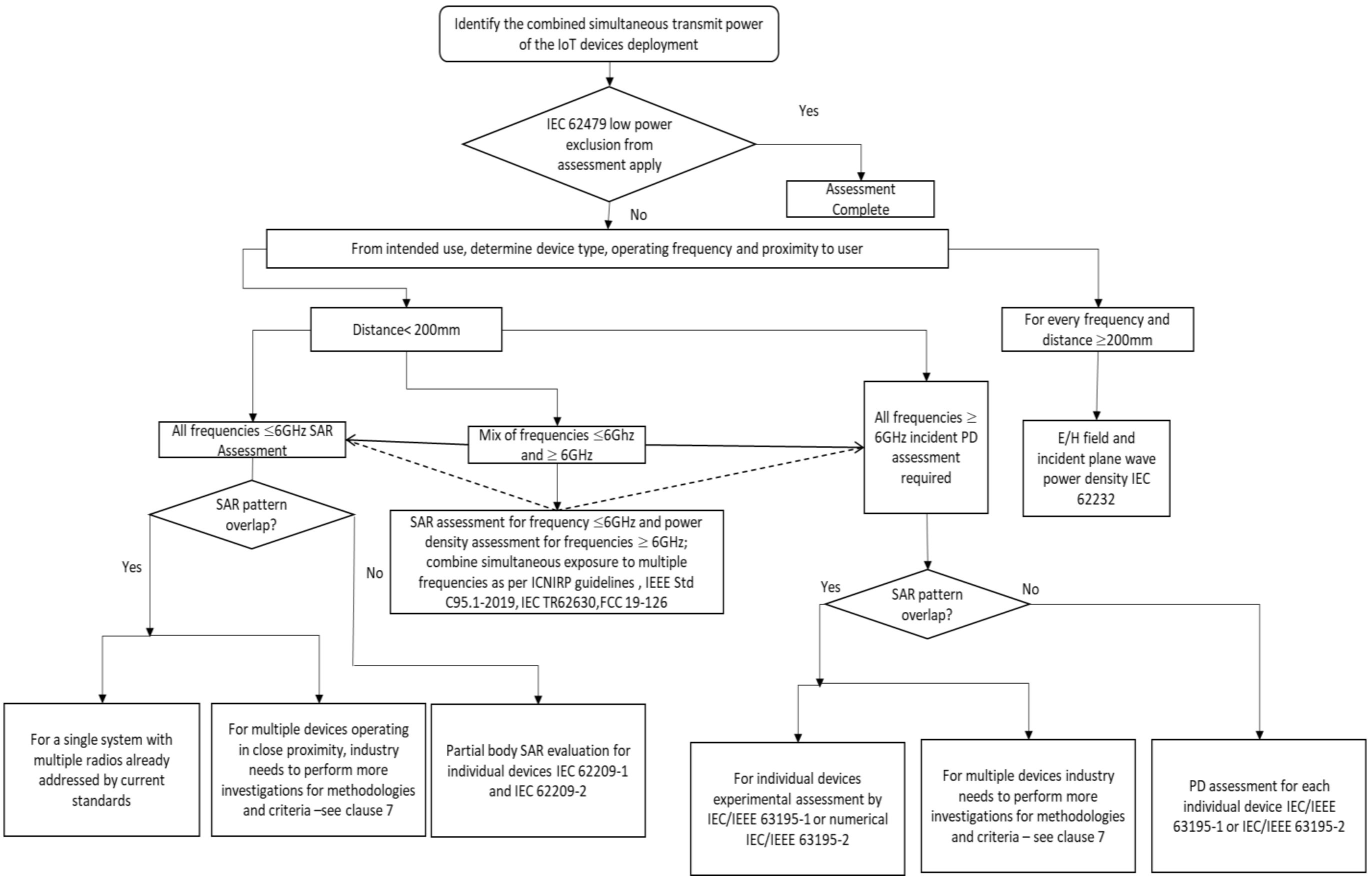

Figure 8:Exposure assessment path for population of IoT devices as per IEEE Std 1528.7-2020

Annexure-9: Derivation of low-power exclusion as per IEC 62479:2010 Standard

Values of P_{max} are derived from EMF exposure limits.

Low-power exclusion level P, based on considerations of SAR

When SAR is the basic restriction, a conservative minimum value for P_{max} can be derived, equal to the localized SAR limit (SAR_{max}) multiplied by the averaging mass (m):

$$P_{max} = SAR_{max} * m \quad \text{(A.5)}$$

Example values of P_{max} according to Equation (A.5) are provided in Table 28 for cases described by the ICNIRP guidelines, IEEE Std C95.1-1999 and IEEE Std C95.1-2005 where SAR limits are defined. Other exposure guidelines or standards may be applicable depending on national regulations.

Guideline / Standard	SAR limit, SAR_{max} (W/kg)	Averaging mass, *m* (g)	P_{max} (mW)	Exposure tier[a]	Region of body[a]
ICNIRP [1]	2	10	20	General public	Head and trunk
	4	10	40	General public	Limbs
	10	10	100	Occupational	Head and trunk
	20	10	200	Occupational	Limbs
IEEE Std C95.1-1999 [2]	1.6	1	1.6	Uncontrolled environment	Head, trunk,arms, legs
	4	10	40	Uncontrolled environment	Hands, wrists, feet and ankles
	8	1	8	Controlled environment	Head, trunk,arms, legs
	20	10	200	Controlled environment	Hands, wrists, feet and ankles
IEEE Std C95.1-2005 [3]	2	10	20	Action Level	Body except extremities and pinnae
	4	10	40	Action Level	Extremities and pinnae
	10	10	100	Controlled environment	Body except extremities and pinnae
	20	10	200	Controlled environment	Extremities and pinnae
[a] Consult the appropriate standard for more information and definitions of terms.					

Table 28: Example values of SAR-based Power for some cases described by ICNIRP, IEEE Std C95.1-1999 and IEEE Std C95.1-2005

P_{max} based on considerations of power density

When power density is the basic restriction, a conservative minimum value for P_{max} can be derived, equal to the power density limit (S) multiplied by the averaging area (a):

$$P_{max} = Sa \qquad \text{(A.6)}$$

For example, ICNIRP guidelines provide power density limits of 10 W/m^2 and 50 W/m^2 over the 10 GHz to 300 GHz frequency range for general public and occupational exposures, respectively. The averaging area specified by ICNIRP is 20 cm^2 for both cases. Therefore, Equation (A.6) yields conservative values for P of 20 mW and 100 mW for general public and occupational exposures, respectively. Other exposure guidelines or standards may be applicable depending on national regulations.

Averaging time for P_{max}

The averaging time for P_{max} is as per the applicable limit in the relevant exposure guidelines or standards.

12. Abbreviations

S.No.	Abbreviation	Full Form
1.	3GPP	3rd Generation Partnership Project
2.	ACMA	Australian Communications and Media Authority
3.	APT	Asia-Pacific Telecommunity
4.	ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
5.	BIS	Bureau of Indian Standards
6.	BS	Base station
7.	CENELEC	European Committee for Electrotechnical Standardization
8.	CW	Continuous-Wave
9.	DoT	Department of Telecommunications
10.	DRL	Dosimetric Reference Limit
11.	EHS	Electromagnetic Hypersensitivity
12.	ELF	Extremely low frequency
13.	EME	Electromagnetic Energy
14.	EMF	Electromagnetic field
15.	ERL	Exposure Reference Level
16.	ERP	Effective Radiated Power
17.	ES	Electrostimulation
18.	FCC	Federal Communications Commission
19.	GSMA	Global System for Mobile Communications – Associations
20.	HF	High Frequency
21.	ICNIRP	International Commission on Non-Ionizing Radiation Protection
22.	IEC	International Electrochemical Commission
23.	IEEE	Institute of Electrical and Electronics Engineers
24.	IoT	Internet of Things
25.	ISED	Innovation Science and Economic Development
26.	ITU	International Telecommunication Union
27.	LPWAN	Low power wide area network
28.	LTE	Long Term Evolution
29.	M2M	Machine- to- Machine
30.	MPE	Maximum Permissible Exposure
31.	NDCP	National Digital Communication Policy
32.	NIR	Non-ionizing radiation
33.	NTC	National Telecommunication and Broadcasting Commission
34.	Ofcom	Office of Communications
35.	PsSAR	Peak spatial-average specific absorption rate
36.	QoS	quality-of-service

37.	RF	Radio Frequency
38.	RF-EMF	Radio-Frequency Electromagnetic Fields
39.	SanPIN	Sanitary and epidemiological rules and regulations
40.	SAR	Specific Absorption Rate
41.	SDOs	Standards developing organisations
42.	SPLSR	SAR to peak location separation ratio
43.	TC	Technical Committee
44.	TEC	Telecommunication Engineering Centre
45.	TRAI	Telecom Regulatory Authority of India
46.	UHF	Ultra high Frequency
47.	VHF	Very high Frequency
48.	WHO	World Health Organization
49.	Wi-Fi	Wireless Fidelity
50.	WLAN	Wireless Local Area Network
51.	WNAN	Wireless Neighborhood Area Network
52.	WPAN	Wireless Personal Area Network
53.	WPT	Wireless power transfer
54.	WWAN	Wireless Wide Area Network

13. Definitions

13.1. Average power (P): The time-averaged rate of energy transfer.
NOTE 1— The SI unit of average power is watt (W).
NOTE 2— Average power is expressed as

$$\bar{P} = \frac{1}{t2 - t1} \int_{t1}^{t2} P(t)dt$$

where $P(t)$ is the instantaneous power. The time duration ($t2 - t1$) could be source related (e.g., the waveform repetition period or duty factor) or use related [e.g., the averaging time associated with the exposure reference level (ERL).

13.2. Average (temporal) power density: The power density in a propagating wave averaged over a specific time duration.
NOTE 1— The SI unit of average (temporal) power density is watt per square meter (W/m2).
NOTE 2— The time duration could be source related (e.g., the waveform repetition period) or use related

13.3. Averaging mass: The mass over which the specific absorption rate is averaged when determining compliance with a dosimetric reference limit (DRL).

13.4. Averaging time (T_{avg}): The appropriate time period over which exposure is averaged for purposes of determining compliance with the appropriate exposure reference level (ERL) or dosimetric reference limit (DRL).

13.5. Averaging volume: The volume over which the specific absorption rate is averaged when determining compliance with a dosimetric reference limit (DRL).

13.6. Biological effect: A biological effect caused by, or in response to, exposure to a biological, chemical, or physical agent, including electromagnetic energy.
NOTE 1— Biological effects are alterations of the structure, metabolism, or functions of a whole organism, its organs, tissues, and cells.
NOTE 2— Biological effects can occur without adverse health effects or even be beneficial; they can also cause harm in the short term (e.g., heating, without long-term consequences).
NOTE 3— Biological effects also can include sensation phenomena and adaptive responses

13.7. Conductivity: A property of materials that determines the magnitude of the electric current density when an electric field is impressed on the material.
NOTE—The SI unit of conductivity is siemens per meter (S/m); the inverse of resistivity.

13.8. Close proximity: A separation distance of 20 cm or less from a device antenna to a bystander or a user.

13.9. Device: An apparatus consisting of single or multiple radio frequency (RF) transmitters (or transceivers).

13.10. Dosimetric reference limit (DRL): The exposure limit based on dosimetric thresholds for established adverse health effects expressed as *in situ* electric field strength (0 Hz to 5 MHz), specific absorption rate (100 kHz to 6 GHz), or epithelial power density (6 GHz to 300 GHz) and which provides an adequate margin of safety.

NOTE 1— DRLs are defined in conjunction with specified spatial and temporal averaging requirements
NOTE 2— DRLs are equivalent to the quantity previously referred to as basic restrictions.

13.11. Dosimetry: The discipline that quantifies the relationship between external exposure quantities and internal dose and dose rate quantities.
NOTE—External exposure quantities include electric field, magnetic field, and electromagnetic field (incident power density); internal quantities include *in situ* electric field, dose, dose rate, specific absorption (SA), specific absorption rate (SAR), and epithelial power density, respectively.

13.12. ERP: Product of the maximum antenna gain and the delivered maximum time-averaged power

13.13. Electrostimulation (ES): Induction of a propagating action potential in excitable tissue by an applied electrical stimulus; electrical polarization of presynaptic processes leading to a change in postsynaptic cell activity.
NOTE—Electrostimulation involves excitation of nerve and/or muscle tissue.

13.14. Epithelial energy density: The energy flow through the epithelium per unit area directly under the body surface (i.e., in stratum corneum of the skin or corneal epithelium of eyes).
NOTE—The SI unit for epithelial energy density is joule per square meter (J/m^2).

13.15. Epithelial power density: The power flow through the epithelium per unit area directly under the body surface (i.e., in stratum corneum of the skin or corneal epithelium of eyes).
NOTE 1— The SI unit for epithelial power density is watt per square meter (W/m^2).
NOTE 2— In this standard, the epithelial power density just inside the body surface is employed to define local dosimetric reference limits at frequencies greater than 6 GHz.

13.16. Exposure: The state of being in the presence of electric, magnetic, or electromagnetic fields, or in contact with a current or voltage source.
Exposure environment: A defined area that is characterized by the maximum potential exposure that could occur within it.
a) **restricted environment:** An environment in which exposure can result in exceeding the

unrestricted environment (lower tier) dosimetric reference limit (DRL).
b) **unrestricted environment:** An environment in which exposure does not result in exceeding the dosimetric reference limit (DRL) that marks the safety program initiation level, and which serves as an exposure limit for the general public.

13.17. Exposure reference level (ERL): The maximum exposure level relative to ambient electric and/or magnetic field strength or power density, induced and/or contact current, or contact voltage.

13.18. Adverse health effect: An effect detrimental to an individual's physical well-being due to exposure to an electric, magnetic, or electromagnetic field or to induced or contact currents or voltages. For purposes of this document, adverse effect is interchangeable with adverse health effect or adverse reaction.

13.19. Current density: The ratio of the flowing current to the cross-sectional area perpendicular to the direction of the current.
NOTE—The SI unit of current density is ampere per square meter (A/m^2).

13.20. Electric field strength (E): Force exerted by an electric field on an electric point charge, divided by the electric charge. NOTE—The SI unit for electric field strength is newton per coulomb or volt per meter (N/C = V/m)

13.21. Electric field: A fundamental component of electromagnetic waves, which exists when there is a potential difference between two points in space.

13.22. Electromagnetic field (EMF): The energy field radiating from a source and containing both electric and magnetic field components.

13.23. General public: People who have no knowledge or control of their exposure and are not permitted in a restricted environment. The unrestricted tier exposure limit applies to the general public.

13.24. Host device: A device that includes one or several radio device(s) of different characteristics, type, and manufacturer that operates as an Internet of Things (IoT) device.

13.25. Incident power density: For purposes of this document, the quantity of power per unit area that impinges on the body surface.
NOTE 1—The SI unit for incident power density is watt per square meter (W/m^2).
NOTE 2—In this document, the incident power density just outside the body surface is employed to define local exposure reference levels at frequencies greater than 6 GHz.

13.26. Induced current: Electric current flowing in the body of a person in a freestanding condition (no skin contact with conductive objects) due to an electromagnetic field.

13.27. In situ: For purposes of this document, in situ means within a biological tissue in its normal anatomical position

13.28. Local exposure: An exposure condition in which a limited portion of the body is subject to most of the incident energy and is usually the result of:
1) the source being located very close to the body, or
2) a highly concentrated region of energy associated with contact with an energized conductor exposed to environmental fields.

13.29. Multiple sources: Several radio frequency (RF) transmissions operating at the same or different frequencies that can be emitted from a single or multiple device's.

13.30. Magnetic field: A fundamental component of electromagnetic waves produced by a moving electric charge.

13.31. Magnetic field strength (H): The magnitude of the magnetic field vector.

13.32. Maximum Permissible Exposure (MPE): Refers to the limits to ensure that the public and workers are not exposed to excessive levels of radiofrequency (RF) electromagnetic fields emitted by wireless devices and equipment.

13.32. Plane-wave-equivalent power density (S_E, S_H): The calculated power density of an electromagnetic wave that is equal in magnitude to the power density of a plane wave having the same electric (E) or magnetic (H) field strength.
NOTE 1—The SI unit of plane-wave-equivalent power density is watt per square meter (W/m2).
NOTE 2—Plane-wave-equivalent power density is computed as follows:

$$S_E = \frac{|E|^2}{\eta_0} \text{ W/m}^2 \quad \text{or} \quad S_H = \eta_0 |H|^2 \text{ W/m}^2$$

where |E| and |H| are the root mean square (rms) values of the electric field strengths and magnetic field strengths, respectively, and η0 is the wave impedance of a plane wave in a vacuum ($\eta_0 \approx 377\ \Omega$).

13.33. Power density (S): Electromagnetic power per unit area crossing a surface of interest. See also: plane-wave equivalent power density.
NOTE 1—The SI unit of power density is watt per square meter (W/m2).
NOTE 2—For an arbitrary time-dependent signal waveform, the instantaneous power density point value is

St t(t) = E (t) ×H (t). nˆ

where nˆ is the unit-vector normal to the surface of interest, E (t) is the instantaneous electric

13.34. Radio frequency (RF): A frequency that is useful for radio transmission, generally considered frequencies between approximately 3 kHz and 300 GHz.

13.35. Thermal effects: Changes associated with heating of the whole body or an affected region sufficient to induce a biological effect.

NOTE—Established adverse health effects are associated with whole-body heating at levels that usually increase core temperature by approximately 1 °C or more.

13.36. Threshold: The level of a stimulus marking the boundary between a response and a nonresponse.

13.37. Whole-body exposure: The case in which the projected area of the entire body is exposed to the incident

14. List of meetings

S.No.	Date of Conference Call
1.	20th September 2022
2.	21st October 2022
3.	24th November 2022
4.	22nd December 2022
5.	14th February 2023
6.	06th March 2023
7.	16th March 2023
8.	21st March 2023
9.	29th March 2023
10.	18th May 2023

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