भारतीय दूरसंचार विनियामक प्राधिकरण

Telecom Regulatory Authority of India

Recommendations on the Tera Hertz Spectrum

New Delhi, India

21st August, 2024

World Trade Center, Tower-F, Nauroji Nagar, New Delhi -110029

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Chapter-I: Introduction and Background

A. Tera Hertz Band

1.1 Ever since Guglielmo Marconi invented radio telegraphy, technologies that use radio spectrum have drastically altered our everyday lives, as well as society as a whole. The radio spectrum, commonly referred to as "spectrum", refers to the part of the electromagnetic frequencies spanning from 3 Hz to the 3,000 GHz range. The lower frequencies can travel long distances but may be less suitable for providing high-capacity services. Higher frequencies are more suitable for carrying large amounts of data but only over relatively short distances. Frequencies in the middle are suitable for providing sufficiently high-capacity services, such as mobile, over a reasonable distance. These middle-range frequencies – typically between 300 MHz to 6 GHz, are particularly suitable for the provision of wireless communication services[1].

1.2 Spectrum is the lifeblood of all wireless connectivity. Without spectrum there can be no mobile phone networks; no broadcasting; no Wi-Fi; no smart homes or smart cities; no satellites; no remote sensing; and much more. As a result, the demand for spectrum continues to grow, in line with rapid technological progress, consumer demand, and digitisation across different industry sectors. In many countries, what is referred to as the "prime spectrum range" has already been assigned to users, and demand often exceeds supply. To help avoid access to spectrum becoming a bottleneck to innovation and growth, it is important to take full advantage of the frequency bands, hitherto unused.

1.3 Once dubbed 'tremendously high frequency', Tera Hertz[2] band pushes the upper boundary of the usable spectrum well beyond the range currently used

[1] Source: https://www.oecd-ilibrary.org/docserver/175e7ce5-en.pdf?expires=1719036594&id=id&accname=guest&checksum=2F6F71CADB264D0C44B590845CB92958

[2] 1 Tera Hertz = 10^{12} Hertz = 1,000 GHz

by devices like mobile phones and Wi-Fi[3]. Tera Hertz band is, generally, identified as lying between 100 GHz and 3 THz (3,000 GHz). A large amount of spectrum available in the Tera Hertz band holds the potential to provide extremely wide bandwidths for any given service. The following figure depicts the position of Tera Hertz band in the radio spectrum:

Figure 1.1: Position of Tera Hertz band in the radio spectrum[4]

1.4 It is easy to produce effective radiations with the help of oscillating circuits made of high-speed transistors at lower microwave frequencies. On the other hand, it is easy to produce effective radiations with semiconductor lasers at higher frequencies of the visible spectrum[5]. Conventionally, electronics (transistors and other electronic devices) have an upper limit of about 300 GHz while photonics (semiconductor lasers and light emitting diodes) have a lower limit of about 30 THz. In the Tera Hertz band, practical technologies for generating and detecting radiation for a long time did not exist. Traditionally, the Tera Hertz band seemed to be "too high" for the electronics community and "too low" for the photonics engineering. For this reason, the Tera Hertz band was also referred to as the Tera Hertz gap. The following figure depicts the Tera Hertz gap.

[3] Wi-Fi is a wireless networking technology that uses radio waves to provide wireless high-speed Internet access. Wi-Fi is a trademarked phrase that refers to IEEE 802.11x standards. Source: https://watech.wa.gov/wifi-definition-and-meaning#:~:text=Wi%2DFi%20is%20a%20wireless,to%20IEEE%20802.11x%20standards.

[4] Source: https://www.ofcom.org.uk/spectrum/innovative-use-of-spectrum/terahertz/

[5] The visible spectrum has the frequency range between 400 THz to 800 THz.

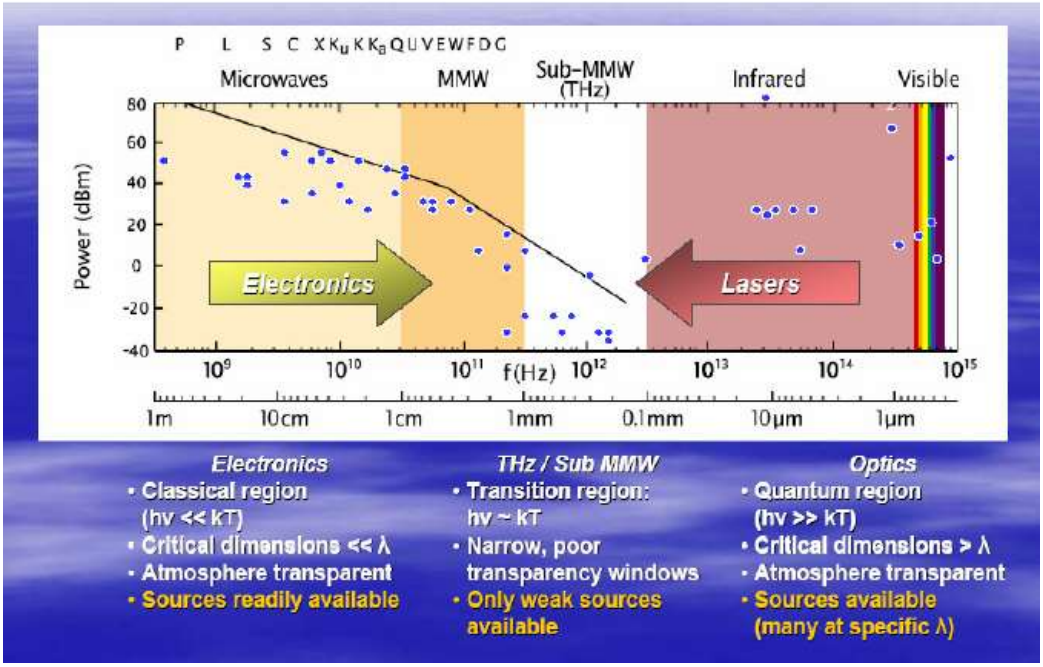


Figure 1.2: Terahertz gap[6]

1.5 Today, efficient Tera Hertz systems are no longer far-fetched due to the advancements in optical, electronic, and plasmonic transceiver design. Institute of Electrical and Electronics Engineers (IEEE), in its article named 'Next Generation Terahertz Communications: A Rendezvous of Sensing, Imaging, and Localization (December 2020)'[7] has presented a progressive vision of how the traditional "Tera Hertz gap" will transform into a "Tera Hertz rush" over the next few years.

1.6 Unlike mmWave communications, Tera Hertz communications can leverage the large available bandwidths in the Tera Hertz band to achieve a terabit per second (Tbps) data rate without additional spectral efficiency enhancement techniques. Due to their shorter wavelengths, Tera Hertz communication systems can support higher link directionality, are less susceptible to free-space diffraction and inter-antenna interference, can be realized in much smaller footprints, and possess a higher resilience to eavesdropping. Furthermore, the

[6] Source: https://www.researchgate.net/figure/Illustration-of-the-THz-gap_fig1_234944264
[7] Source: https://ieeexplore.ieee.org/document/9112745

Tera Hertz band promises to support higher user densities, higher reliability, less latency, more energy efficiency, higher positioning accuracy, better spectrum utilization, and increased adaptability to propagation scenarios. However, many challenges need to be addressed for the widespread adoption of Tera Hertz communications. For instance, the high propagation losses and power limitations of the Tera Hertz band result in very short communication distances. Besides, frequency dependent molecular absorptions result in band-splitting and bandwidth reduction.[8]

1.7 Until now, the practical use of the Tera Hertz spectrum has been mainly for taking scientific measurements of the Earth from satellites. Such applications include the use of passive sensors to receive and measure natural emissions produced by the Earth's surface and its atmosphere. The knowledge of such emissions helps us to monitor weather and climate change[9]. Tera Hertz signals have also begun to be used for wireless sensing and imaging in applications such as quality control, food safety, and security. Several Tera Hertz-wave propagation properties, which microwave and infrared waves lack, make the Tera Hertz signal a good candidate for material and gas sensing. Tera Hertz signals can penetrate a variety of non-conducting, amorphous, and dielectric materials, such as glass, plastic, and wood. Moreover, metals strongly reflect the Tera Hertz radiation, which enables detecting weapons. Tera Hertz signals can be used for the gas detection and to observe water dynamics. Tera Hertz localization is another potential use case. It is expected that the Tera Hertz frequencies will provide centimetre-level accuracy that conventional GPS and cell multilateration-based localization techniques fail to provide.

1.8 The high-speed point-to-point wireless data link is an emerging usage of Tera Hertz radiation. For this reason, communications in the Tera Hertz band are expected to play a pivotal role in the upcoming 6th generation (6G) of wireless mobile communications, enabling ultra-high bandwidth communication

[8] Source: https://ieeexplore.ieee.org/document/9112745
[9] Source: https://www.ofcom.org.uk/spectrum/innovative-use-of-spectrum/terahertz/

paradigms. The large Tera Hertz bandwidths and massive antenna arrays, combined with the inherent densification caused by machine-type communications, will result in an enhanced communication system performance.[10]

1.9 Ofcom in its paper on 'Unlocking the potential of Terahertz radio spectrum: The role of spectrum management' (December 2021)[11] has identified potential usages of the Tera Hertz spectrum as below:

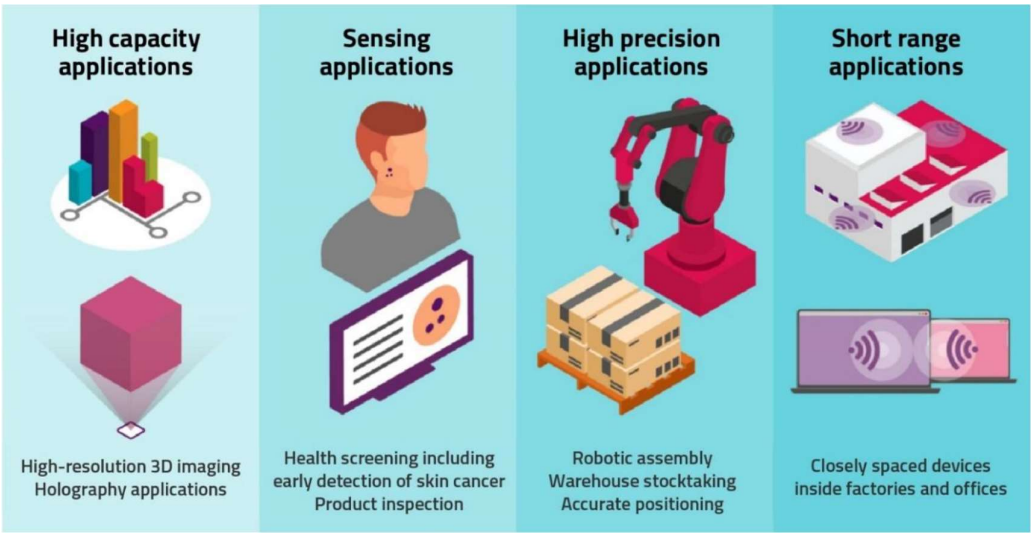


Figure 1.3: Potential usages of the Tera Hertz spectrum

1.10 IEEE in its article named 'Next Generation Terahertz Communications: A Rendezvous of Sensing, Imaging, and Localization (December 2020)'[12] has illustrated the specific services that the Tera Hertz spectrum might support in future through the following figure:

[10] Source: https://ieeexplore.ieee.org/document/9112745
[11] Source: https://www.ofcom.org.uk/siteassets/resources/documents/spectrum/spectrum-management/terahertz-spectrum-paper.pdf
[12] Source: https://ieeexplore.ieee.org/document/9112745

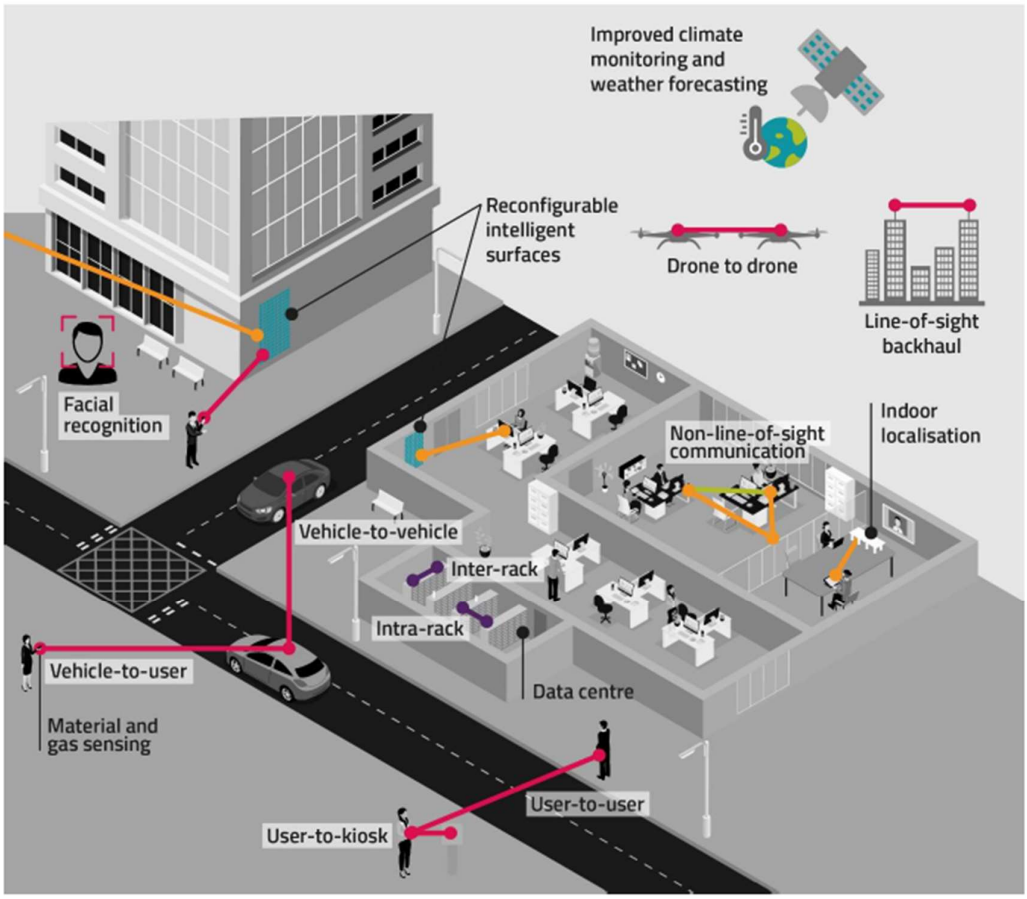


Figure 1.4: Prospective applications of Tera Hertz communications

1.11 In a paper titled 'Seven Defining Features of Terahertz (THz) Wireless Systems: A Fellowship of Communication and Sensing' (September 2021), Christina Chaccour, et al, envisioned the seven defining features and four potential use cases of the future Tera Hertz-based wireless systems as below:

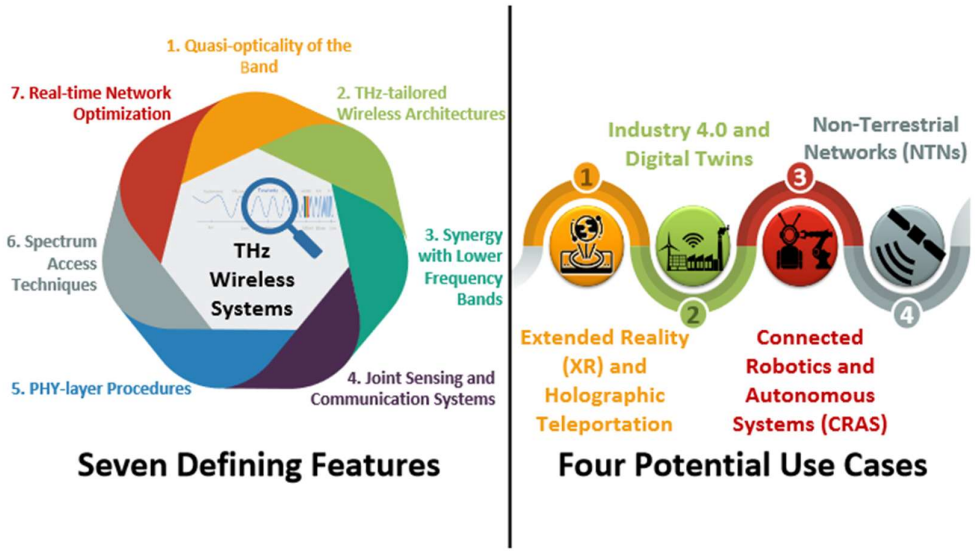


Figure 1.5: Illustrative figure showcasing the seven unique defining features of wireless THz systems and their key use cases[13]

B. The DoT's Reference Dated 08.12.2022

1.12 Through a reference dated 08.12.2022 (enclosed as **Annexure-I**), the Department of Telecommunications (DoT), Ministry of Communication, Government of India requested the Telecom Regulatory Authority of India (hereinafter also referred to as, "TRAI" or "the Authority") to provide recommendations under Section 11(1)(a) of TRAI Act, 1997 (as amended) on 'Open and De-Licensed use of Unused or Limited Used Spectrum Bands for Demand Generation for Limited Period in Tera Hertz Range'. The DoT's reference dated 08.12.2022 is reproduced below:

"In various parts of the world, administrations, with a view to encourage technology development, have come up with regulations allowing conduct of experiments in the spectrum bands beyond 95 GHz. Accordingly, it has been decided to encourage the development of new communications technologies and new services in the country in the spectrum ranges above 95 GHz.

[13] Source: http://arxiv.org/pdf/2102.07668

2. In view of the above, a Committee was constituted under the Chairmanship of Wireless Adviser to give its recommendations on the issue. The Committee has submitted its report (copy enclosed for ready reference). The summary of recommendations of the Committee is given below:

a. The spectrum beyond 95 GHz and upto 3 THz may be opened for experiments under 'Spectrum-Terahertz Applications License'. There shall not be any restriction on technical condition for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services.

b. The frequency bands, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz may be opened for unlicensed use. Initially FCC's Technical specifications may be adopted. After study in Indian environment, technical parameters may be revised.

c. The frequency band 77-81 GHz band may also be delicensed for automotive radar applications in line with international practice.

3. However, with a view to come up with a well-rounded regulatory regime on the subject matter, it was considered appropriate to seek TRAI recommendation as well. Therefore, under the terms of clause 11 (1)(a) of TRAI Act, 1997 as amended by TRAI Amendment Act 2000, TRAI is requested to provide recommendations on the following:

(a) Terms and Conditions for opening of spectrum beyond 95 GHz and upto 3 THz for experiments under a regime which may be named as 'Spectrum-Terahertz Applications License' for Experiment' and 'Demonstration' of equipment designed to operate on any frequency above 95 GHz while protecting any "Passive" services in these frequency ranges. The licensees may also be permitted to market such experimental devices via direct sale. The regime may be opened for a defined period.

(b) Terms and conditions including technical parameters for permitting licensed-exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges, while protecting both passive and active services in and around these frequency ranges

(c) Terms and conditions including technical parameters for permitting licensed-exempt operations in 77-81 GHz band for automotive radar applications in line with international practice.

(d) Any other techno-regulatory recommendations relevant to the issue."

1.13 Hereinafter, in this document, the afore-mentioned reference will be referred to as "the DoT's reference dated 08.12.2022".

1.14 The DoT's reference dated 08.12.2022 read with its annexure suggests that a committee comprising officers from the DoT and academia was constituted with a term of reference *"[to] give its recommendations for Open and De-license unused or limited used spectrum bands for demand generation for limited period including THz band".* The committee (hereinafter referred to as "the DoT's Committee on Tera Hertz Spectrum") submitted its report to the DoT in September 2022. In its report, the DoT's Committee on Tera Hertz Spectrum studied the characteristics of Tera Hertz spectrum, the allocation of Tera Hertz spectrum in the ITU Radio Regulations, the questions being studied at ITU in respect of Tera Hertz spectrum, and international practices on Tera Hertz spectrum, and provided its recommendations on the matter.

C. The TRAI's Consultation Paper Dated 27.09.2023

1.15 In this background, the Authority, on 27.09.2023, issued a Consultation Paper on 'Open and De-Licensed use of Unused or Limited Used Spectrum Bands for Demand Generation for Limited Period in Tera Hertz Range' (hereinafter referred to as "the Consultation Paper dated 27.09.2023")[14]. Written comments of stakeholders on the Consultation Paper dated 27.09.2023 were invited from stakeholders by 25.10.2023 and counter-comments by 08.11.2023. Upon request of some stakeholders, the last dates for furnishing comments and

[14] The Consultation Paper dated 27.09.2023 is available at the following URL: https://www.trai.gov.in/sites/default/files/CP_27092023.pdf

counter-comments were extended to 15.11.2023 and 29.11.2023 respectively. Upon a further request from a few stakeholders for extension in timelines, the last dates for furnishing comments and counter-comments were extended to 29.11.2023 and 13.12.2023 respectively. The Authority received written comments from 17 stakeholders and counter-comments from two stakeholders. The comments and counter-comments received from stakeholders were placed on the TRAI's website[15]. An online Open House Discussion (OHD) on the Consultation Paper dated 27.09.2023 was held on 08.03.2024 with stakeholders. Based on the comments and counter-comments received from stakeholders during the consultation process, and further analysis, the Authority has arrived at the present recommendations.

1.16 The present recommendations comprise of three chapters. Chapter-I provides an introduction and background of the subject. Chapter-II presents an analysis of the issues raised in the Consultation Paper dated 27.09.2023. Chapter-III provides a summary of the recommendations on the subject.

[15] The comments and counter comments on the Consultation Paper dated 27.09.2023 are available at the following URL: https://trai.gov.in/consultation-paper-open-and-de-licensed-use-unused-or-limited-used-spectrum-bands-demand-generation

Chapter-II: Analysis of Issues

2.1 This chapter peruses the relevant provisions of the Telecommunications Act, 2023, and the National Frequency Allocation Plan-2022, before presenting an analysis of the issues raised in the Consultation Paper dated 27.09.2023.

A. The Telecommunications Act, 2023

2.2 Prior to the enactment of the Telecommunications Act, 2023, the Central Government administered telecommunications broadly through the Indian Telegraph Act, 1885, and the Indian Wireless Telegraphy Act, 1933[16]. In December 2023, the Indian Parliament enacted a new statute namely, the Telecommunication Act, 2023[17]. The Act amends and consolidates the law relating to development, expansion and operation of telecommunication services and telecommunication networks, assignment of spectrum, and for matters connected therewith or incidental thereto[18].

2.3 The Section 3 of the Telecommunications Act, 2023 grants the power of authorisation to the Central Government. The sub-sections 1 to 4 of section 3 of the Act are reproduced below:

"3(1) Any person intending to —

(a) provide telecommunication services;

(b) establish, operate, maintain or expand telecommunication network; or

(c) possess radio equipment,

[16] Hitherto, the Indian Telegraph Act, 1885 was the main legislation dealing with the establishment, maintenance and working of telegraphs in the country. It provided the Central Government an exclusive privilege of establishing, maintaining, and working telegraphs in India, and a power to grant a license, on such conditions and in consideration of such payments as it thinks fit, to any person to establish, maintain or work a telegraph within any part of India. The Indian Wireless Telegraphy Act, 1933 regulated the possession of wireless telegraphy apparatus in the country. Section 3 of the Wireless Telegraphy Act, 1933 prohibited the possession without licence of wireless telegraphy apparatus.
Apart from these two statutes namely, the Indian Telegraph Act, 1885 and the Indian Wireless Telegraphy Act, 1933, Parliament enacted the Telecom Regulatory Authority of India Act, 1997. Through this Act (as amended), TRAI and Telecom Disputes Settlement and Appellate Tribunal (TDSAT) have been established - TRAI for regulating the telecommunication services, and TDSAT for adjudicating disputes and dispose of appeals.

[17] The Telecommunications Act, 2023 is available at the following URL:
https://dot.gov.in/sites/default/files/Telecommunications%20Act%202023_1.pdf?download=1

[18] Section 60(1) of the Telecommunications Act, 2023 provides that *"[s]ubject to the other provisions of this section, the enactments namely, the Indian Telegraph Act, 1885 and the Indian Wireless Telegraphy Act, 1933, are hereby repealed.*

shall obtain an authorisation from the Central Government, subject to such terms and conditions, including fees or charges, as may be prescribed.

(2) The Central Government may while making rules under sub-section (1) provide for different terms and conditions of authorisation for different types of telecommunication services, telecommunication network or radio equipment.

(3) The Central Government, if it determines that it is necessary in the public interest so to do, may provide exemption from the requirement of authorisation under sub-section (1), in such manner as may be prescribed.

(4) Any exemption granted prior to the appointed day under the Indian Telegraph Act, 1885 or the Indian Wireless Telegraphy Act, 1933 shall continue under this Act, unless otherwise notified by the Central Government."

2.4 The section 4 of the Telecommunications Act, 2023 grants the power of assignment of spectrum to the Central Government. The relevant sub-sections of section 4 are reproduced below:

"4. (1) The Central Government, being the owner of the spectrum[19] on behalf of the people, shall assign the spectrum in accordance with this Act, and may notify a National Frequency Allocation Plan from time to time.

(2) Any person intending to use spectrum shall require an assignment from the Central Government.

(3) The Central Government may prescribe such terms and conditions as may be applicable, for such assignment of spectrum, including the frequency range, methodology for pricing, price, fees and charges, payment mechanism, duration and procedure for the same.

(4) The Central Government shall assign spectrum for telecommunication through auction except for entries listed in the First Schedule for which assignment shall be done by administrative process.

Explanation.—For the purposes of this sub-section,— (a) "administrative process" means assignment of spectrum without holding an auction; (b) "auction" means a bid process for assignment of spectrum."

[19] Section 2 (o) and 2(m) of the Telecommunications Act, 2023 define the term "spectrum" and "radio waves" as below:
(o) "spectrum" means the range of frequencies of Hertzian or radio waves;
(m) "radio waves" means electromagnetic waves of frequencies propagated in space without any artificial guide;

…

(6) The Central Government, if it determines that it is necessary in the public interest so to do, may exempt,— (a) from the requirement of assignment under sub-section (2), in such manner as may be prescribed; and (b) by notification, specific usages within specified frequencies and parameters, from the requirements of sub-section (2).

(7) Any exemption with respect to use of spectrum granted under the Indian Telegraph Act, 1885 and the Indian Wireless Telegraphy Act, 1933 prior to the appointed day, shall continue under this Act, unless otherwise notified by the Central Government."

2.5 The First Schedule of the Telecommunications Act, 2023 deals with the 'assignment of spectrum through administrative process'. The 19th entry of the First Schedule is reproduced below:

"19. Testing, trial, experimental, demonstration purposes for enabling implementation of new technologies, including for creation of one or more Regulatory Sandboxes[20]."

2.6 For the purpose of the issues at hand, the provisions of the Telecommunications Act, 2023 are summarized below:

(a) Unless the Central Government has exempted from the requirement of authorisation, any person intending - (i) to provide telecommunication services, (ii) to establish, operate, maintain, or expand telecommunication network; and (iii) to possess radio equipment, will require an authorisation from the Central Government.

(b) Unless the Central Government has exempted from the requirement of assignment, any person intending to use spectrum will require an assignment from the Central Government.

[20] The explanation under Section 27 of the Telecommunications Act, 2023 provides a definition of the expression "regulatory sandbox". Section 27 is reproduced below:

"27. The Central Government may, for the purposes of encouraging and facilitating innovation and technological development in telecommunication, create one or more regulatory sandboxes, in such manner, and for such duration, as may be prescribed. Explanation.—For the purposes of this section, the expression "regulatory sandbox" refers to a live testing environment where new products, services, processes and business models which may be deployed, on a limited set of users, for a specified period of time, with certain relaxations from the provisions of this Act."

(c) The Central Government shall assign spectrum for testing, trial, experimental, demonstration purposes for enabling implementation of new technologies, including for creation of one or more Regulatory Sandboxes by administrative process.

B. The NFAP-2022

2.7 The sub-section (1) of section 4 of the Telecommunications Act, 2023 provides, *inter-alia*, that *"[t]he Central Government …may notify a National Frequency Allocation Plan*[21] *from time to time.* At present, the Central Government governs the use of spectrum through the National Frequency allocation Plan (NFAP)-2022. The NFAP-2022[22] provides a broad regulatory framework, identifying which frequency bands are available for cellular mobile service, Wi-fi, sound and television broadcasting, radionavigation for aircrafts and ships, defence and security communications, disaster relief and emergency communications, satellite communications and satellite-broadcasting, amateur service etc. The Radio Regulations, an international treaty signed by India and other Member States of the International Telecommunication Union (ITU)[23], governs the use of radio-frequency spectrum and satellite orbits at the global level. The radio Regulations (Edition of 2020) is the foundational text used for drawing up the NFAP-2022. The central theme of the NFAP-2022 is the allocation[24] of radio frequency spectrum to different radiocommunication services in India. The NFAP-2022, though governing the use of spectrum in India, does not by itself provide the right to use the spectrum. Before any part of the spectrum is put to use in India, an assignment is required from the Government, unless such a

[21] Section 2(h) of the Telecommunications Act, 2023 define the term " National Frequency Allocation Plan" as below:
(h) "National Frequency Allocation Plan" means guidelines issued from time to time by the Central Government for the use of the spectrum;
[22] Source: https://dot.gov.in/sites/default/files/NFAP%202022%20Document%20for%20e-release.pdf?download=1
[23] The ITU is the United Nations specialized agency for information and communication technologies (ICTs). ITU promotes the shared global use of the radio spectrum, facilitates international cooperation in assigning satellite orbits, assists in developing and coordinating worldwide technical standards, and works to improve telecommunication infrastructure in the developing world. The ITU Radio Regulations (also referred to as "ITU-RR" or "Radio Regulations") is a basic document of the ITU that regulates the utilization of radio frequencies. The ITU-RR regulates the part of the allocated radio frequency spectrum from 8.3 KHz to 275 GHz. There is no allocation beyond 275 GHz in the ITU-RR.
[24] Clause 2.13 of the NFAP-2022 provides a definition of allocation (of a frequency band) as below:
"allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy services under specified conditions. This term shall also be applied to the frequency band concerned."

requirement is exempted by the Government. The Annexure-1 of the NFAP-2022 provides a list of frequency bands which have been exempted from licensing for specific usages within specified parameters.

2.8 In line with the ITU Radio Regulations, the NFAP-2022 regulates the use of radio frequency spectrum from 8.3 KHz to 275 GHz in India. As per the NFAP-2022, the spectrum beyond 95 GHz is allocated largely to Radio Astronomy Service (RAS) and satellite based services such as Earth Exploration Satellite Service (EESS), Space Research Service (SRS), Amateur Satellite Service, Radio Navigation Satellite Service and Mobile Satellite Service etc. on primary[25] basis. There is no allocation beyond 275 GHz in the NFAP-2022. Besides Satellite and Radio Astronomy, allocation has also been made in the NFAP-2022 for Fixed Service and Mobile Service on primary basis in 12 frequency bands with about 102 GHz spectrum between 95 GHz to 275 GHz, which accounts for about 57% of the total frequency spectrum available between 95 GHz to 275 GHz. The percentage of allocation of frequency spectrum in the 95-275 GHz frequency range to different services is given in the following table:

Table 2.1: Allocation of frequency spectrum to different services in the 95-275 GHz frequency range in the NFAP-2022

S. No.	Service	Allocated Bandwidth (in GHz)*	Percent Allocation
1	Fixed	102.2	56.78%
2	Mobile	102.2	56.78%
3	Earth Exploration Satellite	58.8	32.67%
4	Space Research	70.75	39.31%
5	Inter Satellite	35.23	19.57%

[25] Clause 1.8 of the NFAP-2022 provides that "[*w]here a frequency band is allocated to more than one radiocommunication service, each service using the band is categorised either as a "primary" service or a "secondary" service. A station in a secondary service can't cause harmful interference to stations of primary services, nor can it claim protection from harmful interference originating from stations of primary services, irrespective of the date the stations in the primary services begin operating."*

S. No.	Service	Allocated Bandwidth (in GHz)*	Percent Allocation
6	Fixed Satellite	35	19.44%
7	Mobile Satellite	33.71	18.73%
8	Amateur	4.01	2.23%
9	Amateur Satellite	4.01	2.23%
10	Radio Astronomy	112.8	62.67%
11	Radiolocation	26.51	14.73%
12	Radionavigation	35.21	19.56%
13	Radionavigation Satellite	35.21	19.56%

* More than one services share the same band.

2.9 Though there is no allocation of spectrum beyond 275 GHz in the ITU-RR/ NFAP-2022, there are two footnotes in the ITU-RR/ NFAP-2022 viz. Footnote 5.564A and Footnote 5.565 in respect of the spectrum in the 275-3,000 GHz frequency range. The Footnote 5.564A identifies frequency bands for fixed and land mobile service applications in the 275-450 GHz frequency range. The Footnote 5.565 identifies frequency bands for RAS, EESS (passive) and SRS (passive) in the frequency range 275-1,000 GHz; it provides for the coexistence of passive services like RAS, EESS (passive) and SRS (passive) with active services in the frequency range 275-1,000 GHz. Studies are also being carried out in ITU- Radiocommunication (ITU-R) sector on certain aspects related to the Tera Hertz band. A brief description of the Footnote 5.564A and Footnote 5.565 of the ITU-RR/ NFAP-2022 and the questions being studied in ITU-R related to the Tera Hertz spectrum is given in the **Annexure-II**.

C. Analysis on the issues raised in the Consultation Paper dated 27.09.2023

2.10 Through the Consultation Paper dated 27.09.2023, the Authority solicited comments of stakeholders on broadly the following issues:

(a) Separate experimental license for the spectrum in 95 GHz to 3 THz range;

(b) License-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges; and

(c) License-exempt operations in the 77-81 GHz band for automotive radar applications.

2.11 An analysis of these issues, considering the comments received from stakeholders in the consultation process, is being presented below.

(1) Separate Experimental License for the Spectrum in 95 GHz to 3 THz range

2.12 In its report, the DoT's Committee on Tera Hertz Spectrum stated as below:

"4.1.1 Considering the requirements of emerging new radiocommunications technologies, to promote R&D activities, indoor/ outdoor testing/ experimentation in the field of wireless radiocommunications and also to promote Make in India in wireless products, and international practices, the committee recommends that a new experimental radio license category 'Spectrum-Terahertz Applications License (STAL)' may be created that will be applicable for 'Experiment' and 'Demonstration' of equipment designed to operate exclusively on any frequency above 95 GHz.

4.1.2 As per available frequency assignment, there are very few assignments above 95 GHz. The spectrum beyond 95 GHz is considered to be vacant, therefore, spectrum beyond 95 GHz and upto 3 THz may be opened for experiments under 'Spectrum-Terahertz Applications License'.

4.1.3 It is anticipated this new License will make experimentation more attractive, resulting in a greater number of thoughtful and innovative experiments. Such experiments are vital for the development of new applications and services suited for the unique properties of the bands above 95 GHz. It would promote a more rapid development of new products and services that will reach a larger number and wider variety of users than would be possible under the existing experimental licensing rules.

4.1.4 Any Indian National or any Indian Entity (Academic institutes, R&D Labs, Central/ State Governments or their PSUs, UTs, Technology parks, TSPs, incubators, industry partners, OEMs etc.) may be allowed. The other eligibility criteria may be kept similar to the existing experimental license to encourage wider participation.

4.1.5 There shall not be any restriction on technical conditions for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services.

4.1.6 No exclusive assignment should be given under 'STAL'. The assignment will be given on 'Non-interference basis and Non-protection basis' (NIB/ NPB). The operations under the license would also not claim any protection from allocated services or incumbent users.

4.1.7 The License may be given initially for five years and further extendable for periods of five years at a time with an interim report to be submitted at the time of each renewal for an experiment considering research/ innovation is a time taking process and short duration license would not give desired result.

4.1.8 The applicant may submit details of experiment to be undertaken along with possible outcomes and interference mitigation techniques that may be required to protect the existing users.

4.1.9 There should not be any restriction on geographical areas for STAL. The user may be allowed to request operations over any area, except restricted areas, that they deem appropriate for their experiment.

4.1.10 The spectrum assignment is subject to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use will entail termination/ modification/ relocation of any test or experimentation being

carried out in the said spectrum band. In the event, user will be offered alternative spectrum band. If alternative spectrum band is not feasible, the user will be allowed to continue experiment till the completion of license period in coordination with the licensed assignees.

4.1.11 The licensees will be permitted to market experimental devices designed to operate in the bands above 95 GHz via direct sale. The characteristics of signals in the bands above 95 GHz effectively limit the range of each device to such an extent that a larger number of devices can operate without increasing the potential of harmful interference to authorized services. However, the licensees shall ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial. Additionally, each device sold under this program must be labeled as "Authorized Under STAL and may be subject to further conditions including Termination of Operation" and carry with it a licensee assigned equipment ID number to be issued by WPC, DoT. Licensees who take advantage of these marketing provisions must uniquely identify each device (e.g., through a serial number) in a manner that will enable them to easily track each one. Finally, at the time of sale, the licensee is required to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the licensee or the licensor, and the device will be surrendered or rendered inoperable at the conclusion of the experiment.

4.1.12 Government may prescribe any test/ measurement etc. from health safety/ environment safety/ EMI/ EMC etc. as per international practice, if case application wants to market experimental devices.

4.1.13 The Committee recommends that applicant will have to pay Rs.1000/- towards spectrum charges for 5 years."

2.13 The Government considered the above recommendation of the DoT's Committee on Tera Hertz Spectrum. However, with a view to come up with a well-rounded regulatory regime on the subject matter, the Government requested TRAI to provide recommendations, *inter-alia*, on the following topic:

"Terms and Conditions for opening of spectrum beyond 95 GHz and upto 3 THz for experiments under a regime which may be named as 'Spectrum Terahertz Application License' for 'Experiment' and 'Demonstration' of equipment designed to operate on any frequency above 95 GHz while protecting any "passive" services in these frequency ranges. The licensees may also be permitted to market such experimental devices via direct sale. The regime may be opened for a defined period."

2.14 In this background, through the Consultation Paper dated 27.09.2023, the Authority solicited comments of stakeholders on the following questions:

Q6. Whether there is a need to open the frequency spectrum between 95 GHz to 3 THz for experiment and demonstration of equipment designed to operate on any frequency above 95 GHz through a separate experimental license? Please provide a detailed response with justification.

Q7. In case it is decided to open the frequency spectrum between 95 GHz to 3 THz for experiment and demonstration of equipment designed to operate on any frequency above 95 GHz through a separate experimental license -

(a) what should be the terms and conditions under such a license? Kindly provide inputs in respect of, inter alia, the following aspects for the proposed separate experimental license:

i. Purpose of the license;

ii. Scope of the license;

iii. Eligibility conditions for entities seeking to acquire the license;

iv. Mode of applying for the license;

v. Duration of the license;

vi. Obligation under the license;

vii. Financial conditions including the license fees;

viii. Technical conditions and other terms and conditions for operations under the license;

ix. Mechanism to ensure protection to passive services in the frequency range between 95 GHz to 3 THz;

x. Any other (please specify).

(b) whether the licensees should be permitted to market experimental devices designed to operate in the frequency range between 95 GHz to 3 THz via direct sale? If yes, what should be the associated terms and conditions?

Please provide a detailed response with justification.

Comments of stakeholders on the Q6

2.15 In response to the Q6, many stakeholders favored the proposal of opening the frequency spectrum between 95 GHz to 3 THz for experiment and demonstration of equipment through a separate experimental license. A few other stakeholders opined that the frequency spectrum between 95 GHz to 3 THz should be given to the interested organizations for experiment and demonstration of equipment under the present experimental licensing framework laid down by the DoT through the Office Memorandum dated 23.07.2019 (hereinafter referred to as "the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019")[26]; there is no need for a separate experimental license for 95 GHz to 3 THz frequency range.

2.16 A broad summary of the comments of the stakeholders, who favored a separate experimentation license for the frequency spectrum between 95 GHz to 3 THz, is given below:

(a) The proposed experimental licensing regime for designing and conducting experiments and tests in the country in the frequency range from 95 GHz to 3 THz will encourage the development of new communication technologies and new services. The proposed regime has the potential to significantly improve the fidelity of emerging technologies, and support

[26] The DoT has issued an Office Memorandum No. R-14016/0112019-NT(Pt.) dated 23.07.2019 to regulate Experimental and Technology trial licenses; Manufacturing and Testing licenses; and Demonstration licenses. Source: https://dot.gov.in/sites/default/files/OM%20dated%2023rd%20July%202019_0.pdf

applications that are infeasible today. It will boost the 'Make in India' initiatives.

(b) In future, India is going to become a developer of new technologies rather than being a consumer of technologies. For this purpose, the ecosystem of start-ups, research and development (R&D) institutions, and innovators should be catalyzed. The proposed regime for the experimentation in Tera Hertz band will make it possible for the innovators in the country to develop technologies at higher frequencies with a large quantum of bandwidth.

(c) The proposed experimental licensing regime for the Tera Hertz range can stimulate scientific research in imaging, spectroscopy, communication technologies and sensing. It can also drive advancements in medical imaging.

2.17 On the other hand, a few other stakeholders opined that there is no need for a separate experimental license for the Tera Hertz spectrum. They averred that the present experimental licensing framework laid down through the DoT's Office Memorandum dated 23.07.2019 is well equipped to accommodate the R&D, experimentation, and demonstration aspects pertaining to the Tera Hertz spectrum as well; a single experimental licensing framework for all frequencies including Tera Hertz spectrum would also help in maintaining regulatory clarity and simplicity. A stakeholder, who opposed a separate experimentation license for the frequency spectrum between 95 GHz to 3 THz, opined that in case there are certain restrictions in the license under the DoT's Office Memorandum on Experimental License dated 23.07.2019, a lighter version of the said license can be considered in place of establishing a separate experimental licensing regime for Tera Hertz frequencies.

Comments of stakeholders on the Q7 (a)

2.18 The stakeholders, who favored a separate experimentation license for the frequency spectrum between 95 GHz to 3 THz, provided the following inputs with respect to the terms and conditions of the experimental license in the Tera Hertz range:

(a) The terms and conditions of the proposed experimental license for Tera Hertz spectrum should be similar to the conditions set out by the Federal Communications Commission (FCC), USA. [Remarks: In May 2019, the FCC, USA introduced a new experimental radio license named 'the Spectrum Horizons Experimental Radio License' for experiments and demonstration of equipment designed to operate exclusively on any frequency from 95 GHz to 3 THz[27].]

(b) There should not be any restrictions on technical conditions for designing and conducting experiments and tests provided they should not cause harmful interference to the existing services, including secondary services.

2.19 One of the stakeholders, who contended that there is no need for a separate experimental licensing regime for Tera Hertz spectrum, stated that the assignment can be done under the existing experimental use license with specific additions in the purpose and technical conditions. The inputs of the stakeholder on this aspect are summarized below:

i. Purpose: The purpose of the license should be to promote R&D activities, indoor/ outdoor testing/ experimentation in the field of wireless radiocommunications and also to promote 'Make in India' in wireless products.

ii. Validity period: The initial validity period of the license should be one year, and post that an automatic extension for one year should be provided, if sought by the applicant. However, post the two-year period, the

[27] Source: https://www.federalregister.gov/documents/2019/06/04/2019-10925/spectrum-horizons

government should examine whether the license needs to be migrated from experimental license to full-scale commercial service under the scope of Unified License along with auction of spectrum. As the experimental use of this spectrum is going on globally, we should expect that in near future, the use cases may achieve a critical mass to become full-fledged commercial services, therefore, a time-bound review is required. After two years of experimental services, in case any need is felt for a further allocation of spectrum for commercial services then the same should be through auction only.

iii. License fees: Rs. 1,000

iv. Licensed area: The applicants should be required to define the area where they propose to use the frequencies assigned under the experimental license. However, the area assignment should be done with a liberal and progressive mindset to help promote the services and help discover new use cases.

v. Technical conditions: There should not be any restriction on the technical conditions for designing and conducting experiments and tests provided they do not cause harmful interference to the existing services including secondary services. The interreference management should be the licensee's responsibility. In case of any instance of interference with commercial communication services under the Unified License, the experimental licensee should rectify on an immediate basis. In case no solution is found, the experimental licensee should be required to discontinue services in the affected area.

vi. Terms and conditions: The licensee may be permitted to market experimental devices designed to operate in the bands above 95 GHz via direct sale. However, it should be as per the DoT's guidelines[28] for network testing before the launch of any services on a commercial basis. Further,

[28] Through a letter dated 09.10.2018 to the licensees holding Unified License with Access Services, CMTS and UASL for mobile services, the DoT has stipulated conditions for network testing before launch of commercial services through the "Norms for Network testing before launch of Commercial Services". The norms are available at the URL: https://dot.gov.in/sites/default/files/norms%20for%20network%20testing%20before%20launch%20of%20commercial%20services.pdf?download=1

the licensee should ensure complete disclosure to the users about the experimental nature of the services. The licensee should provide an undertaking for not claiming any third-party right on account of such marketing. There should be a verifiable framework for tracking the devices. The DoT and Law Enforcement Agencies (LEAs) should have an on-demand access to the tracking mechanism. The licensee should ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial. Additionally, each device sold under this program should be labelled as "Authorized under STAL and may be subject to further conditions including termination of operation" and carry with it a licensee assigned equipment ID number to be issued by the WPC, DoT.

vii. Exclusive assignment: No exclusive assignment should be given to the experimental licensee. The licensee should be responsible for interference management.

viii. Spectrum assignment: The spectrum assignment should be subject to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use, will entail termination/ modification/ relocation of any test or experimentation being carried out in the said spectrum band. In such an event, the experimental licensee should be offered an alternative spectrum band. If any alternative spectrum band is not feasible, the experimental licensee should be allowed to continue the experiment till the completion of license period in coordination with the licensed assignees.

ix. Obligations under the license: The obligations under the license should be limited to providing regular reports to the DoT and TRAI on the progress of use cases proposed by the applicant. Further, in case the applicant desires to add new use cases or discontinue any experiment, it would be obligatory on it to inform the DoT and TRAI.

Comments of stakeholders on the Q7 (b)

2.20 In response to the Q7 (b) related to the appropriateness of permitting the marketing of the experimental devices designed to operate in the frequency range between 95 GHz to 3 THz via direct sale, the following views were received from stakeholders:

(a) A few stakeholders opined that the conditions under the proposed experimental license should be similar to the conditions imposed by the FCC on Spectrum Horizon Licenses[29].

(b) A few other stakeholders opposed the marketing of the experimental devices designed to operate in the frequency range between 95 GHz to 3 THz via direct sale mainly on the following grounds:

(i) It is critical to maintain the spirit of experimental licenses, which is focussed on R&D, and demonstration. Otherwise, it will be tantamount to commercialization and competition in the market, bypassing the legitimate route of the licensing regime. For example, when the telecom service providers were assigned 5G spectrum on a trial basis for a few months, the trial was conducted in an isolated and controlled environment to test various use cases and network elements. However, the spectrum was not assigned for commercial usage.

(ii) Based on the TRAI's recommendations, the Government issued the guidelines for network testing before the launch of any service on a commercial basis. Any service of a commercial nature had to be conducted under the proper licensing framework and the guidelines for the usage of spectrum on a commercial basis rather than under the garb of experimental licenses. Such a sale on an experimental basis, would result in the misuse of these licenses and distort market conditions and the regulatory regime.

[29] https://www.federalregister.gov/documents/2019/06/04/2019-10925/spectrum-horizons

(c) A stakeholder opined that it is not opposed to the marketing of experimental devise via direct sale if the following safeguards are scrupulously adhered to by the licensees:

(i) The licensees should offer services in compliance with the DoT's guidelines for network testing before the launch of any services on a commercial basis.

(ii) The Licensee should uniquely identify each device through a serial number.

(iii) The licensee should establish an online real-time device tracking mechanism. Access to this mechanism should be provided to the DoT and LEAs on demand.

(iv) The licensee should provide a written disclosure that the equipment being purchased is a part of an experiment that may be terminated at any time by the licensee or the licensor, and the device will be surrendered or rendered inoperable at the end of the experiment. The licensee should provide an undertaking for not claiming any third party rights on account of such marketing.

(v) Each device sold under the license should be labeled as "Authorized Under Experimental license valid till xx.xx.xx [date]".

(vi) Each device should carry with it a licensee assigned equipment ID number issued by the WPC, DoT.

Analysis of the issues raised through the Q6 & Q7

2.21 In the NFAP-2022, the frequency range from 95 GHz to 3 THz is, at present, regulated on three different levels as outlined below:

(a) The frequency range from 95 GHz to 275 GHz is allocated to various services such as Fixed Service, Mobile Service, RAS and satellite based services such as ESS, SRS, Amateur Satellite Radio Service, Navigation Satellite Service, and Mobile Satellite Service etc.

(b) The frequency range between 275 GHz to 1 THz is not allocated to any service. However, this frequency range is identified for Fixed Service and

Mobile Service [Footnote 5.564A] as well as for passive services namely Radio Astronomy Service, Earth Exploration Satellite Service (passive) and Space Research Service (passive) [Footnote 5.564A].

(c) The frequency range between 1 THz to 3 THz is neither allocated nor identified for any service. This spectrum can be used freely for both active and passive services.

2.22 In its report, the DoT's Committee on Tera Hertz Spectrum, mentioned that *"[a]s per available frequency assignment, there are very few assignments above 95 GHz. The spectrum beyond 95 GHz is considered to be vacant …"*

2.23 The Australian Communications and Media Authority (ACMA) in its information paper named 'Terahertz use-cases and regulatory models' (March 2023)[30] mentioned that *"[i]n Australia, no licences have been issued in the terahertz range to date."*

2.24 The Federal Communications Commission (FCC)[31] in its notice on proposed rulemaking and order (FCC 18-17) dated 28.02.2018[32] observed that *"the spectrum above 95 GHz currently presents a largely blank slate upon which bold new technologies can be written, and the large channel sizes potentially available could enable new innovative services*."

2.25 In short, the spectrum beyond 95 GHz is lying mostly unutilized, worldwide. The Authority notes that the FCC has done pioneering work in the direction of liberalizing the experimental licensing regime for spectrum between 95 GHz to 3 THz. Many stakeholders, in the current consultation process, have suggested that the Tera Hertz spectrum between 95 GHz to 3 THz should be opened in

[30]Source:https://www.acma.gov.au/sites/default/files/2023-03/Terahertz%20use-cases%20and%20regulatory%20models_information%20paper.docx#:~:text=3-,Terahertz%20spectrum,bandwidths%20for%20any%20given%20service.

[31] The Federal Communications Commission regulates interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia and U.S. territories. An independent U.S. government agency overseen by Congress, the Commission is the federal agency responsible for implementing and enforcing America's communications law and regulations. Source: https://www.fcc.gov/about/overview

[32] Source: https://docs.fcc.gov/public/attachments/FCC-18-17A1.pdf

India for experimental purposes with conditions similar to those set out by the FCC. The Authority perused the experimental radio licensing regime introduced by the FCC for spectrum between 95 GHz and 3 THz in 2019. A brief description of the said regime is given below:

Spectrum Horizons License of the FCC

2.26 On 04.06.2019, the FCC introduced the final rule for a new experimental radio license named 'the Spectrum Horizons Experimental Radio License' (in short, 'Spectrum Horizons License') for experiments and demonstrations of equipment designed to operate exclusively on any frequency within 95 GHz to 3 THz[33]. The FCC emphasized that "*the Spectrum Horizon License will differ from other experimental radio licenses by providing for, among other things, broad eligibility, a longer term, and additional flexibility to market devices*." The salient features of the spectrum Horizon License are given below:

(a) Available frequencies: "*Applicants for Spectrum Horizons Licenses may request authorization on any frequency within the 95 GHz to 3 THz frequency range."*

(b) License Term and Interim Reporting Requirements: "*The Commission adopt its proposal to authorize Spectrum Horizons Licenses for the longest license term - ten years - of any experimental license to encourage entrepreneurs to invest in this largely untested spectrum and yield more useful long-term information and data in support of subsequent rulemaking activity or waiver requests for operations in these bands. … The Commission will not provide for the renewal of a Spectrum Horizons License, …. The Commission also adopt a requirement that Spectrum Horizons licensees submit an interim report on the progress of the experiment no later than five years from the date of grant. …"*

(c) Geographic Area: "*… Spectrum Horizons License applicants will be able to request operations over any area they deem appropriate for their experiment. … the Commission may impose limitations on the geographic*

[33] Source: https://www.federalregister.gov/documents/2019/06/04/2019-10925/spectrum-horizons

extent of a license as necessary based upon the specific parameters requested and other circumstances, …"

(d) Marketing: *"Spectrum Horizons licensees will permit to market experimental devices designed to operate in the bands above 95 GHz via direct sale. … Additionally, the Commission will not limit the number of devices a licensee can market as part of the experiment. … the Commission will require licensees to ensure that trial devices are either rendered inoperable or retrieve at the conclusion of the trial. Additionally, each device sold under this program must be labeled as "Authorized Under An Experimental License and May be Subject to Further Conditions Including Termination of Operation" and carry with it a licensee-assigned equipment ID number. … Finally, at the time of sale, the licensee is required to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the licensee or the Commission, and the device will be surrendered or rendered inoperable at the conclusion of the experiment. … … Spectrum Horizons License operations will not be entitled to exclusive use; will not be protected from harmful interference from allocated services; and will be prohibited from causing harmful interference to stations of allocated services. …"*

2.27 The Authority notes that, in its report, the DoT's Committee on Tera Hertz Spectrum stated that *"[c]onsidering the requirement of emerging new radiocommunications technologies, to promote R&D activities, indoor/ outdoor testing/ experimentation in the field of wireless radiocommunications and also to promote Make in India in wireless products, and international practices, the committee recommends that a **new** experimental radio license category 'Spectrum -Terahertz Applications License (STAL)' may be created that will be applicable for 'Experiment' and 'Demonstration' of equipment designed to operate exclusively on any frequency above 95 GHz."* The DoT's Committee on Tera Hertz Spectrum also recommended the terms and conditions to be made applicable on STAL.

2.28 The Authority examined the terms and conditions of the 'Experimental (Radiating) license including license for spectrum for Indoor and Outdoor testing' license prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019. The following table presents a comparison between - (a) the terms and conditions of the 'Experimental (Radiating) license including license for spectrum for Indoor and Outdoor testing' license prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019 and (b) the terms and conditions of Spectrum-Terahertz Applications License (STAL) recommended by the DoT's Committee on Tera Hertz Spectrum:

Table 2.2: Comparison of the terms and conditions

Item	**The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019**	**The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum**
License Category	Experimental (Radiating) License including license for spectrum for Indoor and Outdoor testing	Spectrum- Terahertz Applications License (STAL)
Purpose	R&D and Experimentation	To promote R&D activities, indoor/ outdoor testing/ experimentation in the field of wireless radiocommunications and also to promote 'Make in India' in wireless products.
Eligible entities	Indian Entities involved in R&D, incubation, manufacturing, testing,	Any Indian National or any Indian Entity (Academic institutes, R&D

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
	Telecom Service Providers (TSPs) and Academia	Labs, Central/ State Governments or their public sector units, Union Territories, Technology parks, TSPs, incubators, industry partners, OEMs etc.) may be allowed.
Period of License	• Up to two years (renewable on case-to-case basis by the WPC, DoT) subject to truncation to prevent interference to licensed operations. • Restricted power levels, coordination, relocation of the test site may be tried to complete the test.	Initially for five years and further extendable for periods of five years at a time with an interim report to be submitted at the time of each renewal. • The spectrum assignment is subject to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use will entail termination/ modification/ relocation of any test or experimentation being carried out in the said

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
		spectrum band. In such event, user will be offered alternative spectrum band. If alternative spectrum band is not feasible, the user will be allowed to continue experiment till the completion of license period in coordination with the licensed assignees.
License Fee/ Spectrum Charges	Rs.5,000 per License per spectrum band; No royalty charges; All devices in the experiment are included under one license.	Rs. 1,000 towards spectrum charges for 5 years.
Geographical Area	-	No restriction on geographical areas; the user may be allowed to request operations over any area, except restricted areas, that they deem appropriate for their experiment.

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
Spectrum	All bands including new, unallocated, unallotted, unassigned, unsold, unused bands and others as may be feasible enabling international market access opportunities for Indian entities	Exclusively on any frequency above 95 GHz
Terms & Conditions	• No commercial services • Review by an Expert Committee appointed by DoT on quarterly basis to monitor and ascertain effective usage of spectrum • The license includes the necessary permissions for importing wireless products/ assemblies/ modules and associated accessories including antennae operating in both licensed and license-exempt bands. Such imported products shall not be for commercial use/ sale.	• No restriction on technical conditions for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services • Permitted to market experimental devices designed to operate in the bands above 95 GHz via direct sale. • The licensees shall ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial.

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
		• Additionally, each device sold under this program must be labelled as "Authorized Under STAL and may be subject to further conditions including Termination of Operation" and carry with it a licensee assigned equipment ID number to be issued by the WPC, DoT. • Licensees who take advantage of these marketing provisions must uniquely identify each device (e.g., through a serial number) in a manner that will enable them to easily track each one. • At the time of sale, the licensee is required to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
		experiment that may be terminated at any time by the licensee or the licensor, and the device will be surrendered or rendered inoperable at the conclusion of the experiment. • Government may prescribe any test/ measurement etc. from health safety/ environment safety/ EMI/ EMC etc. as per international practice, if case application wants to market experimental devices.
	Non protection and Non-interference basis	• No exclusive assignment should be given under 'STAL'. • The assignment will be given on 'Non-interference basis and Non-protection Basis' (NIB/NPB). • The operations under the license would also not

Item	The terms and conditions prescribed through the DoT's Office Memorandum on Experimental Licenses dated 23.07.2019	The terms and conditions recommended by the DoT's Committee on Tera Hertz Spectrum
		claim any protection from allocated services or incumbent users.
	Review by an Expert Committee appointed by DoT on Quarterly basis to monitor and ascertain effective usage of spectrum	

2.29 The Authority observed the following key differences in the terms and conditions recommended for the Spectrum Tera Hertz Application License (STAL) by the DoT's Committee on Tera Hertz Spectrum, and the terms and conditions for 'Experimental (Radiating) License including license for spectrum for Indoor and Outdoor testing':

(a) Period of license: The present experimental license is granted for a period up to two years, extendable on case-to-case basis by the Wireless Planning and Coordination (WPC) Wing of the DoT. On the other hand, the proposed validity period of STAL is five years, extendable for periods of five years at a time.

(b) Commercial exploitation: The present experimental license does not permit commercial services under the license, whereas, under the proposed STAL, the marketing of experimental devices designed to operate in the bands above 95 GHz would be permitted via direct sale.

(c) Fee: The license fee of the present experimental license is Rs. 5,000 per license per spectrum band. On the other hand, under the proposed STAL, the spectrum charge is Rs. 1,000 for 5 years.

2.30 While analyzing the issues related to the need for a separate experimental license for the Tera Hertz band, the Authority took note of the following aspects:

(a) The spectrum in the Tera Hertz band is lying mostly vacant. Worldwide, a wide range of research and experimentation is being conducted in the Tera Hertz band, which suggests a keen interest of both industry and academia in this band. The ITU, in its journal on Tera Hertz Communication (2021), has stated that *"[i]t is anticipated that THz band communications will enable unprecedented applications both at the macro-scale and at the nano-scale, ranging from high-speed satellite communications, ultra-high-capacity wireless fronthaul/ backhaul in cellular networks, ultra-high-speed short-distance data transfer between devices, to inter/ intra-chip communications and instantaneous data exchange between nano-scale devices*".

(b) The FCC has introduced a liberalized experimental licensing regime ('Spectrum Horizons License') for the Tera Hertz band in the USA, under which, it has allowed the marketing of experimental devices in the bands above 95 GHz via direct sale. Prior to issuing the final order on the Spectrum Horizons License on 04.06.2019, the FCC had issued a 'Notice for Proposed Rulemaking and Order'[34] on 28.02.2018 for seeking comments of stakeholders in the matter. In the Notice, the FCC made the following observations with respect to the marketing of experimental devices in the bands above 95 GHz via direct sale:

"73. In the spectrum range above 95 GHz, we believe that marketing of innovative devices at a relatively early stage of experimentation may be particularly important to permit entrepreneurs to gauge consumer acceptance and to determine whether to proceed to the next stage of the experiment. As operations extend further into the spectrum above 95 GHz, the unique technical issues associated with such operations make capable devices more expensive to produce. Further, these same issues also make

[34] Source: https://docs.fcc.gov/public/attachments/FCC-18-17A1.pdf

it less likely that such devices could be easily adapted for use in the lower spectrum. Thus, entrepreneurs will be reluctant to proceed without a clear signal from consumers that they are interested in purchasing such devices.

74. …For example, our existing rules for market trials permit the sale of devices only between two licensed parties, which is intended to reduce the risk of interference from uncertified devices that remain with consumers after the trial ends. We believe that the characteristics of the spectrum above 95 GHz (such as the limited propagation capabilities and lack of existing services) warrant a less burdensome regulatory approach. We propose to allow experimental devices used in market trials in these bands to be sold directly to participants to encourage experimentation, as well as to help innovators share device manufacturing costs with potential early adopters who are willing to bear the risks associated with experimental licensing in this range. …"

(c) Currently, the marketing of experimental devices is not permitted in the experimental and technology trial licenses in India.

(d) At present, the research and development in the Tera Hertz band is at a nascent stage in India. In case a liberal regulatory framework for experimentation in the Tera Hertz band is introduced in the country with a permission to market the experimental devices via direct sale, the entrepreneurs and academia would be encouraged to develop innovative new technologies and services in the Tera Hertz band. Such a liberalized regulatory approach would help the experimenters to evaluate the performance of products in the Tera Hertz band in the conception, development and design stages. It, in turn, would pave a path to ascertain the technical viability of technologies and services built on Tera Hertz spectrum. However, while permitting to market the experimental devices via direct sale, suitable safeguard against the experimental devices causing harmful interference would require to be imposed.

2.31 In light of the above, **the Authority recommends that-**

(a) The Government should introduce a new experimental authorisation for the spectrum in the 95 GHz to 3 THz range. The authorisation may be termed as 'Tera Hertz Experimental Authorisation' (in short, THEA).

(b) The authorisation framework for THEA should be as below:

i. <u>Purpose</u>: The purpose of THEA should be to promote Research & Development (R&D), indoor and outdoor testing, technology trial, experimentation, and demonstration in the 95 GHz to 3 THz range.

ii. <u>Eligibility condition</u>: Any Indian Entity (Academic institute, R&D Laboratory, Central/ State Government, public sector unit, Union Territory, Technology Park, telecommunication service provider, incubator, original equipment manufacturer etc.) should be eligible to obtain THEA.

iii. <u>Application for THEA</u>: The entire process for application and grant of THEA should be online. The applicant should include a narrative statement describing in detail how its experiment could lead to the development of innovative devices and/or services in the 95 GHz to 3 THz range and an interference analysis. Unless a sufficient methodology for preventing harmful inference is detailed by the applicant, such operations should not be permitted. Certain parameters of the applications should be required to be disclosed publicly including frequency(s), type of emissions, power, and location. The applicants that propose to use spectrum exclusively allocated for passive use(s), should be required to provide an explanation why nearby bands with non-passive allocations are not appropriate or adequate for the experiment and acknowledge that they intend to transition any potential

long term use to a band with appropriate allocations. The applicant should identify a single point of contact (SPOC) responsible for all operations conducted under THEA and for ensuring compliance with applicable laws apart from rules, regulations and instructions issued by the DoT.

iv. **Geographical area: The applicant should be required to define the geographical area where it proposes to use the frequencies assigned under THEA with a justification. The applicant should be allowed to conduct its operations over any area, except in restricted areas, identified by the Central Government.**

v. **Authorisation period: The authorisation period of THEA should be up to five years. The authorisation should be further extendable for periods of up to five years at a time.**

vi. **Scope: The scope of THEA should be to conduct R&D, indoor and outdoor testing, technology trial, experimentation, and demonstration in the 95 GHz to 3 THz range; and to market experimental devices designed to operate in the 95 GHz to 3 THz range via direct sale.**

vii. **Assignment of spectrum: Applicants for THEA should be permitted to request assignment of any frequency in the range of 95 GHz to 3 THz. No exclusive assignment of spectrum should be given under THEA. The assignment of spectrum should be given on a 'Non-interference basis and Non-protection Basis' (NIB/ NPB). The Authorised Entity should not be permitted to claim any protection from the allocated services including secondary services and incumbent users.**

viii. **Provision of termination, modification, or relocation of experimentation: The spectrum in the 95 GHz to 3 THz range should be assigned to the Authorised Entity subject**

to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use will entail termination, modification, or relocation of any test or experimentation being carried out in the said spectrum band.

ix. <u>Special conditions for marketing experimental devices</u>: Marketing of experimental devices designed to operate in the 95 GHz to 3 THz range should be permitted under THEA via direct sale. If the Authorised Entity opts to market experimental devices designed to operate in the 95 GHz to 3 THz range, it should be mandated to uniquely identify each experimental device (e.g., through a serial number) in a manner that would enable it to easily track each device. The Authorised Entity should be mandated to provide an on-demand access to the tracking mechanism to the Government. At the time of sale, the Authorised Entity should be mandated to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the Authorised Entity or the Central Government, and the device will be surrendered or rendered inoperable at the conclusion of the experiment. The Authorised Entity should be mandated to ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial. Additionally, each experimental device sold should be mandatorily labelled as "Authorised Under THEA and may be subject to further conditions including termination of operation" and carry with it an Authorised Entity assigned device identification number to be issued by the WPC Wing of the DoT. The authorized entity should provide an undertaking of not claiming any third-party right on

account of the marketing of experimental devices. There should be a provision that the Central Government may prescribe any test/ measurement etc. from health safety/ environment safety/ EMI/ EMC etc. as per international practice, in case the Authorised Entity intends to market experimental devices.

x. **<u>Reporting requirement</u>: The Authorised Entity should provide a report on the progress of use cases to the Government on an annual basis.**

xi. **<u>Authorisation fee</u>: The authorisation fee for THEA should be Rs. 1,000 for a period up to five years.**

2.32 The following section deals with the issues related to authorisation and assignment exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges.

(2) Authorisation and assignment exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges

2.33 In its report, the DoT's Committee on Tera Hera Hertz Spectrum stated as below:

"4.2.1 FCC has offered four different frequency bands namely, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz under unlicensed category. Ofcom has made available frequency bands 116-122 GHz, 174.8-182 GHz and 185-190 GHz on non-protection and non-interference basis. CEPT has also recommended frequency bands 122.0-122.25 GHz and 244-246 GHz for unlicensed use.

4.2.2. Considering the international practice and to gain advantage of scale of economy, the frequency bands, 116-123 GHz, 174.8 -182 GHz, 185-190 GHz and 244-246 GHz may be opened for unlicensed use. …

4.2.3 The devices in above bands would operate on non-interference and non-protection basis while protecting both passive and active services running in these bands and adjacent bands. Services such as earth exploration satellite, and radio astronomy services in these bands and adjacent bands require stringent protection criteria as these services received signals from space. There is no risk of harmful interference from unlicensed devices to space research service (passive) because stations in this service are space-based and looking away from earth. The other services namely fixed service, mobile service and radio location services have not yet been deployed due to non-availability of eco system. Therefore, protection criteria for these services may not be required at this stage. The inter-satellite service operates solely between satellites in space and therefore there is no significant risk of harmful interference from relatively low power unlicensed devices operating on the Earth.

4.2.5 Considering the scale of economy, technical parameters for unlicensed devices in above bands devised by the FCC may be adopted. …

4.2.4 It may be noted that Indian environment namely; temperature, wind speed and rain conditions are different than other parts of the globe. Therefore, limit on transmit power, beamwidth etc. may be different from other parts of the world for Indian environment. It is recommended that FCC's technical parameters may be adopted initially and after conducting intensive research in Indian environment, technical parameters may accordingly be modified at later stage."

2.34 The Government considered the above recommendation of the DoT's Committee on Tera Hertz Spectrum. However, with a view to come up with a well-rounded regulatory regime on the subject matter, the Government requested TRAI to provide recommendations, *inter-alia*, on the following topic: *"Terms and Conditions including technical parameters for permitting license-exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246*

GHz frequency ranges, while protecting both passive and active services in and around these frequency ranges."

2.35 In this background, through the Consultation Paper dated 27.09.2023, the Authority solicited comments of stakeholders on the following questions:

Q1. Whether there is a need for permitting license-exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges? Please provide a detailed response with justification.

Q2. In case it is decided to permit license-exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges, what should be the terms and conditions including technical parameters for permitting license-exempt operations in these bands, while protecting both passive and active services in and around these frequency ranges? Please provide a detailed response with justification.

Q3. Whether there is a need for permitting license-exempt operations in any other bands in the 95 GHz to 3 THz frequency range? Please provide a detailed response with justification.

Comments of stakeholders on the Q1

2.36 In response to the Q1, many stakeholders favoured the license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency range. On the other hand, many other stakeholders opposed the license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency range.

2.37 A summary of the comments of stakeholders who are in favour of permitting license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency range is given below:

(a) Due to the limited distance propagation characteristics associated with sub-Tera Hertz bands, these bands are best suited for a license-exempt regulatory framework. Exempting these bands from the requirement of a license will foster the development of cutting-edge technologies, such as Tera Hertz imaging, communication, and sensing. In turn, it will drive innovation in various sectors.

(b) De-licensing spectrum bands allows researchers, scientists, and innovators to experiment with new technologies without licensing fees or regulations, leading to technological advancements. Entrepreneurs can explore novel business ideas without the financial burden of acquiring expensive licenses, facilitating the growth of innovative ventures.

(c) Access to de-licensed spectrum bands enables faster, efficient wireless communication due to high data rates offered by Tera Hertz frequencies and alleviates congestion in lower frequency bands, particularly in densely populated areas.

2.38 A summary of the comments of stakeholders, who are not in favour of license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges, is given below:

(a) Tera Hertz communications are expected to be a crucial technology for 6G by 2030. Tera Hertz bands offer a large bandwidth that enhances network performance for Tera-IoT and Tera-IAB[35]. The very small wavelength of Tera Hertz waves opens the doors for nanoscale electromagnetic communication networks like IoNT and WiNoC[36].

(b) International Mobile Telephony (IMT) deployments beyond 92 GHz are feasible, and frequencies beyond 92 GHz can enhance user throughput and network capacity. Original Equipment Manufacturers are exploring W, D, and H/ J bands[37] for backhaul. These bands have a potential to offer

[35] Tera-IoT refers to Internet of Things (IoT) solutions based on Tera Hertz frequencies.
Tera-IAB is Tbps integrated access and backhaul (Tera-IAB).
[36] IoNT is an acronym of 'Internet of nano things'.
WiNoC is an acronym of 'Wireless Network on Chip'.
[37] W band: 75-110 GHz, D Band: 130-174.8 GHz, H-band: 220-325 GHz, J Band: 252-325 GHz

high throughput, low latency, and high-resolution sensing. ITU-R and ETSI are undertaking various studies to address the requirements of wireless communications in Tera Hertz bands.

(c) Delicensing the spectrum can lead to irreversible consequences. Once a spectrum band is delicensed and the device ecosystem is established, a reversal of the same becomes extremely challenging. Delicensing at such an early stage and when the use cases are still evolving, may prevent the Government from realizing the full economic value of spectrum.

Comments of stakeholders on the Q2

2.39 A summary of the comments of stakeholders on the terms and conditions including technical parameters for license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges is given below:

(a) Technical specifications of the FCC for delicensed use in 116-123 GHz, 174.8-182 GHz and 185-190 GHz bands may be adopted. For the 244-246 GHz band, a reference may be drawn to ERC 70-03 Annex 1.p.

(b) Specific operating bandwidths within each band, maximum permissible power levels based on antenna type and application, stringent emission masks to restrict out-of-band emissions to safeguard adjacent services and geographical restrictions like exclusion zones around sensitive sites like radio telescope should be defined. Regular reviews and updates of technical parameters and regulations are necessary to adapt to technological advancements and emerging interference challenges.

Comments of stakeholders on the Q3

2.40 A summary of the comments of stakeholders on the issue of permitting license-exempt operations in any other bands in the 95 GHz to 3 THz frequency range are given below:

(a) To fully utilize the potential of the 95 GHz to 3 THz frequency range, a wider bandwidth of 20 GHz or more is essential.

(b) TRAI should allow license-exempt operations from 252 Hz to 450 GHz.

(c) Applications investigated in ECC Reports 334 and 351, such as vehicular radars in the 122.25-130 GHz, 134-141 GHz, and 141-148.5 GHz bands, should be considered for license-exempt operation. Additionally, a contiguous band of at least 25 GHz should be available for very short-distance communication applications below 350 GHz, such as the 252-296 GHz band and the 252-325 GHz band.

Analysis on the issue raised through the Q1, Q2 and Q3

2.41 The DoT's Committee on Tera Hertz Spectrum has recommended that "*the frequency bands, 116-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246 GHz may be opened for unlicensed use*". The allocation of these bands in the ITU-RR is given below.

Table 2.3: Allocation of the frequency range from 116-123 GHz, 174.8 – 182 GHz, 185-190 GHz, and 244-246 GHz in the ITU-RR

Band (GHz)	**Current Allocation**
116-122.25	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
122.25-123	FIXED INTER-SATELLITE MOBILE Amateur
174.8 – 182	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)

Band (GHz)	Current Allocation
185-190	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
244-246	RADIO ASTRONOMY RADIOLOCATION Amateur Amateur-satellite

2.42 The Authority examined the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands on the following aspects:

(a) Whether emissions are prohibited in some of these bands in ITU-RR?

(b) Whether some of these bands are designated as Industrial, Scientific, and Medical (ISM) bands as per ITU-RR?

(c) Whether some of these bands have been identified/ are under consideration for the deployment of International Mobile Telecommunication (IMT) systems?

2.43 Prohibited emissions: Footnote 5.340 of the ITU RR[38] deals with the bands in which all emissions are prohibited. The Footnote 5.340 is reproduced below:

"*All emissions are prohibited in the following bands:*

1400-1427 MHz,

2690-2700 MHz, except those provided for by No. 5.422,

10.68-10.7 GHz, except those provided for by No. 5.483,

15.35-15.4 GHz, except those provided for by No. 5.511,

23.6-24 GHz,

31.3-31.5 GHz,

31.5-31.8 GHz, in Region 2,

48.94-49.04 GHz, from airborne stations

[38] Source: https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.44.48.en.101.pdf

50.2-50.4 GHz,

52.6-54.25 GHz,

86-92 GHz,

100-102 GHz,

109.5-111.8 GHz,

114.25-116 GHz,

148.5-151.5 GHz,

164-167 GHz,

182-185 GHz,

190-191.8 GHz,

200-209 GHz,

226-231.5 GHz,

250-252 GHz. (WRC-03)"

2.44 The Authority notes that emissions are not prohibited in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and the 244-246 GHz bands.

2.45 ISM bands: Footnote 5.138 and Footnote 5.150 of the ITU-RR deal with the bands designated as Industrial Scientific and Medical (ISM) Bands. ISM bands are those bands where operation of equipment or appliances, designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes excluding applications in the field of telecommunications, are permitted. The Authority notes that the 122-123 GHz and the 244-246 GHz frequency bands are designated as ISM Bands by ITU-RR in the footnote 5.138.

2.46 Annexure 1 to the NFAP 2022[39] provides details of the wireless equipment exempted from licensing in India. The Authority notes that the 122-123 GHz and 244-246 GHz bands, though designated as ISM bands by ITU-RR, are not

[39] https://dot.gov.in/sites/default/files/NFAP%202022%20Document%20for%20e-release.pdf?download=1

part of the bands listed in the Annexure 1 to the NFAP 2022 as frequency ranges exempted for licensing in India.

2.47 IMT bands: IND 16 of the NFAP 2022 provides details of the bands identified for implementation of IMT in India. The bands identified for IMT in India, as per IND 16 of the NFAP 2022, are reproduced below:

(a) 450-960 MHz
(b) 1427-1518 MHz
(c) 1710-2200 MHz
(d) 2300-2450 MHz
(e) 2500-2690 MHz
(f) 3300-3670 MHz
(g) 24.25-28.5 GHz
(h) 37-43.5 GHz
(i) 47.2-48.2 GHz
(j) 66-71 GHz

2.48 The Authority notes that, at present, there is no identification for IMT in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and the 244-246 GHz bands.

2.49 World Radio-communication Conferences (WRCs) are held every three to four years. The WRC reviews, and, if necessary, revises the Radio Regulations (ITU-RR). WRC 23 was the last WRC held in October 2023 in Dubai. The Final Acts[40] of the WRC provide the decisions taken during the last WRC. The Authority perused the decisions on deployment of IMT in the Tera Hertz bands taken during WRC 23.

2.50 The Res 255 (WRC-23) deals with 'Studies on frequency-related matters for International Mobile Telecommunications (IMT) identification in the frequency bands [102-109.5 GHz, 151.5-164 GHz, 167-174.8 GHz, 209-226 GHz and 252-

[40] https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.16-2024-PDF-E.pdf

275 GHz] for the future development of IMT*'. The relevant 'resolve' of the Res 255 (WRC 23) is reproduced below:

"resolves to invite the ITU Radiocommunication Sector to complete in time for the 2031 world radiocommunication conference

1. …

2. the appropriate sharing and compatibility studies, taking into account the protection of services to which the frequency band is allocated on a primary basis for the following frequency bands:

– [102-109.5 GHz, 151.5-164 GHz, 167-174.8 GHz, 209-226 GHz and 252-275 GHz],"

2.51 The Res 814 (WRC-23) deals with 'Preliminary agenda for the 2031 World Radio Conference'. The relevant 'resolve' of Res 814 (WRC 23) is reproduced below:

"To consider the identification of the frequency bands [102-109.5 GHz, 151.5-164 GHz, 167-174.8 GHz, 209-226 GHz and 252-275 GHz] for International Mobile Telecommunications, in accordance with Resolution 255 (WRC-23)"

2.52 The Authority notes that the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands have not been identified by the ITU as possible candidates for future development of IMT.

2.53 In short, the Authority observed the following aspects in respect of the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands:

(a) Emissions are not prohibited in these bands.

(b) 122-123 GHz and 244-246 GHz bands are designated as ISM bands in ITU-RR.

(c) None of these bands have been identified or under consideration for the deployment of IMT systems.

2.54 With a view to carry out further analysis in respect of the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands, the Authority segregated these bands into two parts as given below:

(a) ISM bands: 122-123 GHz, and 244-246 GHz bands;

(b) Other bands: 116-122 GHz, 174.8-182 GHz, and the 185-190 GHz bands.

122-123 GHz, and 244-246 GHz bands

2.55 The Authority took note of the following international developments in respect of 122-123 GHz and 244-246 GHz bands:

(a) ITU-RR has designated the 122-123 GHz and 244-246 GHz bands as ISM bands.

(b) In March 2019, the FCC, through the first report and order (FCC 19-19)[41], designated, *inter-alia*, 122-123 GHz, and 244-246 GHz bands for unlicensed operation; devices using these bands will operate on a non-interference basis while protecting both passive and active services.

(c) In February 2021, The European Communication Committee (ECC) in its recommendation No. ERC 70-03 relating to the use of Short Range Devices (SRD)[42], recommended, *inter-alia*, the license exempt use of 122-123 and 244-246 GHz bands for non-specific Short-Range Devices (SRD).

(d) In December 2022, Innovation, Science and Economic Development Canada (ISED)[43], allowed both indoor and outdoor license-exempt use in, *inter-alia*, the 122-123 GHz, and 244-246 GHz bands, on a no-protection, no-interference basis.

2.56 Besides, the DoT's Committee on Tera Hertz Spectrum has recommended, *inter-alia*, that these bands may be opened for unlicensed use. Considering the international developments in respect of 122-123 GHz and 244-246 GHz bands and the fact that the ITU has designated these bands for ISM applications, the Authority is of the view that in case the authorisation and assignment-exempt operation is permitted in 122-123 GHz, and 244-246 GHz bands in India, it may yield the following benefits:

[41] Source: https://docs.fcc.gov/public/attachments/FCC-19-19A1.pdf
[42] Source: https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf
[43] ISED is a department of the Government of Canada.

(a) Authorisation and assignment-exempt use in these bands would provide international economies of scale of research and development in the future use of frequencies in the Tera Hertz range.

(b) Opening up these bands for authorisation and assignment-exempt use would support the introduction of next-generation wireless technologies that could be deployed both indoor and outdoor, operating over distances ranging from less than a meter to several hundred meters, and deliver increased capacity and reliability for existing use cases as well as new and emerging use cases. Releasing these bands would also support a variety of innovative use cases that will significantly enhance operations and growth in vertical industries.

2.57 In light of the foregoing discussion, the Authority is of the view that authorisation and assignment exempt operations should be permitted in the 122-123 GHz, and 244-246 GHz bands in India.

116-122 GHz, 174.8-182 GHz, and the 185-190 GHz bands

2.58 The allocation of the 116-122 GHz, 174.8-182 GHz, and the 185-190 GHz bands as per the table of frequency allocations of ITU-RR is given in the following table:

Table 2.4: Allocation of the 116-122 GHz, 174.8-182 GHz and the 185-190 GHz bands in the ITU-RR

Band (GHz)	**Current Allocation**
116-119.98	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562C SPACE RESEARCH (passive) 5.341

Band (GHz)	Current Allocation
119.98-122.25	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562C SPACE RESEARCH (passive) 5.138 5.341
174.8-182	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562H SPACE RESEARCH (passive)
185-190	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE 5.562H SPACE RESEARCH (passive)

2.59 As may be seen from the above table, the frequency ranges which are being examined in this section viz. 116-122 GHz, 174.8-182 GHz and 185-190 GHz are allocated to only three services on primary basis. In these ranges, the Earth Exploration Satellite Service (Passive), and the Space Research Service (Passive) are the passive services while the Inter Satellite Service is the active service subject to certain footnotes[44].

2.60 The Authority took note of the following international developments in respect of 116-122 GHz, 174.8-182 GHz, and 185-190 GHz bands:

(a) In March 2019, the FCC, through the first report and order (FCC 19-19)[45], designated, *inter-alia*, 116-122 GHz, 174.8-182 GHz and 185-190 bands

[44] The relevant footnotes, mentioned in these bands, are described below:

(a) *"5.34 In the bands 1400-1727 MHz, 101-120 GHz and 197-220 GHz, passive research is being conducted by some countries in a programme for international emissions of extraterrestrial origin."*

(b) *"5.562C Use of the band 116-122.25 GHz by the inter-satellite service is limited to satellites in the geostationary satellite orbit. The single entry power flux-density produced by a station in the inter-satellite service, for all conditions and for all methods of modulation, at all altitudes from 0 km to 1000 km above the Earth's surface and in the vicinity of all geostationary orbital positions occupied by passive sensors, shall not exceed -148 dB (w/m^2.MHz) for all angles of arrival. (WRC-2000)"*

(c) *"5.562H Use of the band 174.8-182 GHz and 185-190 GHz by the inter-satellite service is limited to satellites in the geostationary satellite orbit. The single entry power flux-density produced by a station in the inter-satellite service, for all conditions and for all methods of modulation, at all altitudes from 0 km to 1000 km above the Earth's surface and in the vicinity of all geostationary orbital positions occupied by passive sensors, shall not exceed -144 dB (w/m^2.MHz) for all angles of arrival. (WRC-2000)"*

[45] Source: https://docs.fcc.gov/public/attachments/FCC-19-19A1.pdf

for unlicensed operation; devices using these bands will operate on a non-interference basis while protecting both passive and active services.

(b) In October 2021, Ofcom introduced a new license (the 'Spectrum Access: EHF' license) to make available the 116-122 GHz, 174.8-182 GHz, and 185-190 GHz bands for terrestrial use. Each license will enable access to one of these bands across the UK on a non-protection and non-interference basis, with use of multiple devices permitted[46].

(c) In December 2022, the ISED Canada allowed both indoor and outdoor license-exempt use in, *inter-alia*, the 116-122 GHz, 174.8-182 GHz, and 185-190 GHz bands, on a no-protection, no-interference basis.

2.61 Besides, the DoT's Committee on Tera Hertz Spectrum has recommended, *inter-alia*, that these bands may be opened for unlicensed use. It recommended that devices in these bands should operate on non-interference and non-protection basis while protecting both passive and active services running in these bands and adjacent bands. In respect of the concern of harmful interference to the services to which the 116-122 GHz, 174.8-182 GHz, and 185-190 GHz bands have been allocated, the DoT's Committee on Tera Hertz Spectrum remarked as below:

"4.2.3 … *Services such as earth exploration satellite and radio astronomy in these bands and adjacent bands require stringent protection criteria ….There is no risk of harmful interference from unlicensed devices to space research service (passive) because stations in this service are space-based and looking away from earth. The other services namely fixed service, mobile service and radiolocation services have not yet been deployed due to non-availability of ecosystem. Therefore, protection criteria for these services may not be required at this stage. ... The inter-satellite service operates solely between satellites in space and therefore there is no significant risk of harmful interference from relatively low power devices operating on the Earth."*

[46] Source: https://www.ofcom.org.uk/spectrum/frequencies/supporting-innovation-100-200-ghz/#:~:text=We%20want%20to%20support%20innovation,in%20January%20and%20May%202020

2.62 The FCC, in the first report and order (FCC 19-19)[47] dated 21.03.2019, examined the issue related to co-existence of unlicensed devices with EESS and made the following observations:

"38. To assess whether unlicensed devices can co-exist with the Earth exploration-satellite service, we determine how many unlicensed devices would produce aggregate emissions that would exceed the harmful interference protection threshold, as set forth in ITU-R RS.2017. Using the U.S. Standard Atmosphere model and assuming all point-to-point systems are operating at maximum power, we determine that the potential for harmful interference into Earth exploration-satellite services in the 174.8-182 GHz and 185-190 GHz bands is insignificant. Our analysis shows that up to 42,704 outdoor unlicensed devices can operate simultaneously at maximum power per square kilometer and still meet the protection levels for the vertical satellite scan of an Earth exploration satellite (also referred to as nadir scan or sounding). For an Earth exploration satellite angle scan (also referred to as limb sounder sensing) our analysis shows that up to 96.5 million unlicensed devices can operate simultaneously at maximum power per square kilometer without causing harmful interference. Based on these large device densities, we conclude that the potential for harmful interference to Earth exploration satellite exploration satellite sensors in these bands is negligible. The same analysis is also applicable to the 116-122 GHz band but would result in an even lower likelihood of harmful interference because that band is subject to 20 dB higher atmospheric attenuation than the 174.8-182 GHz and 185-190 GHz bands. IEEE GRSS notes that Earth exploration satellite sensors are not only space-based, but also located on the ground. Such ground-based systems are pointed skyward, making them less susceptible to interference from energy received from ground-based unlicensed devices. Also, because EESS operations require a relatively quiet spectrum environment, we believe the majority, if not all, ground-based EESS sensors are located in rural, isolated areas. These same factors should similarly deter widespread installation of unlicensed devices in

[47] Source: https://docs.fcc.gov/public/attachments/FCC-19-19A1.pdf

this band in these areas as there are much more cost-effective ways to cover large rural areas at lower frequency bands which have less propagation loss. Further, due to the aforementioned characteristics of this band, we expect deployed unlicensed systems to use highly directional antennas and/or be used for short distance localized operations. Together, all these factors will limit single entry and aggregate interference, not only to space-based stations, but also to ground-based receivers."

2.63 The Ofcom in its statement titled 'Supporting innovation in the 100-200 GHz range' (October 2020)[48] observed that the 116-122 GHz, 174.8-182 GHz, and 185-190 GHz are most suitable for coexistence with existing allocations and for internationally compatible devices which might emerge in the future for the following reasons:

"

a) the physical properties of these bands which are particularly suited to shared use between existing and new users. In these bands, propagation losses and the absorption of the signals by physical objects are higher compared with lower frequency bands, which reduces the likelihood of interference between different spectrum users. In addition, as a consequence of the short signal wavelengths, 100-200 GHz bands can use small sized antennas, with relatively high directivity and narrow beams. This means that most devices are likely to have some directivity and narrow beams, which also reduces the risk of interference.

b) the limited current use of these bands in the UK. Under the Radio Regulations, the 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands are allocated for primary use to Earth Exploration-Satellite Services, Inter-Satellite and Space research (passive). Of these categories, we are only aware of EESS use which would need to be considered for the purposes

[48]Source:https://www.ofcom.org.uk/spectrum/frequencies/supporting-innovation-100-200-ghz/#:~:text=We%20want%20to%20support%20innovation,in%20January%20and%20May%202020.

of avoiding undue in-band interference from terrestrial users, based on current use and the sensitivity of passive EESS sensors.

c) *the potential for internationally compatible devices to be developed for these bands. The FCC has decided to make the proposed bands available on an unlicensed basis in the US; and the 116-134 GHz band is also available for terrestrial use by broadcast auxiliary services in Japan. Opening up similar bands in the UK has the potential to provide international economies of scale for research and development in the future use of frequencies above 100 GHz and into the development and manufacture of future receiver and transmitter equipment, which is likely to drive future demand for access to this spectrum."*

2.64 The ISED, Canada in the 'Decision on the Technical and Policy Framework for the Frequency Bands Above 95 GHz' of December 2022 expressed its view that "*the propagation characteristics in the proposed frequency bands and additional losses such as clutter and terrain, together with the appropriate technical rules and the use of highly directional antennas, would significantly reduce the likelihood of harmful interference to other radio services operating in the band*."

2.65 The Authority notes that the signals in Tera Hertz bands are significantly affected by the presence of oxygen and water vapour within the atmosphere. The amount of signal attenuation due to oxygen and water vapour varies with frequency and other factors. The attenuation caused by oxygen increases dramatically around 120 GHz and 183 GHz. The ITU, in its recommendation No. P.676-11 on Attenuation by atmospheric gases[49], has depicted specific attenuation due to atmospheric gases in the 1GHz-350 GHz range as below:

[49] Source: https://www.itu.int/rec/R-REC-P.676-11-201609-S/en

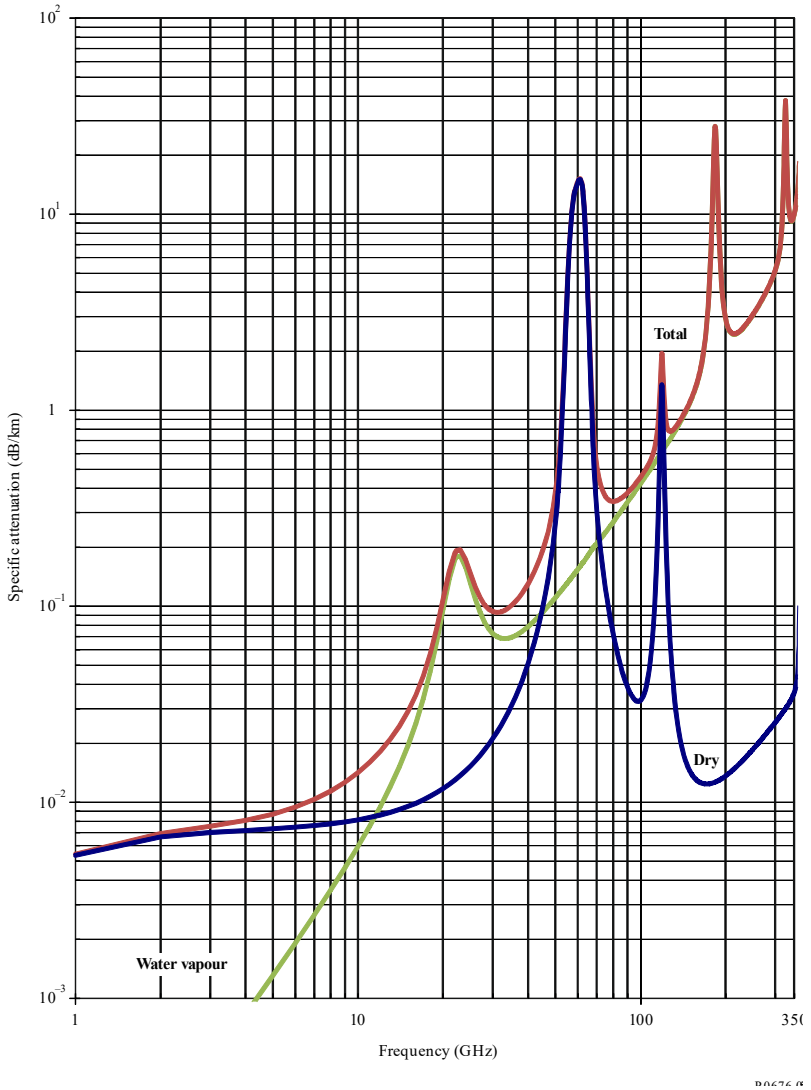


Figure 2.1: Specific attenuation due to atmospheric gases[50]
(Pressure = 1 013.25 hPa; Temperature = 15°C; Water Vapour Density = 7.5 g/m^3)

2.66 FCC in its Notice of Proposed Rulemaking and Order (FCC-18-17) dated 28.02.2018[51] made use of a graph similar to the above. It depicted the attenuation of radio waves per kilometer travelled caused by atmospheric absorption as a function of frequency during typical conditions from 20 GHz to 275 GHz as below:

[50] Source: https://www.itu.int/rec/R-REC-P.676-11-201609-S/en
[51] Source: https://docs.fcc.gov/public/attachments/FCC-18-17A1.pdf

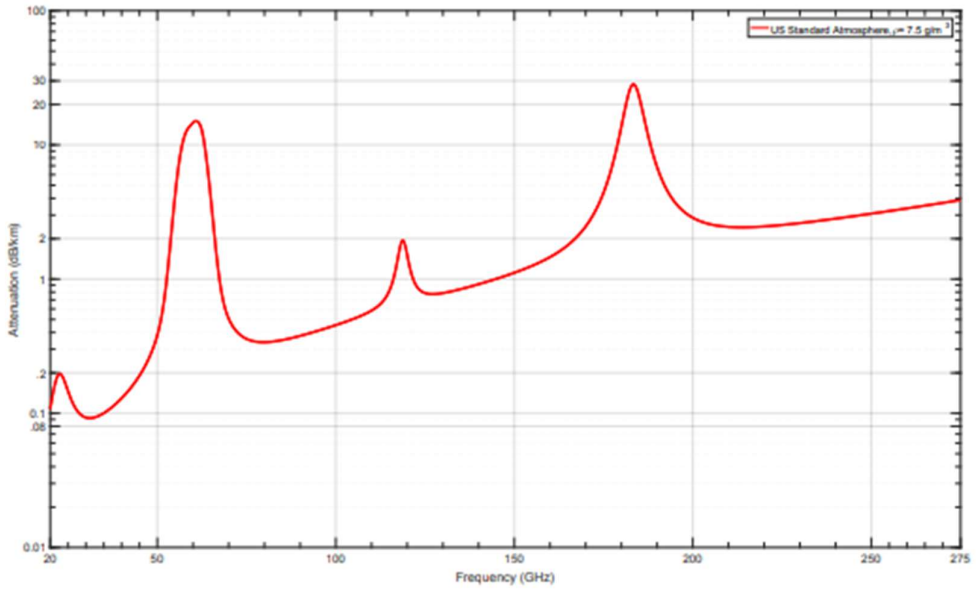


Figure 2.2: Specific Attenuation Due to Atmospheric Gases

2.67 The above atmospheric loss curves suggest that in the spectrum above 95 GHz there are high absorption windows in the frequency ranges of 114.5 GHz-130 GHz, and 174.5 GHz-200 GHz. In the first high absorption window of 114.5 GHz–130 GHz, the propagation loss increases to 2 dB/ km around the peak. In the second high absorption window of 174.5 GHz–200 GHz, the propagation loss increases to 30 dB/ km around the peak. For this reason, in 116-122 GHz, 174.8-182 GHz and 185-190 GHz bands, transmissions over only short distances will be possible using current technology. It also means that the interference between devices will be less likely in these frequency ranges.

2.68 Considering the international developments in respect of 116-122 GHz, 174.8-182 GHz and 185-190 bands and the fact that these bands suffer from a significantly high atmospheric attenuation, the Authority is of the view that the authorisation and assignment exempt operation should be permitted in 116-122 GHz, 174.8-182 GHz, and 185-190 GHz bands. The Authority is of the opinion that authorisation and assignment-exempt use of the spectrum in these bands would provide international economies of scale of research and development in the future use of the spectrum in these bands. Together with

the spectrum in 122-123 GHz and 244-246 GHz ranges, the spectrum in 116-122 GHz, 174.8-182 GHz and 185-190 GHz ranges will provide a total of 21.2 GHz of authorisation exempt spectrum to Indian innovators, which will be adequate for research and development in the Tera Hertz range. The Authority is of the view that, at this stage, any other frequency bands is not required to be permitted for authorisation and assignment exempt operation in the country.

Technical Parameters for the authorisation and assignment-exempt use of the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands

2.69 The Authority notes the averment of a few stakeholders that the technical specifications of the FCC for the delicensed use in 116-123 GHz, 174.8-182 GHz and 185-190 GHz should be adopted; for the 244-246 GHz band, a reference may be drawn to the ERC 70-03 Annex 1.p. In this regard, the Authority perused the FCC's technical parameters for license exempt use of these bands, and the relevant provisions of ERC 70-03.

2.70 Technical specifications of the FCC: The FCC has stipulated the following technical specifications on radiated emission limits etc. in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz[52]:

"

(a) Operation on board an aircraft or a satellite is prohibited.

(b) Emission levels within the 116–123 GHz, 174.8–182 GHz, 185–190 GHz and 244–246 GHz bands shall not exceed the following equivalent isotropically radiated power (EIRP) limits as measured during the transmit interval:

(1) The average power of any emission shall not exceed 40 dBm and the peak power of any emission shall not exceed 43 dBm; or

[52] Source: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-C/subject-group-ECFR2f2e5828339709e/section-15.258

(2) For fixed point-to-point transmitters located outdoors, the average power of any emission shall not exceed 82 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The peak power of any emission shall not exceed 85 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The provisions in this paragraph (b)(2) for reducing transmit power based on antenna gain shall not require that the power levels be reduced below the limits specified in paragraph (b)(1) of this section.

(3) The peak power shall be measured with a detection bandwidth that encompasses the entire occupied bandwidth within the intended band of operation, e.g., 116–123 GHz, 174.8–182 GHz, 185–190 GHz or 244–246 GHz. The average emission levels shall be measured over the actual time period during which transmission occurs.

(4) Transmitters with an emission bandwidth of less than 100 MHz must limit their peak radiated power to the product of the maximum permissible radiated power (in milliwatts) times their emission bandwidth divided by 100 MHz. For the purposes of this paragraph (b)(4), emission bandwidth is defined as the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g., for frequency hopping devices).

(c) Spurious emissions shall be limited as follows:

(1) The power density of any emissions outside the band of operation, e.g., 116–123 GHz, 174.8–182 GHz, 185–190 GHz or 244–246 GHz, shall consist solely of spurious emissions.

(2) Radiated emissions below 40 GHz shall not exceed the general limits in § 15.209.

(3) Between 40 GHz and the highest frequency specified in § 15.33, the level of these emissions shall not exceed 90 pW/cm2 at a distance of 3 meters.

(4) The levels of the spurious emissions shall not exceed the level of the fundamental emission.

(d) Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to + 50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

(e) Regardless of the power density levels permitted under this section, devices operating under the provisions of this section are subject to the radiofrequency radiation exposure requirements specified in §§ 1.1307(b), 2.1091, and 2.1093 of this chapter, as appropriate. Applications for equipment authorization of devices operating under this section must contain a statement confirming compliance with these requirements for both fundamental emissions and unwanted emissions. Technical information showing the basis for this statement must be submitted to the Commission upon request.

(f) Any transmitter that has received the necessary FCC equipment authorization under the rules of this chapter may be mounted in a group installation for simultaneous operation with one or more other transmitter(s) that have received the necessary FCC equipment authorization, without any additional equipment authorization. However, no transmitter operating under the provisions of this section may be equipped with external phase-locking inputs that permit beam-forming arrays to be realized.

(g) Measurement procedures that have been found to be acceptable to the Commission in accordance with § 2.947 of this chapter may be used to demonstrate compliance."

2.71 The salient technical parameters stipulated by the FCC for the license exempt use of the 116–123 GHz, 174.8–182 GHz, 185–190 GHz or 244–246 GHz are summarized below:

Table 2.5: Salient technical parameters for the license exempt use of the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz stipulated by the FCC

Technical Parameters	**Limit**
Maximum EIRP	40 dBm (average); 43 dBm (peak)
Maximum EIRP (outdoors) for fixed point-to-point transmitters	82 dBm (average); 85 dBm (peak) The power shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi.
Out-of band emission limit	90 picowatts per cm^2 at a 3-meter distance

2.72 Technical specifications of ERC 70-03: A few stakeholders have opined that ERC 70-03[53] Annex 1,p rules may be considered for the wider band of 244–246 GHz. The Authority notes that the ERC Decision 70-03 on the use of Short-Range Devices provides the maximum EIRP of 100 mW (20 dBm) for 244-246 GHz band.

2.73 The Authority notes that the FCC, USA and the ISED, Canada have specified identical technical parameters for the license-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands. The Authority is of the view that in case the same technical parameters as stipulated by the FCC and ISED are prescribed for authorisation exempt use of the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands in India, the benefits of the global harmonization such as a greater equipment ecosystem and economies of scale for the devices operating in these bands can be reaped. At the same time, the Authority notes that the Indian environment in terms of

[53] Source: https://docdb.cept.org/download/3700

temperature, rain conditions, humidity, and wind speed etc. is different from other parts of the world. Therefore, technical parameters, such as maximum effective isotropic radiated power (EIRP) in these bands may have to be modified for making them suitable for the Indian environment. In India, the Telecom Engineering Center (TEC), which is a technical body of the DoT, develops standards for the telecom sector in the country. The TEC can obtain inputs from relevant stakeholders and formulate technical parameters for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in the country.

2.74 Considering the above, the Authority is of the view that, initially, the FCC's technical specifications on 'Operation in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz' may be adopted for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in the country. After obtaining inputs from the TEC, the technical specifications may be modified.

2.75 Considering the comments of stakeholders and the foregoing analysis, **the Authority recommends that**:

(a) The authorisation and assignment-exempt operations should be permitted in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in India.

(b) Initially, the technical specifications provided in the FCC's eCFR [Title 47, Chapter I, Subchapter A, Part 15, Subpart C, item 15.258[54]] on 'Operation in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz' may be adopted for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in the country. After obtaining inputs from the Telecom Engineering Center (TEC), the technical arm of the DoT, the

[54] https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-C/subject-group-ECFR2f2e5828339709e

technical specifications for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands may be modified, if required.

2.76 The following section deals with the issues related to authorisation and assignment-exempt operations in the 77-81 GHz range for automotive radar applications.

(3) Authorisation and assignment exempt operations in the 77-81 GHz range for automotive radar applications

2.77 In its report, the DoT's Committee on Tera Hera Hertz Spectrum made the following observations in respect of the frequency bands between 40 GHz and 95 GHz:

"4.3.1 It may be noted that Government is already in the process of making regulations for V band (57 GHz to 66 GHz) and E band (71-76 GHz/ 81-86 GHz). The frequency band 76-77 GHz has already been delicensed vide G.S.R. 699 (E) dated 16.09.2015 for the purpose of usage of very low power radio frequency devices or equipment for short range radar systems.

4.3.2 Department of Telecom has constituted a committee for implementation of V2X in the country. Frequency bands 76-77 GHz and 77-81 GHz are being used for long range radar and short & medium range radars respectively for V2X application.

4.3.3 The Federal Communications Commission (FCC) and the Ministry of Internal Affairs and Communication (MIC) in Japan have designated 76-77 GHz for automotive radar. MIC, Japan has also recommended introduction of high-resolution radar in 77-81 GHz band for safety related applications. The European Conference of Postal & Telecommunications (CEPT) has designated the band 77-81 GHz for automotive radars. The European Telecommunications Stan7dards Institute (ETSI) has adopted the harmonized standard in the frequency band 77-81 GHz for the applications of short-range radars. FCC has

also allowed 77-81 GHz band for vehicular radar operations aligning with rest of the world. Countries in Asia Pacific have also designated 76-77 GHz and 77-81 GHz bands for short range automotive radar applications for ITS. Therefore, the frequency band 76-78 GHz and 77-81 GHz band are globally harmonized bands for short range radar applications.

4.3.4 It is recommended that frequency band 77-81 GHz band may also be delicensed for automotive radar applications in line with international practice."

2.78 The Government considered the above recommendation of the DoT's Committee on Tera Hertz Spectrum. However, with a view to come up with a well-rounded regulatory regime on the subject matter, the Government requested TRAI to provide recommendations, inter-alia, on the following topic: *"Terms and conditions including technical parameters for permitting license-exempt operations in 77-81 GHz band for automotive radar applications in line with international practice."*

2.79 In this background, through the Consultation Paper dated 27.09.2023, the Authority solicited comments of stakeholders on the following questions:

Q4. Whether there is a need for permitting license-exempt operation in 77-81 GHz band for automotive radar applications? Please provide a detailed response with justification.

Q5. In case it is decided to permit license-exempt operations in the 77-81 GHz band for automotive radar applications, what should be the terms and conditions including technical parameters for permitting licensed-exempt operations in this frequency band? Please provide detailed response with justification.

Comments of stakeholders on the Q4

2.80 In response to the above set of questions, while most of the stakeholders opined that there is a need to permit license-exempt operations in the 77-81

GHz band for automotive radars, a few other stakeholders provided an opposite view.

2.81 A broad summary of the comments of stakeholders who are in favour of permitting license-exempt operations in the 77-81 GHz band for automotive radars are given below:

(a) The frequency band 77-81 GHz is already a globally harmonized band for short range radar applications. This band is permitted for use of automotive radars in the USA, Japan, Europe, and many other countries worldwide including Egypt, South Africa, Bahrain, Saudi Arabia, UAE, South Korea, Taiwan, Thailand, Australia, Canada, Mexico , Brazil etc.

(b) India has recently introduced the Bharat New Car Assessment Programme (BNCAP) for the Indian automotive industry. The car manufacturers can now voluntarily achieve a star rating in adult occupant protection, child occupant protection and safety assist technologies (SAE). For Indian automotive industry to become competitive in the export market, the vehicles manufactured in India should be enabled to use the level of radar sensor technology that allows them to compete in the world market. The modern automotive market is moving towards increased driver assistance and autonomy of the vehicles. These systems require detailed information regarding the surrounding environment; therefore, vehicles are being fitted with an ever-increasing range of sensors. The use of 77-81 GHz radar technology is needed to fulfil the following requirements:

(i) To achieve SAE level 4 and 5 vehicle autonomy, it is essential to use high resolution imaging radar that can sense the environment at a wide (~100 degree) field of view in high resolution at 1-2 degrees in both azimuth and elevation.

(ii) Imaging radars need to also create a detailed image of the road at a range of 300 meters or more and capture the size, azimuth, elevation, and velocity data of objects surrounding the car.

(c) For realizing increased safety and comfort, vehicles must be equipped with sensors which detect the surroundings. The 4 GHz bandwidth in 77-81 GHz range will enable advanced performance in resolution and support applications such as obstacle detection, stop & go, blind spot detection, parking aid, backup aid and pre-crash warning, intersection assistance, parking assist and autonomous parking.

(d) The 77-81 GHz band offers a number of advantages for automotive radar applications, including high bandwidth which enables automotive radars to achieve high resolution and range, low interference from other sources such as satellite communications and Wi-fi.

2.82 A broad summary of the comments of stakeholders who are not in favour of permitting license-exempt operations in the 77-81 GHz band for automotive radars is given below:

(a) The 77-81 GHz frequency band is primarily allocated for radio communication and radar systems, and a license-exempt approach for one user group could potentially have adverse implications for the broader community.

(b) Access to this band should be kept free of harmful interference. A study by the International Telecommunication Union (ITU) found potential adverse implications of using vehicular radars in the 76-81 range in E-band. 77-81 GHz band is part of the guard band of the E Band. A study is required before permitting license-exempt operation in 77-81 GHz Band as E-Band links are expected to be widely deployed for 4G/ 5G services.

(c) License exempt operations invariably lead to underutilization or mis-utilization of valuable resources and the process becomes irreversible, even if later on better use cases are developed using these spectrum bands. Therefore, instead of license-exempt usage, the first preference should be auction-based assignment, and in case the auction is not feasible due to extremely low demand or technical infeasibility, then a

light touch licensing regime with nominal license fees and compliance requirements for radar applications using this spectrum band should be put in place.

Comments of stakeholders on the Q5

2.83 The stakeholders, who are in favour of permitting license-exempt operations in the 77-81 GHz band for automotive radar, have proposed power levels for license exempt use in these bands which are as given below:

(a) The current 77-81 GHz regulations in Europe and the USA allow upto 50 dBm average and 55 dBm peak EIRP.

(b) The same EIRP should be allowed for the 77-81 GHz range, as is already allowed in India for the range 76-77 GHz namely EIRP RMS of Maximum 5 Watt (37 dBm)[55]. This maximum value is reasonable with the international limit for human exposure to radiation of maximum 1 mW/ cm^2 applied at 20 cm distance and averaged over time.

(c) For permitting license-exempt operation in 77-81 GHz band, ETSI system reference document for automotive collision warning short range radar should be referred to.

Analysis on the issue raised through the Q4 and Q5

2.84 Radar operations involve the transmission of radio frequency signals and analysis of the reflections from objects or people to determine their speed, range, and direction. Information regarding the speed, range, and direction of nearby objects can facilitate a host of applications that are beneficial to the public. Vehicular radars can determine the distance and relative speed of objects in front of, besides, or behind a vehicle to improve the driver's ability to perceive objects under poor visibility conditions or objects in blind spots.

[55] Refers to the Gazette notification No. G.S.R. 699(E) dated 16.09.2015, available at the URL: https://dot.gov.in/sites/default/files/Delicensing%20in%2036-38%20MHz%20band%20%5BGSR%20696%20%28E%29%5D%2C%20302-351%20KHz%20band%20%5BGSR%20697%20%28E%29%5D%2C%20433-434_79%20MHz%20band%20%5BGSR%20698%20%28E%29%5D%2C%2076-77%20GHz%20band%20%5BGSR%20699%20%28E%29%5D_0.pdf?download=1

Long-range vehicular radars (LRRs) use up to 1 GHz of bandwidth and typically provide a spatial resolution on the order of 0.5 meters. The vehicular radar industry has also developed short-range vehicular radar (SRR) applications that use up to 4 GHz of bandwidth, and typically provide a higher spatial resolution than LRRs of the order of 0.1 meters[56].

2.85 SRR units operating at 79 GHz (i.e. in the band 77 GHz to 81 GHz) require an operating range from 0 m to 30 m approximately, and are used for a number of applications to enhance the active and passive safety for all kind of road users. Applications which enhance passive safety include obstacle detection, collision warning, lane departure warning, lane change aid, blind spot detection, parking aid and airbag arming. The combination of these functions is referred to in the literature as a "safety belt" for cars[57]. European Telecommunications Standards Institute (ETSI) has depicted SRR functions relevant for enhancement of road safety through the following figure:

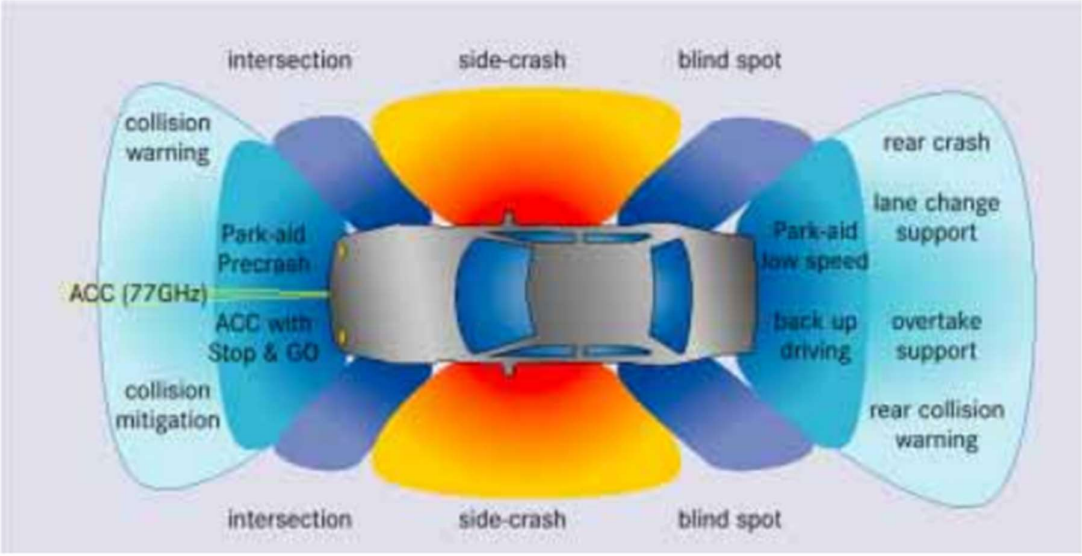


Figure 2.3: SRR functions relevant for enhancement of road safety

[56] Source: https://docs.fcc.gov/public/attachments/DOC-345476A1.pdf
[57] Source: https://www.etsi.org/deliver/etsi_tr/102200_102299/102263/01.01.02_60/tr_102263v010102p.pdf

2.86 The Authority took note of the following international developments in respect of 122-123 GHz and 244-246 GHz bands:

(a) In March 2004, The European Conference of Postal & Telecommunications (CEPT)[58] decided to designate the frequency band 77-81 GHz for the use of Automotive Short Range Radars. In ECC Decision (04)03, the CEPT stated that "*the use of the 79 GHz frequency range (77-81 GHz) has been considered as the most suitable band for Short Range Radars*" and that "*for the purpose of this Decision, SRR equipment are defined as applications providing road vehicle based radar functions for collision mitigation and traffic safety applications*".

(b) In February 2017, European Telecommunications Standards Institute (ETSI) developed harmonized European standards for Short Range Radar equipment operating in the 77 GHz to 81 GHz band[59].

(c) In June 2017, the FCC designated 76-77 GHz band for operating radars without an individual license. Radar systems operating in the 76-81 GHz band may operate as vehicular radars, or as fixed or mobile radars in airport air operations areas, including but not limited to Foreign Object Debris (FOD) detection radars and aircraft-mounted radars for ground use only.[60]

(d) The Ministry of Internal Affairs and Communications (MIC) in Japan has recommended the introduction of high-resolution radar in 77-81 GHz band for safety related applications. Some countries in Asia Pacific Region like China and Singapore have also designated 77-81 GHz bands for short range automotive radar applications[61].

(e) ITU has stated that evolving demands related to automotive safety applications, including the reduction of traffic fatalities and accidents

[58] Source: https://docdb.cept.org/download/1696
[59] Source: https://www.etsi.org/deliver/etsi_en/302200_302299/302264/02.01.01_30/en_302264v020101v.pdf
[60] § 95.3305 Radar operator eligibility in the 76-81 GHz Band.
Subject to the requirements of §§ 95.305 and 95.307, any person is eligible to operate a radar in the 76-81 GHz band without an individual license; such operation must comply with all applicable rules in this subpart.
Source: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-D/part-95/subpart-M
[61] Source: Report of the DoT's Committee on Tera Hertz Spectrum

require a range resolution for automotive radar systems leading to a necessary bandwidth of 4 GHz[62].

2.87 The Authority noted that through the Gazette notification No. G.S.R. 699(E) dated 16.09.2015, the Central Government has notified the Use of Very Low Power Radio Frequency Devices or Equipment for Short Range Radar Systems (Exemption from Licensing Requirement) Rules, 2015. Through these rules, the government has stated that *"[n]o licence shall be required by any person to establish, maintain, work, possess or deal in any wireless equipment for the purpose of usage of very low power Radio Frequency devices or equipment for short range radar systems in the 76 to 77 GHz frequency band on non-interference, non-protection and shared (non-exclusive) basis*" with the maximum Effective Radiated Power Limit of 5 Watt (37 dBm).

2.88 The Authority also notes that ITU has issued recommendation ITU-R M.2057-1[63] on 'Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications. This recommendation provides detailed technical characteristics of automotive radar systems operating in the frequency band 76-81 GHz.

2.89 The ITU's recommendation emphasizes that regarding functional and safety requirements, the automotive radar systems operating in the 76-81 GHz range can be separated in two categories:

(a) Category 1: Adaptive cruise control (ACC) and collision avoidance (CA) radar, for measurement ranges up to 250 meters. For these applications, a maximum continuous bandwidth of 1 GHz is required. Such radars are considered to add additional comfort functions for the driver, giving support for more stress-free driving.

(b) Category 2: Sensors for high resolution applications such as blind spot detection, lane-change assist and rear-traffic-crossing-alert, detection of

[62] Source: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2057-1-201801-I!!PDF-E.pdf
[63] ibid

pedestrians and bicycles near a vehicle, for measurement ranges up to 100 meters. For these applications, a necessary bandwidth of 4 GHz is required. Such radars directly add to the passive and active safety of a vehicle and are therefore an essential benefit towards improved traffic safety.

2.90 The ITU's recommendation also provides the technical parameters of the radiolocation radars operating in the frequency band 76-81 GHz. The salient parameters are presented in the following table.

Table 2.7: Automotive radar characteristics in the frequency band 76-81 GHz

Parameter	Units	**Category 1**	**Category 2**			
		Radar A Automotive radar For front applications for e.g. for ACC	**Radar B** Automotive high-resolution radar For front applications	**Radar C** Automotive high-resolution radar For corner applications	**Radar D** Automotive high-resolution radar	**Radar E** Automotive high-resolution radar Very short-range applications (e.g. parking aid, CA at very low speed)
Sub-band used	GHz	76-77	77-81	77-81	77-81	77-81
Typical operating range	meter	Up to 250	Up to 100	Up to 100	Up to 100	Up to 50
Typical emission type		FMCW[64], Fast-FMCW	FMCW, Fast-FMCW	FMCW, Fast-FMCW	FMCW	FMCW, Fast-FMCW
Max necessary bandwidth	GHz	1	4	4	4	4
Maximum EIRP.	dBm	55	33	33	45	33

2.91 In short, the Authority took note of the following aspects in respect of the 77-81 GHz band:

[64] In automotive radar applications, frequency-modulated continuous wave (FMCW) modulation has been popularly implemented. The Fast Chirp-Frequency-Modulated Continuous Wave (Fast-FMCW) modulation improves the range resolution of the radar system as compared to a FMCW Radar system.

(a) The frequency band 77-81 GHz is a globally harmonized band for short range automotive radar applications. Many countries have allowed the license exempt use of 77-81 GHz band for automotive radar applications.

(b) ITU has recommended detailed technical parameters for various applications of automotive radar systems operating in this band.

2.92 In light of the comments of stakeholders and further analysis, the Authority is of the view that short-range vehicular radar (SRR) applications can significantly enhance the safety of drivers and other road users. In case the authorisation and assignment-exempt use of the 77-81 GHz band is permitted for automotive radars in India, it will enable the benefits of automotive radars to enhance road safety in the country while leveraging on the worldwide technical development. As the 77-81 GHz band is a globally harmonized band for short range automotive radar applications; and many countries have allowed the license-exempt use of 77-81 GHz band for automotive radar applications, an authorisation and assignment-exempt use of 77-81 GHz band for automotive radar applications would provide international economies of scale for research and development in this field in the country. Further, the technical parameters of automotive radar systems operating in the 77-81 GHz band (Radar B, Radar C, Radar D and Radar E) as recommended by ITU, through its recommendation ITU-R M.2057-1, may be adopted to reap the benefits of the globally aligned technical parameters for automotive radar applications.

2.93 In view of the above, **the Authority recommends that:**

(a) The 77-81 GHz frequency range should be opened for authorisation and assignment-exempt operations of automotive radar systems in India.

(b) Technical parameters given in the Table 1 of the ITU's Recommendation ITU-R M.2057-1 (01/2018) on 'System characteristics of automotive radars operating in the frequency

band 76-81 GHz for intelligent transport system applications'[65] should be adopted for authorisation and assignment-exempt operations of automotive radar systems in the 77-81 GHz frequency range.

2.94 The following chapter lists a summary of recommendations.

[65] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2057-1-201801-I!!PDF-E.pdf

Chapter-III: Summary of Recommendations

3.1 The Authority recommends that:

(a) The Government should introduce a new experimental authorisation for the spectrum in the 95 GHz to 3 THz range. The authorisation may be termed as 'Tera Hertz Experimental Authorisation' (in short, THEA).

(b) The authorisation framework for THEA should be as below:

i. <u>Purpose</u>: The purpose of THEA should be to promote Research & Development (R&D), indoor and outdoor testing, technology trial, experimentation, and demonstration in the 95 GHz to 3 THz range.

ii. <u>Eligibility condition</u>: Any Indian Entity (Academic institute, R&D Laboratory, Central/ State Government, public sector unit, Union Territory, Technology Park, telecommunication service provider, incubator, original equipment manufacturer etc.) should be eligible to obtain THEA.

iii. <u>Application for THEA</u>: The entire process for application and grant of THEA should be online. The applicant should include a narrative statement describing in detail how its experiment could lead to the development of innovative devices and/or services in the 95 GHz to 3 THz range and an interference analysis. Unless a sufficient methodology for preventing harmful inference is detailed by the applicant, such operations should not be permitted. Certain parameters of the applications should be required to be disclosed publicly including frequency(s), type of emissions, power, and location. The applicants that propose to use spectrum exclusively allocated for passive use(s), should be required to provide an explanation why nearby bands with non-passive allocations are not appropriate or adequate for the experiment and

acknowledge that they intend to transition any potential long term use to a band with appropriate allocations. The applicant should identify a single point of contact (SPOC) responsible for all operations conducted under THEA and for ensuring compliance with applicable laws apart from rules, regulations and instructions issued by the DoT.

iv. **Geographical area: The applicant should be required to define the geographical area where it proposes to use the frequencies assigned under THEA with a justification. The applicant should be allowed to conduct its operations over any area, except in restricted areas, identified by the Central Government.**

v. **Authorisation period: The authorisation period of THEA should be up to five years. The authorisation should be further extendable for periods of up to five years at a time.**

vi. **Scope: The scope of THEA should be to conduct R&D, indoor and outdoor testing, technology trial, experimentation, and demonstration in the 95 GHz to 3 THz range; and to market experimental devices designed to operate in the 95 GHz to 3 THz range via direct sale.**

vii. **Assignment of spectrum: Applicants for THEA should be permitted to request assignment of any frequency in the range of 95 GHz to 3 THz. No exclusive assignment of spectrum should be given under THEA. The assignment of spectrum should be given on a 'Non-interference basis and Non-protection Basis' (NIB/ NPB). The Authorised Entity should not be permitted to claim any protection from the allocated services including secondary services and incumbent users.**

viii. **Provision of termination, modification, or relocation of experimentation: The spectrum in the 95 GHz to 3 THz range should be assigned to the Authorised Entity subject**

to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use will entail termination, modification, or relocation of any test or experimentation being carried out in the said spectrum band.

ix. <u>Special conditions for marketing experimental devices</u>: Marketing of experimental devices designed to operate in the 95 GHz to 3 THz range should be permitted under THEA via direct sale. If the Authorised Entity opts to market experimental devices designed to operate in the 95 GHz to 3 THz range, it should be mandated to uniquely identify each experimental device (e.g., through a serial number) in a manner that would enable it to easily track each device. The Authorised Entity should be mandated to provide an on-demand access to the tracking mechanism to the Government. At the time of sale, the Authorised Entity should be mandated to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the Authorised Entity or the Central Government, and the device will be surrendered or rendered inoperable at the conclusion of the experiment. The Authorised Entity should be mandated to ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial. Additionally, each experimental device sold should be mandatorily labelled as "Authorised Under THEA and may be subject to further conditions including termination of operation" and carry with it an Authorised Entity assigned device identification number to be issued by the WPC Wing of the DoT. The authorized entity should provide an undertaking of not claiming any third-party right on account of the

marketing of experimental devices. There should be a provision that the Central Government may prescribe any test/ measurement etc. from health safety/ environment safety/ EMI/ EMC etc. as per the international practice, in case the Authorised Entity intends to market experimental devices.

x. <u>Reporting requirement</u>: The Authorised Entity should provide a report on the progress of use cases to the Government on an annual basis.

xi. <u>Authorisation fee</u>: The authorisation fee for THEA should be Rs. 1,000 for a period up to five years.

[Para No. 2.31]

3.2 The Authority recommends that:

(a) The authorisation and assignment-exempt operations should be permitted in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in India.

(b) Initially, the technical specifications provided in the FCC's eCFR [Title 47, Chapter I, Subchapter A, Part 15, Subpart C, item 15.258] on 'Operation in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz' may be adopted for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands in the country. After obtaining inputs from the Telecom Engineering Center (TEC), the technical arm of the DoT, the technical specifications for the authorisation and assignment-exempt operations in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency bands may be modified, if required.

[Para No. 2.75]

3.3 The Authority recommends that:

(a) The 77-81 GHz frequency range should be opened for authorisation and assignment-exempt operations of automotive radar systems in India.

(b) Technical parameters given in the Table 1 of the ITU's Recommendation ITU-R M.2057-1 (01/2018) on 'System characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport system applications' should be adopted for authorisation and assignment-exempt operations of automotive radar systems in the 77-81 GHz frequency range.

[Para No. 2.93]

Annexure-I

DoT's Reference Dated 08.12.2022

R-14019/01/2022-SG

I/3073157/2022

Government of India
Ministry of Communications
Department of Telecommunications
Wireless Planning & Coordination (WPC) Wing

6th floor, Sanchar Bhawan,
20, Ashoka Road, New Delhi – 110001.

No.: R-14019/01/2022-SG Date: 08.12.2022

To,

The Secretary
Telecom Regulatory Authority of India
Mahanagar Doorsanchar Bhawan
Jawahar Lal Nehru Marg (Old Minto Road)
New Delhi-110002.

Subject: Seeking TRAI recommendations on Open and De-licensed use of unused or limited used Spectrum bands for demand generation for limited period in Tera Hertz range.

Sir,

In various parts of the world, administrations, with a view to encourage technology development, have come up with regulations allowing conduct of experiments in the spectrum bands beyond 95 GHz. Accordingly, it has been decided to encourage the development of new communications technologies and new services in the country in the spectrum ranges above 95 GHz.

2. In view of the above, a Committee was constituted under the Chairmanship of Wireless Adviser to give its recommendations on the issue. The Committee has submitted its report (copy enclosed for ready reference) . The summary of recommendations of the Committee is given below:

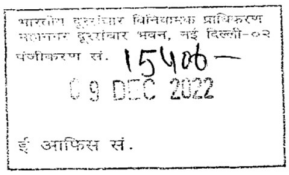
a. The spectrum beyond 95 GHz and upto 3 THz may be opened for experiments under 'Spectrum-Terahertz Applications License'. There shall not be any restriction on technical condition for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services.
b. The frequency bands, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz may be opened for unlicensed use. Initially FCC's Technical specifications may be adopted. After study in Indian environment, technical parameters may be revised.
c. The frequency band 77-81 GHz band may also be delicensed for automotive radar applications in line with international practice.

3. However, with a view to come up with a well-rounded regulatory regime on the subject matter, it was considered appropriate to seek TRAI recommendation as well. Therefore, under the terms of clause 11 (1)(a) of TRAI Act, 1997 as amended by TRAI Amendment Act 2000, TRAI is requested to provide recommendations on the following:

(a) Terms and Conditions for opening of spectrum beyond 95 GHz and upto 3 THz for experiments under a regime which may be named as *'Spectrum-Terahertz Applications License'* for 'Experiment' and 'Demonstration' of equipment designed to operate on any frequency above 95 GHz while protecting any *"Passive"* services in these frequency ranges. The licensees may also be permitted to market such experimental devices via direct sale. The regime may be opened for a defined period.

(b) Terms and conditions including technical parameters for permitting licensed-exempt operations in 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz frequency ranges, while protecting both passive and active services in and around these frequency ranges

(c) Terms and conditions including technical parameters for permitting licensed-exempt operations in 77-81 GHz band for automotive radar applications in line with international practice.



I/3073157/2022

(d) Any other techno-regulatory recommendations relevant to the issue.

4. This issues with the approval of the competent authority.

(Gulab Chand)
Joint Wireless Adviser

Encl: As above (Report of the Committee)

Report of the Committee on Open and De-License Unused or Limited Used Spectrum Bands for Demand Generation for Limited Period Including THz Band

Table of Contents

1. Introduction

1.1 Radio spectrum is lifeline for wireless communication. Innovation in wireless technology makes possible to use of those frequency bands which were thought of unusable in past. Radio frequency is considered upto 3 THz, which often viewed as the transition point from radio technology to infrared technology. Presently, radio spectrum upto 95 GHz is in use and radio spectrum beyond 95 GHz is yet to put in use. There are substantial opportunities for innovation in these frequencies, especially for high-bandwidth applications as well as imaging and sensing operations.

1.2 Advancements in research and technology development have allowed for the inception of new products and applications using spectrum in higher frequency bands. The frequency beyond 95 GHz are characterized by short propagation distances and small wavelengths, and availability of large contiguous bandwidths, which make them suited for a range of applications. The propagation characteristics of frequency above 95 GHz permits least interference to the existing services such as Earth exploration-satellite service, radio astronomy service, space research service, inter-satellite service and fixed and mobile services, which make suitable for coexistence of numerous short range applications.

1.3 To encourage the development of new communications technologies and expedite the deployment of new services in the spectrum above 95 GHz, worldwide various administrations have made regulations to conduct experiment in the spectrum band beyond 95 GHz. Accordingly, Indian administration has also desired to open radio spectrum beyond 95 GHz for experiment.

1.4 A Committee with the following composition has been constituted to give its recommendations for Open and De-license unused or limited used Spectrum bands for demand generation for limited including THz band in view of Post-budget webinar on "Technology enabled Development" held on 02.03.2022 "Breakaway session 1: Building a strong 5G ecosystem for Service Delivery" organized by the Government.

1. Shri R.K. Saxena, Wireless Advisor -Chairman
2. Prof. Abhay Karindkar, Director, IIT Kanpur – Co Chair
3. Shri YGSC Kishore Babu, DDG (SRI) – Member
4. Shri V.J. Christopher, Director WMO – Member
5. Shri M.K. Pattanaik, Sr. DWA (Sat)- Member
6. Shri. P.S.M. Tripathi, DWA (Security)- Member Convener

1.5 The Term of Reference (TOR) of the above committee is under:

To give its recommendations for Open and De-license unused or limited used Spectrum bands for demand generation for limited period including THz band.

1.6 The Committee met several times and provided valuable inputs for the report. The summary of recommendations of the Committee is given below:

- The spectrum beyond 95 GHz and upto 3 THz may be opened for experiments under 'Spectrum-Terahertz Applications License'. There shall not be any restriction on technical condition for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services.

- The frequency bands, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz may be opened for unlicensed use. Initially FCC's Technical specifications may be adopted. After study in Indian environment, technical parameters may be revised.

- The frequency band 77-81 GHz band may also be delicensed for automotive radar applications in line with international practice.

2. Terahertz (THz) Radio Spectrum

2.1 The terahertz (THz) band is the part of the electromagnetic waves in the frequency between 100 GHz–30 THz i.e. between microwaves and infrared waves. It is also called the sub-millimetre band. The THz band offers a much larger bandwidth, which ranges from tens of GHz up to several THz and suitable for Nano cell. THz communication system is highly directional, more energy efficient, less latency, less susceptible to free space diffraction and able to address the capacity limitations of current wireless systems. At 100 GHz the wavelength is 3 mm, halving to 1.5 mm at 200 GHz, etc. This means that modest size antennas can have dimensions that are many wavelengths so their beams can have well focused mean beams.

2.2 According to Friis Law, free space propagation loss is directly proportional to square of frequency. Therefore, high propagation loss drastically reduces the coverage with THz communication system. Besides free space loss, atmospheric absorptions (e.g., oxygen and water molecule absorptions) resulting in additional path loss. This atmospheric absorption varies with frequency, humidity and altitude, generally increasing in frequency and decreasing with altitude although at certain frequencies with strong molecular resonances. However, atmospheric absorption has not any fixed pattern. In general, atmospheric absorption increases with frequency but exhibit high absorption at some of the frequency. The absorption peaks create spectral windows, which drastically change with the variation of the distance.

2.3 As per Radio Regulation, allocation of radio spectrum beyond 100 GHz are allocated largely to Radio Astronomy and Satellite based services such as Earth Exploration Satellite, Space Research, Amateur Satellite, Radio Navigation Satellite and Mobile Satellite etc. on primary basis. Besides Satellite and Radio Astronomy, allocation has also been made for Fixed and Mobile services as Primary services in 12 frequency bands with about 100 GHz spectrum between 100-275 GHz, which accounts more than 55% of total

spectrum available between 100-275 GHz. The percentage of allocation to different services in the frequency band 100-275 GHz is given in Table.

S. No.	Service	Allocated Bandwidth* (in GHz)	Allocation (in %)
1	Fixed	97.20	55.54
2	Mobile	97.20	55.54
3	Earth Exploration Satellite	58.80	33.6
4	Space Research	70.75	40.43
5	Inter Satellite	35.23	20.13
6	Fixed Satellite	35.00	20
7	Mobile Satellite	33.71	19.26
8	Amateur	4.01	2.29
9	Amateur Satellite	4.01	2.29
10	Radio Astronomy	107.80	61.6
11	Radiolocation	21.51	12.29
12	Radionavigation	30.21	17.26
13	Radionavigation Satellite	30.21	17.26

* More than one services shared the same band

2.4 The initial allocations above 100 GHz were made at WARC-79 and most of the present allocations, include a large number of passive allocations were made at WRC-2000. Most of the passive allocations are included in Radio Regulation 5.340 (RR5.340).

2.5 The passive allocations above 100 GHz appear to have a major impact on the potential of other radio services in this area where demand and technology are now developing. This was anticipated at WRC-2000 and included as an integral part of the decision for these allocation ITU-R studies under Resolution 731. to explore the feasibility of sharing subject to explicit quantitative protection goals.

2.6 There is no allocation beyond 275 GHz in Radio Regulation. However, WRC-19 introduced a footnote 5.564A for making allocation for frequency

band 275-450 GHz for land mobile and fixed services, allow the coexistence of fixed and land mobile services with active and passive services in the frequency band 275-1000 GHz. Specifically, the radioastronomy service occupies 275-450 GHz, while the earth exploration-satellite and space research services operates in 296-306 GHz, 313-318 GHz and 333-356 GHz bands. The footnote also allows the frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz for the implementation of land mobile and fixed service applications without protection to Earth exploration-satellite service (passive) applications. Further, frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications vide footnote 5.565. These two footnotes are stated as below:

> ***5.564A*** *For the operation of fixed and land mobile service applications in frequency bands in the range 275-450 GHz:*
>
> *The frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz are identified for use by administrations for the implementation of land mobile and fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications.*
>
> *The frequency bands 296-306 GHz, 313-318 GHz and 333-356 GHz may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution* ***731 (Rev.WRC-19)****.*
>
> *In those portions of the frequency range 275-450 GHz where radio astronomy applications are used, specific conditions (e.g. minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio astronomy sites from land mobile and/or fixed service applications, on a case-by-case basis in accordance with Resolution* ***731 (Rev.WRC-19)****.*
>
> *The use of the above-mentioned frequency bands by land mobile and fixed service applications does not preclude use by, and does not establish priority over, any other applications of radio services in the range of 275-450 GHz. (WRC-19).*

5.565 The following frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications:

– radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;

– Earth exploration-satellite service (passive) and space research service (passive): 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz.

The use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range.

All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services. (WRC-12)

2.7 WRC-15/19 has framed the following two study questions:

QUESTION ITU-R 256-1/5 on Technical and operational characteristics of the land mobile service in the frequency range 275-1 000 GHz under which sharing studies between the land mobile and passive services, as well as the land mobile and other active services should be carried out.

QUESTION ITU-R 257-1/5 on Technical and operational characteristics of the fixed service in the frequency range 275-1 000 GHz under which sharing studies between the fixed and other active services should be carried out.

2.8 The study is being undertaken by Working Party 5A and 5C for Question 256-1/5 and 257-1/5 respectively. Study will be undertaken during the two study cycles i.e. 2015 to 2019 and 2019 to 2023 and responses will be

discussed during the WRC-23. The results of these studies shall be in form of ITU's Recommendations, Reports or Handbooks. The above questions are given at Annexure-I.

2.9 Further, WP 5D is also preparing a document on propagation models for the radio waves above 100 GHz for various scenarios including indoor/outdoor in the form of Report. The proposed report would include information on propagation environment and channel models, as well as newly developed technology enablers such as active and passive components, antenna techniques, deployment architectures, and the results of simulations and performance tests.

2.10 The applications of THz frequencies include (shown in figure); high data-rate communications and applications, sensing applications, high precision positioning applications, high density applications, and backhaul infrastructure etc. Further, due to the short wavelengths, THz frequencies are particularly well suited for sensing applications, including health screening, non-invasive quality assurance in pharmaceutical and manufacturing industries, high-resolution positioning, high-density applications and security systems.

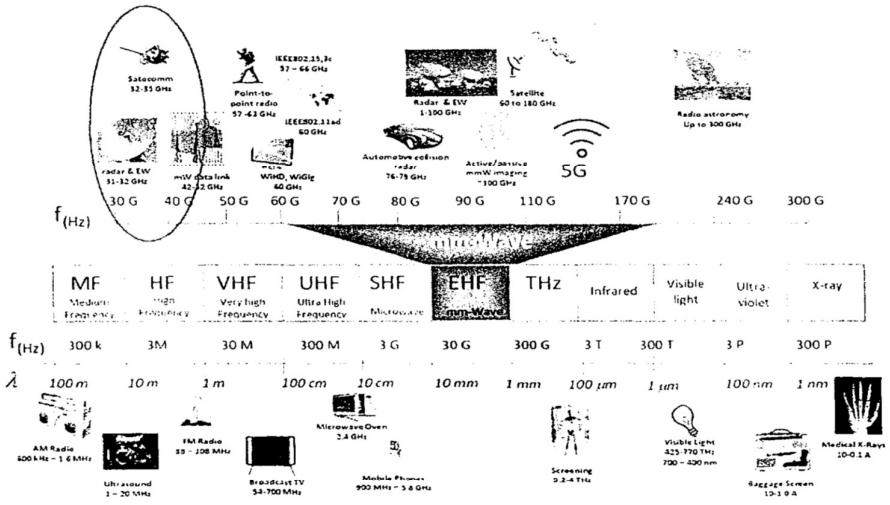


Figure: Terahertz Applications

2.11 Currently, lower terahertz frequency band 95-120 GHz is important for fixed broadband wireless services. As per NFAP 2018, the frequency band 95-120 GHz is allocated for Fixed, Mobile, Radio astronomy, Radionavigation, Radiolocation, Space-research, earth exploration satellite, and Inter-satellite. Out of 25 GHz, 15.7 GHz is allocated for Fixed service as primary service along with other primary services. The rain and gas attenuation is less than 25dB/Km and 1dB/Km respectively. Therefore, gas attenuation is not a dominant factor for this frequency band. It may also be noted that this band is not much affected by Oxygen absorption peaks. The band is most suitable for High Capacity Systems, Mobile backhaul and fronthaul and able to support all services requiring very high speed wireless transmission, drive to the higher part of the spectrum.

2.11 The anticipated massive growth in wireless data traffic require due to introduction of 5G services, backhaul capacity must also continue to increase substantially. Therefore, more backhaul capacity is needed to support the evolving needs of increasing 5G and beyond traffic and number of connected devices. Spectrum above 95 GHz supports wider channels and has higher backhaul capacities.

2.12 The frequency beyond 95 GHz is also well suited for Machine to Machine (M2M) communication. It also supports Industry 4.0 applications, i.e. the next generation of industrial Internet of Things.

2.13 The sixth-generation (6G) wireless system, fully supported by artificial intelligence, will become the dominant paradigm for wireless. 6G is also expected to merge communications and sensing in a new way, and the wide bandwidth needed for data will also benefit many high-precision sensing applications. Therefore, sub-terahertz (subTHz) territory is the focus of active research for 6G communications.

3. International Regulations for Radio Spectrum beyond 95 GHz

3.1 Federal Communication Commission (FCC), USA

(A) Licensed Operation:

- The FCC has created a new experimental radio license, the Spectrum Horizons Experimental Radio License (Spectrum Horizons License), that will be available for experiments and demonstrations of equipment designed to operate exclusively on any frequency above 95 GHz and 3THz.

- These Spectrum Horizons License features should promote a more rapid development of new products and services that will reach a larger number and wider variety of users than would be possible under the existing experimental licensing rules. This would foster an environment where innovators can develop new products and applications absent unnecessary limitation.

- There is no restriction on technical condition for designing and conducting experiments and tests.

- Spectrum Horizons License will be required to show how the experimental operations (and any related devices) will be controlled so that they do not cause harmful interference to other services. Further, Spectrum Horizons License operations will not be entitled to exclusive use; will not be protected from harmful interference from allocated services; and will be prohibited from causing harmful interference to authorized services, including secondary services.

- A Spectrum Horizons License may be authorized over any geographic area.

- Spectrum Horizons Licenses broadly available to persons qualified to conduct the types of operations described in existing experimental radio service rules.

- These licenses will give innovators the flexibility to conduct experiments lasting up to 10 years without further renewal.

- All bands between 95 GHz and 275 GHz are allocated on a shared basis. Above 275 GHz, while there are no allocations, a number of bands are identified for use by passive services. Accordingly, Spectrum Horizons Licenses, will only be granted on a non-interfering basis, only following coordination with existing users and unless a sufficient methodology for preventing harmful interference is detailed, such operations will not be permitted.

- Spectrum Horizons License applicants that propose to use spectrum exclusively allocated for passive use(s), must provide an explanation why nearby bands with non-passive allocations are not appropriate or adequate for the experiment and also acknowledge that they intend to transition any potential long-term use to a band with appropriate allocations.

(B) Unlicensed Operations:

- FCC has also free up 21.2 GHz of the Spectrum Horizons bands for unlicensed use: the 116-123 GHz band, the 174.8-182 GHz band, the 185-190 GHz band, and the 244-246 GHz band. These devices would operate on a non-interference basis while protecting both passive and active services. The services operating in these identified bands are EARTH EXPLORATION-SATELLITE (passive), RADIO ASTRONOMY and SPACE RESEARCH (passive).

- Devices may operate in all of these bands with a maximum EIRP of 40 dBm (average) and 43 dBm (peak), measured with a detection bandwidth that encompasses the band of operation.

- It also permits outdoor fixed point-to-point devices to operate with a higher maximum EIRP of 82 dBm (average) and 85 dBm (peak), also measured with a detection bandwidth that encompasses the band of operation.

- Use of the higher power limits also requires that devices use antennas with a minimum gain of 51 dBi, with a 2 dB reduction in the maximum permissible EIRP for each dB the antenna gain falls below 51 dBi. These highly directional antennas with very narrow beam widths will ensure that the likelihood of harmful interference is minimized.

- Unlicensed devices have to comply with an out-of-band emission limit of 90 picowatts per square centimeter at a distance of three meters.

- No equipment will be permitted to operate on satellites or onboard aircraft.

- Equipment operating in the 174.8-182 GHz and 185-190 GHz bands should not be designed to operate in the 182-185 GHz band

3.2 Office of Communications (Ofcom), United Kingdom

- Ofcom has made available the Spectrum Access in Extremely High Frequency (EHF) band on a non-protection and non-interference basis, with use of multiple devices to support research, innovation and the development and use of new products and applications.

- The following bands has been made available:
    - 57-71GHz
    - 116-122 GHz
    - 174.8-182 GHz
    - 185-190 GHz

- These bands can be shared on uncoordinated basis across the UK with use of multiple devices within the licence band, provided that these meet the licence technical conditions.

- Each licence costs £75, which is payable every five years.
- The maximum permitted equivalent isotropically radiated power (EIRP) is 55 dBm. For outdoor use of 100-200 GHz equipment only, there are additional power limits on EIRP at angles relative to the main beam in the elevation plane.

- "Indoor" means inside premises which: (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed.

Table: Power limits and restrictions on outdoor use

Power limits (*max EIRP in dBm*) and emissions restrictions on outdoor use			
USE	**116-122 GHz**	**174.8-182 GHz**	**185-190 GHz**
Indoor	55	55	55
Outdoor	55	55	55
Restrictions on outdoor use of equipment	When devices are used outdoors, the main beam elevation angle (φ) of licensed devices shall not exceed 20° above horizontal.		
Airborne use	Airborne use not permitted.		

Other usage conditions	For all systems using bandwidths of less than 100 MHz, all of the above EIRP limits must be adjusted as follows: $EIRP\ Reduction = 10\ x\ \log_{10}(^{BW_{MHz}}/_{100})$

- For outdoor use of 100-200 GHz equipment only, the main beam elevation angle of the device must not exceed 20 degrees above horizontal. There are no elevation angle restrictions for indoor use.
- Any out-of-band emissions must be limited to -10 dBm/MHz EIRP.
- Devices must not be used airborne. This means they cannot be used onboard or attached to an aircraft, drone or balloon.
- The licence has an indefinite duration.
- For any mobile use, accurate records must be kept for the postal address (including postcode) and National Grid Reference (to 1m resolution) of the centre of any 5km radius within which the radio equipment is used.
- If a mobile device operates over an area with a radius larger than 5km, records must be kept for the centre of as many 5km radius areas as are required to reflect the areas of use.

3.3 Ministry of Internal Affairs and Communications (MIC), Japan

- In 2015 MIC make 18 GHz of spectrum available 116-134 GHz for "Commercial Telecommunications Service" subject to the provision that "all practicable steps shall be taken to protect the radio astronomy service from harmful interference" in parts of the band. Japan authorities are currently studying future regulation for the 110-174.8

GHz band (which includes part of both D and W bands) for fixed service.

3.4 CEPT Regulation

- European Conference of Postal and Telecommunications Administrations CEPT released a report in September 2018 (ETSI GR mWT 018 V1.1.1 (2019-08) on point-to-point links in frequency ranges 92-114.25 GHz and 130-174.8 GHz, referred to as the W-band and D-band, respectively. The report provides information, considerations and application use cases in the W and D bands and discusses the flexible and efficient use of these bands.

- The European Union (EU) has already adopted harmonized standards, (ETSI EN 305 550-1 and ETSI EN 305 550-2), which allow short range devices (SRDs) to operate between 40 GHz and 246 GHz includes provisions for such devices at 122.0–122.25 GHz and 244–246 GHz. SRDs are allowed to operate at a maximum e.i.r.p. of 10 dBm in the 122-122.25 GHz band and at a maximum e.i.r.p. of 20 dBm in both the 122.25-123 and the 244-246 GHz bands. Unlike the Japanese provisions, power limits are given, and they are quite modest at 20 dBm effective isotropic radiated power (EIRP).

4. Recommendations of the Committee

4.1 Spectrum above 95 GHz

4.1.1 Considering the requirements of emerging new radiocommunications technologies, to promote R&D activities, indoor/outdoor testing/ experimentation in the field of wireless radiocommunications and also to promote Make in India in wireless products, and international practices, the committee recommends that a new experimental radio license category 'Spectrum-Terahertz Applications License (STAL)' may be created that will

(Also refer to the note on Page 22)

be applicable for 'Experiment' and 'Demonstration' of equipment designed to operate exclusively on any frequency above 95 GHz.

4.1.2 As per available frequency assignment, there are very few assignments above 95 GHz. The spectrum beyond 95 GHz is considered to be vacant, therefore, spectrum beyond 95 GHz and upto 3 THz may be opened for experiments under 'Spectrum-Terahertz Applications License'.

4.1.3 It is anticipated this new License will make experimentation more attractive, resulting in a greater number of thoughtful and innovative experiments. Such experiments are vital for the development of new applications and services suited for the unique properties of the bands above 95 GHz. It would promote a more rapid development of new products and services that will reach a larger number and wider variety of users than would be possible under the existing experimental licensing rules.

4.1.4 Any Indian National or any Indian Entity (Academic institutes, R&D Labs, Central/State Governments or their PSUs, UTs, Technology parks, TSPs, incubators, industry partners, OEMs etc.) may be allowed. The other eligibility criteria may be kept similar to the existing experimental license to encourage wider participation.

4.1.5 There shall not be any restriction on technical condition for designing and conducting experiments and tests provided they should not cause harmful interference to existing services including secondary services.

4.1.6 No exclusive assignment should be given under 'STAL'. The assignment will be given on 'Non-interference basis and Non-protection basis' (NIB/NPB). The operations under the license would also not claim any protection from allocated services or incumbent users.

4.1.7 The License may be given initially for five years and further extendable for periods of five years at a time with an interim report to be submitted at the time of each renewal for an experiment considering research/innovation is a time taking process and short duration license would not give desired result.

4.1.8 The applicant may submit details of experiment to be undertaken along with possible outcomes and interference mitigation techniques that may be required to protect the existing users

4.1.9 There should not be any restriction on geographical areas for STAL. The user may be allowed to request operations over any area, except restricted areas, that they deem appropriate for their experiment.

4.1.10 The spectrum assignment is subject to the condition that such spectrum, if subsequently assigned for regular (commercial, strategic, etc.) use will entail termination/modification/relocation of any test or experimentation being carried out in the said spectrum band. In the event, user will be offered alternative spectrum band. If alternative spectrum band is not feasible, the user will be allowed to continue experiment till the completion of license period in coordination with the licensed assignees.

4.1.11 The licensees will be permitted to market experimental devices designed to operate in the bands above 95 GHz via direct sale. The characteristics of signals in the bands above 95 GHz effectively limit the range of each device to such an extent that a larger number of devices can operate without increasing the potential of harmful interference to authorized services. However, the licensees shall ensure that trial devices are either rendered inoperable or retrievable at the conclusion of the trial. Additionally, each device sold under this program must be labeled as "Authorized Under STAL and may be subject to further conditions including Termination of Operation" and carry with it a licensee assigned equipment ID number to be issued by WPC, DOT. Licensees who take advantage of these marketing provisions must uniquely identify each device (e.g., through a serial number) in a manner that will enable them to easily track each one. Finally, at the time of sale, the licensee is required to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the licensee or the licensor, and the device will be surrendered or rendered inoperable at the conclusion of the experiment.

4.1.12 Government may prescribe any test/measurement etc. from health safety/environment safety/EMI/EMC etc. as per international practice, if case application wants to market experimental devices.

4.1.13 The Committee recommends that applicant will have to Rs.1000/- towards spectrum charges for 5 years.

4.2 Delicensed Bands

4.2.1 FCC has offered four different bands namely, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz under unlicensed category. Ofcom has made available frequency bands 116-122 GHz, 174.8-182 GHz and 185-190 GHz on a non-protection and non-interference basis. CEPT has also recommended frequency bands 122.0–122.25 GHz and 244–246 GHz for unlicensed use.

4.2.2 Considering the international practice and to gain the advantage of scale of economy, the frequency bands, 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz may be opened for unlicensed use. As per NFAP 2018, allocation in these bands are as under:

Band (GHz)	Current Allocation
114.25-116	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive)
116-122.25	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
122.25-123	FIXED INTER-SATELLITE MOBILE Amateur

174.8-182	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
185-190	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
244-246	RADIO ASTRONOMY RADIOLOCATION Amateur Amateur-satellite

Note: Frequency band 122-123 GHz and 244-246 GHz are ISM bands and regulate in accordance with RR provision 5.138

4.2.3 The devices in above bands would operate on non-interference and non-protection basis while protecting both passive and active services running in these bands and adjacent bands. Services such as earth exploration satellite, and radio astronomy services in these bands and adjacent bands require stringent protection criteria as these services received signal from space. There is no risk of harmful interference from unlicensed devices to space research service (passive) because stations in this service are space-based and looking away from earth. The other services namely fixed service, mobile service and radiolocation services have not yet been deployed due to non-availability of eco system. Therefore, protection criteria for these services may not be required at this stage. The inter-satellite service operates solely between satellites in space and therefore there is no significant risk of harmful interference from relatively low power unlicensed devices operating on the Earth.

4.2.5 Considering the scale of economy, technical parameters for unlicensed devices in above bands devised by the FCC may be adopted. The initial proposed technical parameters are as under:

- Devices may operate in all of these bands with a maximum EIRP of 40 dBm (average) and 43 dBm (peak), measured with a detection bandwidth that encompasses the band of operation.

- It also permits outdoor fixed point-to-point devices to operate with a higher maximum EIRP of 82 dBm (average) and 85 dBm (peak), also measured with a detection bandwidth that encompasses the band of operation.

- Use of the higher power limits also requires that devices use antennas with a minimum gain of 51 dBi, with a 2 dB reduction in the maximum permissible EIRP for each dB the antenna gain falls below 51 dBi. These highly directional antennas with very narrow beam widths will ensure that the likelihood of harmful interference is minimized.

- Transmitters with an emission bandwidth of less than 100 MHz must limit their peak radiated power to the product of the maximum permissible radiated power (in milliwatts) times their emission bandwidth divided by 100 MHz. The emission bandwidth is defined as the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer.

- The power density of any emissions outside the band of operation shall consist solely of spurious emissions. Unlicensed devices have to comply with an out-of-band emission limit of 90 picowatts per square centimeter at a distance of three meters. The levels of the spurious emissions shall not exceed the level of the fundamental emission.

- No equipment will be permitted to operate on satellites or onboard aircraft. This means they cannot be used onboard or attached to an aircraft.

- Equipment operating in the 174.8-182 GHz and 185-190 GHz bands should not be designed to operate in the 182-185 GHz band

4.2.4 It may be noted that Indian environment namely; temperature, wind speed and rain conditions are different than other parts of the globe. Therefore, limit on transmit power, beamwidth etc. may be different from other parts of the world for Indian environment. It is recommended that FCC's technical parameters may be adopted initially and after conducting intensive research in Indian environment, technical parameters may accordingly be modified at later stage.

4.3 Frequency Bands between 40 GHz and 95 GHz

4.3.1 It may be noted that Government has already in the process for making regulations for V Band (57 GHz to 66 GHz) and E Band (71-76 GHz/81-86 GHz). The frequency band 76-77 GHz has already been delicensed, vide G.S.R 699 (E) dated 16.09.2015, for the purpose of usage of very low power Radio Frequency devices or equipments for short range radar systems.

4.3.2 Department of Telecom has constituted a Committee for implementation of V2X in the country. Frequency bands 76-77 GHz and 77-81 GHz are being used for long range radar and short & medium range radars respectively for V2X application.

4.3.3 The Federal Communications Commission (FCC) and the Ministry of Internal Affairs and Communications (MIC) in Japan have designated 76-77 GHz band for automotive radar. MIC, Japan has also recommended introduction of high-resolution radar in 77-81 GHz band for safety related applications. The European Conference of Postal & Telecommunications (CEPT) has designated the band 77-81 GHz for automotive radars. The European Telecommunications Standards Institute (ETSI) has adopted the harmonized standard in the frequency band 77-81 GHz for the applications of short range radars. FCC has also allowed 77-81 GHz band for vehicular radar operations aligning with rest of the world. Countries in Asia Pacific

Region have also designated 76-77 GHz and 77-81 GHz bands for short range automotive radar application for ITS. Therefore, the frequency bands 76-77 GHz and 77-81 GHz are globally harmonised bands for short range automotive radar applications.

4.3.4 It is recommended that frequency band 77-81 GHz band may also be delicensed for automotive radar applications in line with international practice.

May please also see the NOTE below.

Abhay Karandikar, Director, IIT Kanpur Member	V. J. Christopher Director (WMO) Member	Y G S Kishore Babu DDG(SRI) Member
M. K. Pattanaik Sr. Deputy Wireless Adviser Member	R K Saxena Wireless Adviser Chairman	P S M Tripathi Deputy Wireless Adviser Member

note: Additional specific recommendations from Prof Abhay Karandikar, Director, IITK and YGSC Kishore Babu, DDG(SRI) are placed at Annexure II on Page 27. wants frequency bands between 40 GHz and 95 GHz to enable enhanced utilization of 57-66 GHz and other IMT bands recognized in WRC-2019.

Region have [illegible] designated 76-77 GHz and 77-81 GHz bands [illegible] automotive radar application for ITS. Therefore, the frequency [illegible] GHz and 77-81 GHz are globally recognised band for [illegible] automotive radar applications.

[illegible] It is recommended that frequency band 77-81 GHz [illegible] delicensed for automotive radar applications in line with [illegible] practice.

[illegible]

Abhay Karandikar
Director, IIT Kanpur
Member

V. J. Christopher
Director (WMO)
Member

[illegible] Babu
[illegible]
Member

M. K. Pattenaik
Sr. Deputy Wireless Adviser
Member

R. K. Saxena
Wireless Adviser
Chairman

Annexure-I

QUESTION ITU-R 256-1/5

Technical and operational characteristics of the land mobile service in the frequency range 275-1 000 GHz

(2015-2019)

The ITU Radiocommunication Assembly,

considering

a) that there is a growing demand for high speed and large capacity radiocommunications having data rates of several tens of Gbit/s to over 100 Gbit/s for land mobile service applications;

b) that due to progress in the recent terahertz technologies, the integrated devices and circuits operating above 275 GHz can achieve various sophisticated applications;

c) that the above devices and circuits could provide such high speed and large capacity radiocommunications for land mobile service systems;

d) that standard development organizations such as IEEE are developing standards for terahertz wireless systems which utilize the broadband contiguous bandwidth larger than 50 GHz using the frequency range above 275 GHz;

e) that broadband contiguous bandwidths larger than 50 GHz for the land mobile service are not available in the frequency range below 275 GHz;

f) that certain parts of the frequency range 275-1 000 GHz are identified in Radio Regulations No. **5.565** for use by administrations for passive service applications;

g) that the use of the frequency range 275-1 000 GHz by the passive services does not preclude the use of this range by active services;

h) that the technical and operational characteristics of the land mobile service need to be specified for sharing and compatibility studies with the passive service applications indicated in *considering f);*

i) that the frequency range 275-450 GHz has been studied under WRC-19 for use by the land-mobile and fixed services applications,

recognizing

a) that Report ITU-R RS.2431 "Technical and operational characteristics of EESS (passive) systems in the frequency range 275-450 GHz" provides the technical and operational characteristics of Earth Observation (passive) sensors in the frequency range 275-450 GHz;

b) that Report ITU-R SM.2352 provides the technology trends of active services in the frequency range 275-3 000 GHz;

c) that Report ITU-R RA.2189 initiated sharing studies between the radio astronomy service and active services in the frequency range 275-3 000 GHz,

decides that the following Question should be studied

What are the technical and operational characteristics of the land mobile service in the frequency range 275-1 000 GHz?

further decides

1 that sharing studies between the land mobile and passive services, as well as the land mobile and other active services should be carried out, taking into account the characteristics mentioned in *decides* as well as the relevant results of the studies under WRC-19;

2 that the results of studies in the frequency range 275-1 000 GHz should be brought to the attention of the other Study Groups, in particular, Study Group 7;

3 that the results of the above studies should be included in one or more Recommendations, Reports or Handbooks;

4 that the above studies should be completed by 2023.

QUESTION ITU-R 257-1/5

Technical and operational characteristics of stations in the fixed service in the frequency range 275-1 000 GHz

(2015-2019)

The ITU Radiocommunication Assembly,

considering

a) that there is a growing demand for high speed and large capacity radiocommunications having data rates of several tens of Gbit/s to sometime over 100 Gbit/s for fixed service systems;

b) that due to progress in the recent terahertz technologies, the integrated devices and circuits operating above 275 GHz can achieve various sophisticated applications;

c) that the above devices and circuits will be able to provide such high speed and large capacity radiocommunications for fixed service systems;

d) that the traffic demands for backhaul and fronthaul for mobile systems are increasing due to mobile broadband communications such as IMT-Advanced, IMT-2020 and future IMT;

e) that certain parts of the spectrum in the frequency range 275-1 000 GHz are identified in No. **5.565** for passive services in the Radio Regulations;

f) that the use of the frequency range 275-1 000 GHz by the passive services does not preclude use of this range by active services;

g) that the technical and operational characteristics of the fixed service need to be specified for sharing and compatibility studies with the passive service applications indicated in *considering f)*;

h) that the frequency range 275-450 GHz has been studied for use by the land-mobile and fixed services applications,

noting

a) that Report ITU-R SM.2352 provides the technology trends of active services in the frequency range 275-3 000 GHz;

b) that Report ITU-R F.2323 provides guidance on the future development of the fixed service operating in the millimetric-wave band;

c) that Report ITU-R RA.2189 initiated sharing studies between radio astronomy service and active services in the frequency range 275-3 000 GHz;

d) that Report ITU-R F.2416 provides technical and operational characteristics and applications of the point-to-point fixed service operating in the frequency band 275-450 GHz;

e) that Report ITU-R M.2417 provides technical and operational characteristics of land-mobile service applications in the frequency range 275-450 GHz;

f) that Report ITU-R RS.2431 provides the technical and operational characteristics of Earth Observation (passive) sensors in the frequency range 275-450 GHz,

decides that the following Question should be studied

What are the technical and operational characteristics of the fixed service in the frequency range 275-1 000 GHz?

further decides

1 that sharing studies between the fixed and passive services, as well as the fixed and other active services should be carried out taking into account the characteristics mentioned in *decides*;

2 that the results of studies in the frequency range 275-1 000 GHz should be brought to the attention of the other Study Groups;

3 that the results of the above studies should be included in one or more Recommendations, Reports, or Handbooks;

4 that the above studies should be completed by 2023.

ANNEXURE – II

Additional Recommendations of Prof. Abhay Karandikar and DDG (SRI) as the Members of the Committee

4.3 Frequency Bands between 40 GHz and 95 GHz

1. Band 57-66 GHz

The band 57-71 GHz, popularly known as V Band has been under diverse uses across the world. The WRC 2019 while examining the suitable bands for IMT, apportioned 66-71 GHz for IMT purposes. Further, during the CoS deliberations, the DoS was asked to restrict its services to 57 GHz and 57 GHz-66GHz would be used for telecom as below.

(v) 57 to 66 GHz

- *DoS agreed to limit the EESS services up to 57 GHz, so that the band 57-66 GHz is fully available to DOT for Wi-Fi / Public Wi-Fi, fixed links etc.*

Several countries have delicensed the band 57-66 GHz for innovative applications like Wi-Fi (Wi-Gig) and point to point links etc. The band also includes ISM band (60 GHz). This is envisaged to enable wireless homes, point to point links in rural and urban areas for households and enterprises. Analogy may be drawn how the 5GHz delicensed band has transformed backhaul and enterprise connectivity in both wi-fi, enterprises segments. It is also learnt a few lakhs of point to point links are established in the country in mobile and enterprise segments and also in rural areas apart from home wi-fi.

2. IMT Bands: 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz (WRC 2019)

Further, the IMT bands identified in WRC-2019, viz. 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz are still under development for devices and it may take several more years to build both equipment and device ecosystem. Even in the millimeter band, which is auctioned recently i.e. 24.25-27.5 GHz, only some part is sold and ecosystem is still evolving.

The above bands, yet to be opened in the country, may take several years to build devices and equipment as these frequencies have high attenuation. Hence, it is necessary to generate demand in these bands by opening the bands for TSPs, without any charges/fees for 5 years (extendable) for IMT services only for the products developed and deployed by domestic companies. This should permit marketing and selling of the said products. This will enable indigenous 5G / IMT products development and will also enhance bands' economic value. TSPs may be encouraged to take this opportunity to encourage development and deployment in their networks.

3. Recommendations

1. It is recommended to consider to delicense the band 57-66 GHz for all applications including access, Wi-Fi hotspots and point to point links.
2. The IMT bands in 45.5 GHz – 48.2 GHz, where there is no allocation for India on Primary basis may be taken up to include India in the respective foot-list.
3. The bands 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz, 66-71 GHz will be opened and made available freely to TSPs for development, deployment and sale of indigenously developed products by domestic companies for 5 years (extendable for additional period as may be necessary) for IMT services to generate demand and enhance its economic value[1].

7/10/22

(Prof. Abhay Karandikar), Director IITK **(YGSC Kishore babu) DDG (SRI)**

[1] Domestic Company is defined as those which are owned by resident Indian citizens as defined in the FDI Circular of 2017. A company is considered as 'Owned' by resident Indian citizens if more than 50% of the capital in it is beneficially owned by resident Indian citizens and / or Indian companies, which are ultimately owned and controlled by resident Indian citizens. Further, it should be a DSIR recognized entity holding IPR ownership in India and carrying out R&D activities in India.

Page 27

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(v) 57 to 66 GHz

- *DoS agreed to limit the EESS services up to 57 GHz, so that the band 57-66 GHz is fully available to DOT for Wi-Fi / Public Wi-Fi, fixed links etc.*

Several countries have delicensed the band 57-66 GHz for innovative applications like Wi-Fi (Wi-Gig) and point to point links etc. The band also includes ISM band (60 GHz). This is envisaged to enable wireless homes, point to point links in rural and urban areas for households and enterprises. Analogy may be drawn how the 5GHz delicensed band has transformed backhaul and enterprise connectivity in both wi-fi, enterprises segments. It is also learnt a few lakhs of point to point links are established in the country in mobile and enterprise segments and also in rural areas apart from home wi-fi.

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Further, the IMT bands identified in WRC-2019, viz. 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz are still under development for devices and it may take several more years to build both equipment and device ecosystem. Even in the millimeter band, which is auctioned recently i.e. 24.25-27.5 GHz, only some part is sold and ecosystem is still evolving.

The above bands, yet to be opened in the country, may take several years to build devices and equipment as these frequencies have high attenuation. Hence, it is necessary to generate demand in these bands by opening the bands for TSPs, without any charges/fees for 5 years (extendable) for IMT services only for the products developed and deployed by domestic companies. This should permit marketing and selling of the said products. This will enable indigenous 5G / IMT products development and will also enhance bands' economic value. TSPs may be encouraged to take this opportunity to encourage development and deployment in their networks.

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3. The bands 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz, 66-71 GHz will be opened and made available freely to TSPs for development, deployment and sale of indigenously developed products by domestic companies for 5 years (extendable for additional period as may be necessary) for IMT services to generate demand and enhance its economic value[1].

(Prof. Abhay Karandikar), Director IITK **(YGSC Kishore babu) DDG (SRI)**

[1] Domestic Company is defined as those which are owned by resident Indian citizens as defined in the FDI Circular of 2017. A company is considered as 'Owned' by resident Indian citizens if more than 50% of the capital in it is beneficially owned by resident Indian citizens and / or Indian companies, which are ultimately owned and controlled by resident Indian citizens. Further, it should be a DSIR recognized entity holding IPR ownership in India and carrying out R&D activities in India.

Government of India
Ministry of Communications
Department of Telecommunications
Wireless Planning & Coordination (WPC) Wing
6th Floor, Sanchar Bhawan, 20, Ashoka Road, New Delhi

No: L-14035/08/2022-BWA **Date: 16.06.2022**

Office Memorandum

Sub: Constitution of the committee for Open and De-license unused or limited used Spectrum bands for demand generation for limited period including THz band.

A committee with the following composition has been constituted with the approval of Member (T), Deptt. of Telecom to give its recommendations for Open and De-license unused or limited used Spectrum bands for demand generation for limited period including THz band in view of Post-budget webinar on "Technology enabled Development" held on 02.03.2022 "Breakaway session 1: Building a strong 5G ecosystem for Service Delivery" organized by the Indian Government (see Item no. 11 copy enclosed).

1. Shri R. K. Saxena, Wireless Adviser - Chairman
2. Prof. Abhay Karandikar, Director, IIT Kanpur - Co Chair
3. Shri Y.G.S.C. Kishore Babu, DDG (SRI) - Member
4. Shri V. J. Christopher, Director WMO - Member
5. Shri M. K. Pattanaik, Sr. DWA (Sat) - Member
6. Shri P. S. M. Tripathi, DWA (Security) - Member Convener

2. The Term of Reference (TOR) of the above committee is under:

To give its recommendations for Open and De-license unused or limited used Spectrum bands for demand generation for limited period including THz band.

3. Wireless Adviser may co-opt some member from startup, MSME and Academia with the help of DDG (SRI).

16.6.2022

S.K. Rawat
Assistant Wireless Adviser
To the Govt. of India

To,

1. Shri R. K. Saxena, Wireless Adviser, DoT, Sanchar Bhawan, New Delhi
2. Prof. Abhay Karandikar, Director, IIT Kanpur
3. Shri Y.G.S.C. Kishore Babu, DDG (SRI), DoT, Sanchar Bhawan, New Delhi
4. Shri V. J. Christopher, Director WMO, Pushpa Bhawan, Madangir Road, New Delhi
5. Shri M. K. Pattanaik, Sr. DWA (Sat), DoT, Sanchar Bhawan, New Delhi
6. Shri P. S. M. Tripathi, DWA (Security) - Member Convener

Subject: "Follow up action on inputs received during Post-budget webinar on "Tech Policy enabled Development" held on 2.3.2022 –"Breakaway session 2: Building a Strong 5G ecosystem for Service Delivery"

Sl. No.	Issue	Inputs received	If agreeable, manner of implementation	Responsible Centre/Unit
Theme 1: Promote Make in India of 5G products including semiconductor fab, mobile phones and design led manufacturing				
1.	Issue 1.1	Enhance the PLI Scheme for supporting Design-led manufacturing	DoT has constituted Expert Committee to examine this aspect for design led manufacturing of 5G telecom products. This issue is presently under deliberations in DoT.	DDG(IC)
2.	Issue 1.2	Leverage large home market demand to help achieve economies-of-scale for PLI products	DoT will implement PMI Order to boost economies of scale for domestic manufacturers.	JS(T)
3.	Issue 1.3	Incentivize TSPs for procuring Preference to make in India (PMI) - compliant products	TRAI has issued consultation on Promoting Networking and Telecom Equipment Manufacturing in India on 11th February 2022. One of the issues for consultation is incentivising TSPs for buying domestically manufactured products. DoT would be able to comment after receiving TRAI recommendations.	JS(T)
4.	Issue 1.4	Use of domestic products in critical sectors	Telecom service providers are mandated to use trusted source and trusted products only in the telecom network. However, a policy decision in this regard will be examined with regard to use of domestic products.	DDG(SA)
5.	Issue 1.5	Consortium approach for 5G end to end products from Indian companies	DoT is working with C DoT for 5G end to end products from Indian companies. C DoT has been requested to submit draft strategy in this regard where Government- academia-industry consortium will work for development of 5G products for TSPs and enterprises.	DDG(SRI)/ DDG (SA-II)

6.	Issue 1.6	Set up [illegible] 5G [illegible] beds for use-case development in the country, for testing the products and solutions	DoT is working with [illegible] Department for development of different use cases.	DDG(SRI)
7.	Issue 1.7	Mission Mode approach for 6G Technology development with Institutional Framework- consortium approach	DoT has constituted Technology Innovation Group on 6G in November 2021. DoT will finalise Vision, Mission and deliverables for 6G by June 2022. Based on the report, DoT will work in consortium mode for development of 6G technologies from India including contributions in global standards.	DDG(TD)/ DDG(SRI)

Theme 2: Design, development and creation of technologies for affordable broadband and mobile service proliferation in rural and remote areas

8.	Issue 2.1	• Accelerate R&D investments for 5G products with Indian design and IPR. • R&D grants (on a 1:1 matching basis) for investments made for developing Indian 5G products over the next 2-3 years.	Budget has announced 5% USOF levy for design, development and IPR. The Committee has been constituted for recommendations. Based on the report, DoT will take next steps.	Admn, USOF
9.	Issue 2.2	Building Indian Champions in IPR creation	DoT, under Champion sector scheme, is implementing DCIS scheme for promotion of IPRs from startups/MSMEs.	JS(T)

10.	Issue 2.3	• Collaborate with DISCOMs to deliver fibre to all villages and rural households • Build strong backhaul and plan connectivity in new highways	• DoT will work with Ministry of Power for utilisation of their infrastructure for reaching villages. • DoT is working with Ministry of Road Transport.	DoT, DISCOMs
11.	Issue 2.4	• Open and delicense unused or limitedly used Spectrum bands for demand generation for limited periods including THz band. • Delicense V Band and some carriers in E band	DoT is working on Spectrum Policy.	WPC, WPC

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Annexure-II

A Brief Description of the Footnotes of the ITU's Radio Regulations and the Questions being Studies in ITU-R Related to Tera Hertz Spectrum

1. Footnote 5.564A was introduced in WRC-19 for the operation of Fixed and land Mobile service applications in frequency bands in the range 275-450 GHz. The said footnote is reproduced below:

"5.564A For the operation of Fixed and land Mobile service applications in frequency bands in the range 275-450 GHz:
The frequency bands 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz are identified for use by administrations for the implementation of land Mobile and Fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications.
The frequency bands 296-306 GHz, 313-318 GHz and 333-356 GHz may only be used by Fixed and land Mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev. WRC 19).
In those portions of the frequency range 275-450 GHz where radio astronomy applications are used, specific conditions (e.g., minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio astronomy sites from land Mobile and/or Fixed service applications, on a case-by-case basis in accordance with Resolution 731 (Rev.WRC-19).
The use of the above-mentioned frequency bands by land Mobile and Fixed service applications does not preclude use by, and does not establish priority over, any other applications of radio services in the range of 275-450 GHz. (WRC-19)."

2. Footnote 5.565 was introduced in WRC-12 for the protection of passive services like RAS and EESS (passive) from harmful interference from active services in the frequency range 275-1000 GHz. The footnote is reproduced below:

"5.565 The following frequency bands in the range 275-1000 GHz are identified for use by administrations for passive service applications:

- radio astronomy service: 2 75-323 GHz, 327-371 GHz, 388-424 GHz, 426- 442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;

- Earth exploration-satellite service (passive) and space research service (passive): 2 75-286 GHz, 296-306 GHz, 3 13-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-52 7 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 85 7-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-9 73 GHz and 985-990 GHz.

The use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275-1000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 2 75-1 000 GHz frequency range.

All frequencies in the range l 000-3 000 GHz may be used by both active and passive services. (WRC-12)"

3. Question ITU-R 256-1/5 and Question ITU-R 257-1/5 are being studied through Working Party 5A and Working Party 5C respectively with their responses to be discussed during WRC-27. Question ITU-R 256-1/5 and Question ITU-R 257-1/5 are reproduced below:

"Question ITU-R 256-1/5 The technical and operational characteristics of the land Mobile service in the frequency range 275-1000 GHz under which sharing studies between the land Mobile and passive services, as well as the land Mobile and other active services should be carried out."

"QUESTION ITU-R 257-1/5 Technical and operational characteristics of the Fixed service in the frequency range 275-1000 GHz under which sharing studies between the Fixed and other active services should be carried out.

List of Acronyms

S. No.	Acronym	Description
1.	ACC	Adaptive cruise control
2.	ACMA	Australian Communications and Media Authority
3.	Annex	Annexure
4.	BNCAP	Bharat New Car Assessment Programme
5.	CA	Collision Avoidance
6.	CEPT	European Conference of Postal & Telecommunications
7.	dB	Decibel
8.	dBi	Decibels Relative to Isotropic
9.	dBm	Decibel-milliwatts
10.	DFS	Dynamic Frequency Selection
11.	DoT	Department of Telecommunications
12.	EESS	Earth Exploration Satellite Services
13.	EESS(P)	Earth Exploration Passive Satellite Service (Passive)
14.	EHF	Extremely High Frequency
15.	EIRP	Equivalent Isotropically Radiated Power
16.	ERC	European Research Council
17.	ETSI	European Telecommunications Standards Institute
18.	ETSI TR	ETSI Technical Report

S. No.	Acronym	Description
19.	EU	European Union
20.	FCC	Federal Communications Commission
21.	FMCW	Frequency Modulated Continuous Wave
22.	FOD	Foreign Object Debris
23.	FS	Fixed Service
24.	G.S.R	General Statutory Rules
25.	GHz	Gigahertz
26.	GPS	Global Positioning System
27.	Hz	Hertz
28.	ICTs	Information and Communication Technologies
29.	ID	Identification
30.	IEEE	Institute of Electrical and Electronics Engineers
31.	IMT	International Mobile Telephony
32.	IND	INDIA
33.	IoNT	Internet-of-nano-things
34.	IoT	Internet of Things
35.	IR	Interface Requirement
36.	ISED	Innovation, Science and Economic Development Canada
37.	ISM	Industrial Scientific and Medical

S. No.	Acronym	Description
38.	ITU	International Telecommunication Union
39.	ITU-RR	International Telecommunication Union- Radio Regulation
40.	kHz	Kilohertz
41.	LEAs	Law Enforcement Agencies
42.	LRR	long range radars
43.	MHz	Megahertz
44.	MIC	Ministry of Internal Affairs and Communications, Japan
45.	mW	Milli Watt
46.	NFAP	National Frequency Allocation Plan
47.	NIB	Non-Interference Basis
48.	NPB	Non-Protection Basis
49.	OEMs	Original Equipment Manufacturer
50.	OFCOM	Office Of Communications
51.	OFDM	Orthogonal Frequency Division Multiplexing
52.	PHY	Physical Layer
53.	PSU	Public Sector Undertaking
54.	R&D	Research & Development
55.	RAS	Radio Astronomy Service

S. No.	Acronym	Description
56.	RF	Radio Frequency
57.	RR	Radio Regulation
58.	SPOC	Single point of contact
59.	SRD	Short Range Devices
60.	SRdoc	System Reference document
61.	SRR	Short-Range Radar
62.	SRS(P)	Space Research Service (Passive)
63.	STAL	Spectrum-Terahertz Applications License
64.	Tbps	Terabit per second
65.	THEA	Tera Hertz Experimental Authorisation
66.	THz	Terahertz
67.	TRAI	Telecom Regulatory Authority of India
68.	TSPs	Telecom Service Providers
69.	UWB	Ultra-Wide Band
70.	V2X	Vehicle-to-everything
71.	WiNoC	Wireless Network-on-Chip
72.	WPAN	Wireless Personal Area Network
73.	WPC	Wireless Planning & Coordination
74.	WRC	World Radio-communication Conference