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TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS
GOVERNMENT OF INDIA

Discussion Paper

on

Radio Frequency (RF) Electromagnetic Field (EMF) Compliance Assessment of 5G Base Stations

November, 2022

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Written comments on the Discussion Paper on 'Radio Frequency (RF) Electromagnetic Field (EMF) Compliance Assessment of 5G Base Stations' are invited from the stakeholders by November 25, 2022. Please support your comments with detailed reasons and justifications.

The comments may be sent in the electronic form, preferably on TEC website or via email on dirr1.tec-dot@gov.in and bhoomika.gaur@gov.in with a copy to ddgsat.tec@gov.in

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CHAPTER 1

INTRODUCTION

Background

1.1. Telecommunication services have been recognized world over as an important tool for socio-economic development of a nation and have become core infrastructure required for rapid growth and modernisation of various sectors of the economy. Evolution of IMT technologies from 2G, 3G to 4G and now 5G has enabled cellular services with seamless connectivity, high data download speeds and improved user experience.

1.2. 5G (IMT 2020) is the 5th generation of mobile networks, a significant evolution of the 4G LTE networks. It has been designed to meet very large growth in data and connectivity of today's modern society, the Internet of Things with billions of connected devices, and tomorrow's innovations. The 5G wireless network by enabling high-speed data transmission with ultra-low latency will serve as basic infrastructure for emerging technologies and use cases that will lead the revolutionary concepts such as artificial intelligence, autonomous vehicles, big data, and cloud.

1.3. 5G services go well beyond those of prior generation mobile networks, all of which only delivered services on personal phone platforms. 5G will also connect myriad new devices, including machines, sensors, actuators, vehicles, robots, and drones, to support a much larger range of applications and services. Put together, this can unleash new economic opportunities, giving 5G the potential for being a transformational force for Indian Society. India, in particular, can benefit greatly from 5G as it will enable the country to leapfrog the traditional barriers to development. 5G will also advance the reach and utility of the 'Digital India' allied missions.

1.4. 5G technology has the potential for ushering in a major societal transformation in India by enabling the rapid expansion of the role of information technology across manufacturing, education, healthcare, agriculture, financial and social sectors. India must embrace this opportunity by developing 5G networks early, efficiently, and pervasively as well as emerge as a significant innovator and Technology supplier at the global level. Emphasis should be placed on 5G touching the lives of rural and weaker economic segments so as to make it truly inclusive technology.

1.5. Besides extremely fast wireless data speed, 5G technology is expected to require many more towers than previously needed to provide wireless services due to use of sub 6 GHz and mmWave frequencies. 5G deployment will also involve the densification of the network and increased proximity of the mobile towers along with changes in maximum power, beam forming scenarios. Hence, there appears to be a need to look at RF-EMF exposure from 5G mobile towers and formulate an RF-EMF exposure assessment methodology for 5G.

1.6. Presently, the EMF exposure assessment of IMT Base Station installations is done as per the RF-EMF exposure limits in India, prescribed by the Department of Telecommunications (DoT). The Test Procedure document, developed by Telecommunication Engineering Centre (TEC), DoT provides a detailed EMF measurement & assessment procedure for the certificate of compliance of EMF exposure norms by the Telecom Service Providers (TSPs) and audit by the Licensed Service Area (LSA) Units of the Department of Telecommunications. More information on the steps taken by DoT for ensuring safe EMF exposure from telecommunication installations is available on the DoT website[1].

Scope of Discussion Paper

1.7. The Radio frequency (RF) EMF exposure assessment include measurement or calculation based estimation of the physical quantities (e.g. electric field, magnetic field, power density, Specific Absorption Rate etc) typically used to characterize the exposure, other relevant technical parameters and subsequently overall evaluation of the exposure for demonstration of compliance with respect to the already defined safe exposure limits.

1.8. In India, the safe EMF exposure limits are prescribed by Department of Telecommunications (DoT), while a detailed methodology for compliance assessment of EMF exposure, including measurement and calculation aspects, is prescribed in 'Test Procedure for Measurement of Electromagnetic field from Base Station Antenna[2]' (referred to as 'TEC Test Procedure Document' in later sections of this document). In view of the recent auction of spectrum by DoT[3] and deployment of 5G networks in the country, a review may be required of the existing EMF compliance assessment framework

[1] https://dot.gov.in/journey-emf
[2] https://tec.gov.in/pdf/GR3/TSTP%20EMF%20Measurement.pdf
[3] https://dot.gov.in/sites/default/files/NIA%202022.pdf?download=1

prescribed by the TEC Test Procedure Document and explore the various EMF assessment approaches or best practices followed internationally.

1.9. The scope of this paper is to seek comments from stakeholders on the EMF compliance assessment aspects of IMT networks, specifically Base stations. The paper also specifically seeks comments from stakeholders on the possible modifications that may be required to be incorporated in the TEC Test Procedure Document in the light of 5G (IMT 2020) deployments.

CHAPTER 2

OVERVIEW OF 5G NETWORKS

2.1. 5G is the 5th generation of wireless networks, a significant evolution of the 4G LTE networks. 5G has been designed to meet the very large growth in data and connectivity of today's modern society, the Internet of Things with billions of connected devices, and tomorrow's innovations.

2.2. The 5G wireless network that enables high-speed data transmission with ultra-low latency is the key infrastructure for the future technology that will lead the fourth or next industrial revolution such as artificial intelligence, autonomous vehicle, big data, and cloud.

5G Spectrum

2.3. As per ITU[4], 5G will use additional spectrum predominately in the 3 – 86 GHz range to add significantly more capacity compared to the current mobile technologies. The additional spectrum and greater capacity will enable more users, more data, and faster connections. It is also expected that there will be future reuse of existing low band spectrum for 5G as legacy networks decline in usage and also to support future use cases.

2.4. The increased spectrum also includes the millimetre-wave (mmWave) bands. The mmWave frequencies provide localised coverage as they mainly operate over short line of sight distances.

2.5. Figure 1 shows the existing and new spectrum that will be used for 5G mobile communications.

- **Low band (below 1 GHz)** – providing widespread coverage across urban, suburban, and rural areas and supporting IoT for low data rate applications.
- **Medium band (1 – 6 GHz)** – providing good coverage as well as high speeds required for 5G.
- **High band (above 6 GHz)** – providing ultra-high broadband speeds for advanced mobile broadband applications, and most suitable for applications in dense traffic hotspots.

[4] ITU-T Recommendation Series K Supplement 16 'Electromagnetic field compliance assessments for 5G wireless networks'

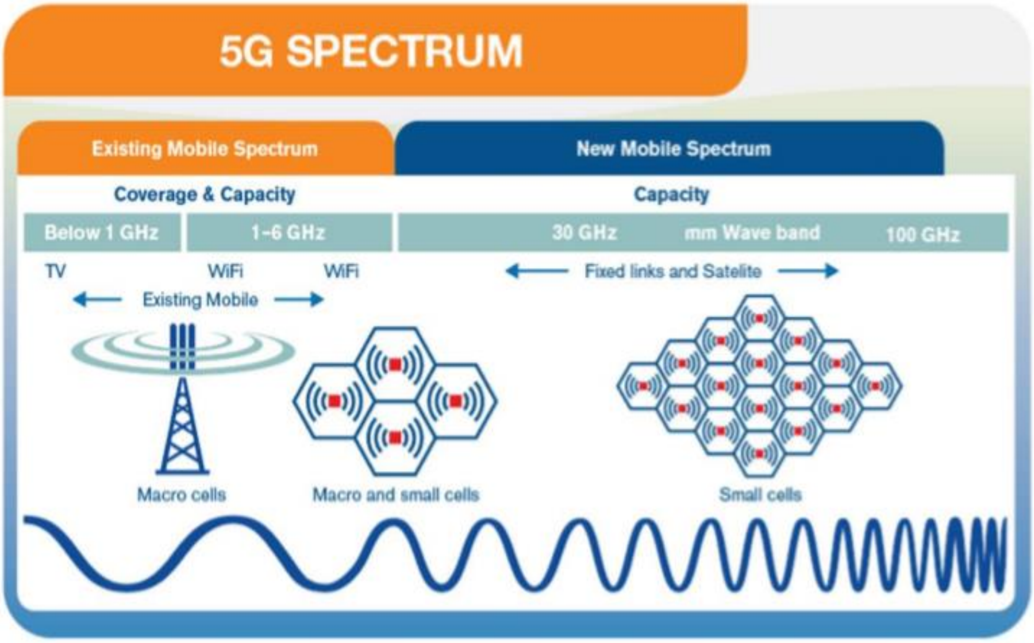

Figure 1 – Existing and new spectrum to be used for 5G mobile communication services

Further, The Government of India, through the Department of Telecommunications ("DoT") in June 2022 put for auction the radio spectrum frequency bands 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500MHz, 3300 MHz and 26 GHz. Though no specific use of technology is mentioned for these bands, these bands are likely to be used for IMT[3] services including IMT-2020 (5G), depending on the availability of a suitable eco-system. Details of frequency range in the abovementioned bands are given in Table I on next page:

Table I : Frequency Bands as per NIA issued by DoT[3]

Band	Paired/ Unpaired	Uplink frequency (MHz)	Downlink frequency (MHz)
600 MHz	Paired	663-703	612-652
700 MHz	Paired	718-748	773-803
800 MHz	Paired	824-844	869-889
900 MHz	Paired	890-915	935-960
1800 MHz	Paired	1710-1765	1805-1860
2100 MHz	Paired	1939-1979	2129-2169
2300 MHz	Unpaired	2300-2380	
2500 MHz	Unpaired	2535-2555 and 2635-2655	
3300 MHz	Unpaired	3300 -3670	
26 GHz	Unpaired	24250 -27500	

5G Network

2.6. A wireless network has two main components: Radio Access Network and Core Network.

5G Radio Access Network

2.7. The radio access network (RAN) consists of various types of facilities including small cells, towers, masts, street furniture and dedicated in-building and home systems which connect mobile users and wireless devices to the main core network. Small cells will be a significant feature of 5G networks particularly at the new mmWave frequencies where the connection range is very short. To provide a continuous connection, small cells will be distributed in clusters depending on where users require connection, and this will complement the macro network.

2.8. 5G macro cells will use antennas that have multiple elements (more commonly referred to as 'massive MIMO' (mMIMO)) to send and receive more data simultaneously and cater for multiple connections. The benefit to users is that more people can simultaneously connect to the network and maintain high throughput.

2.9. Further, 5G base station antennas are expected to use advanced RF technologies like Beam steering and beamforming. Beam steering and beamforming allow the mMIMO base station antennas to direct the radio signal to the users and devices rather than in all directions. The beam steering technology uses advanced signal processing algorithms to determine the best path for the radio signal to reach the user. This increases efficiency as it reduces interference (unwanted radio signals).

Figure 2 shows the difference between conventional sector antennas and the mMIMO antennas. Figure 3 illustrates how beam steering and beamforming works in a 5G network.

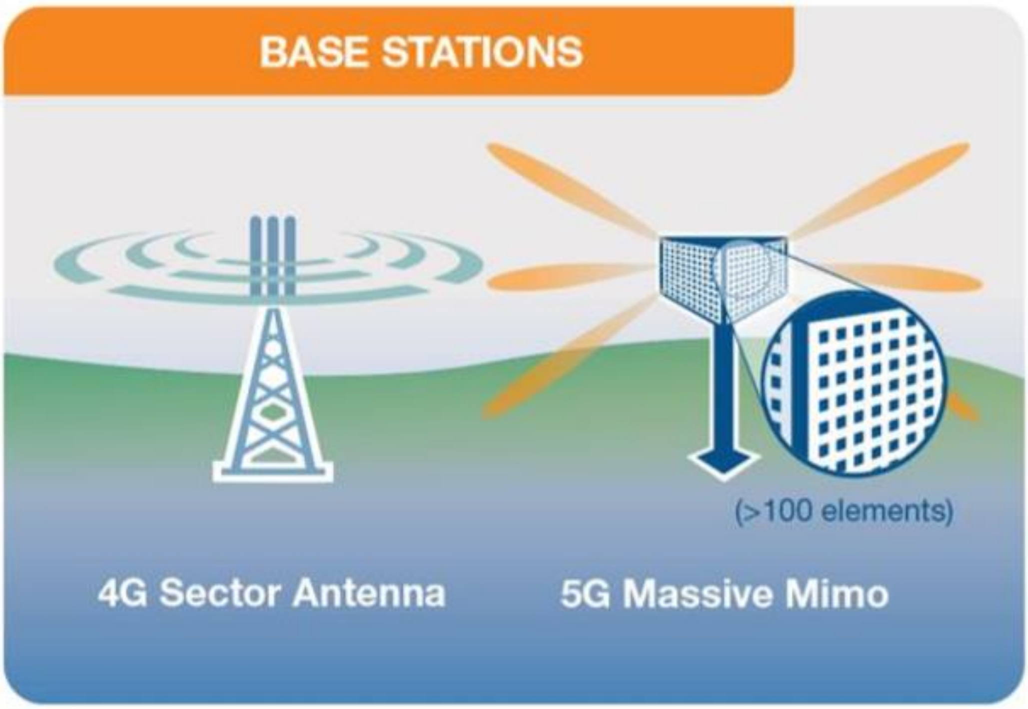

Figure 2: 4G Base station with sector antennas and 5G base station with multi-element Massive MIMO antenna array[4]

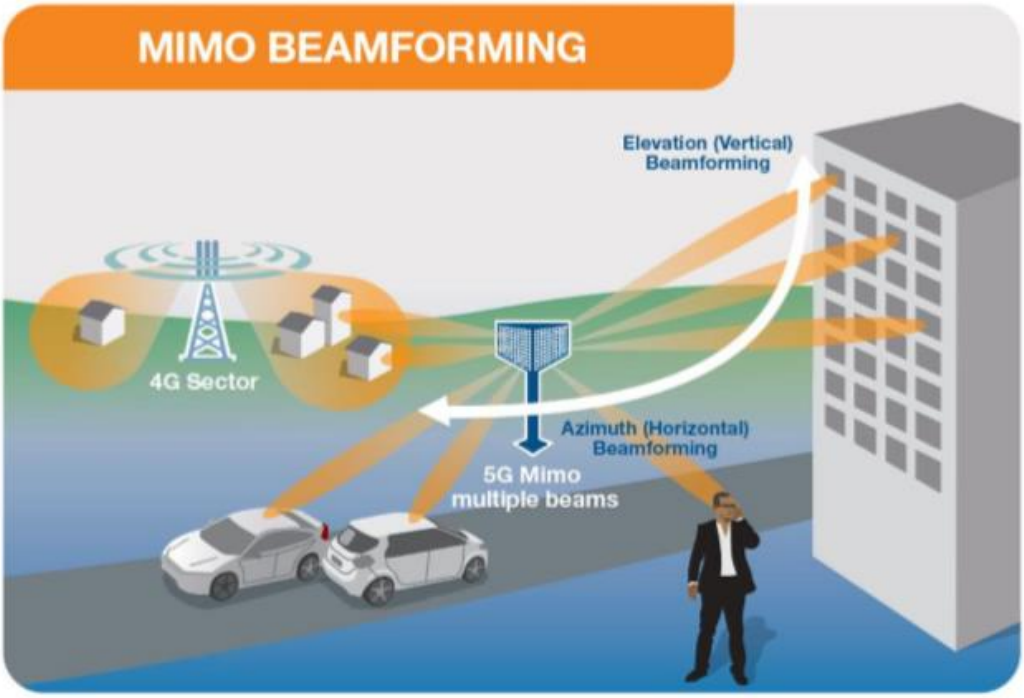

Figure 3: Massive MIMO beamforming and beam steering in a 5G network[4]

5G Core Network

2.10. The core network is the mobile exchange and data network that manages mobile voice, data, and internet connections. For 5G, the core network has been redesigned to better integrate with the internet and cloud based services and also includes distributed servers across the network improving response times (reducing latency). Many of the advanced features of 5G, including network virtualization and network slicing for different applications and services, will be managed in the core network.

2.11. Considering the above, the suitability of the existing EMF assessment methodologies (as prescribed in the Test Procedure for Measurement of Electromagnetic field from Base Station Antenna for 5G Base stations may be relooked at.

Q 1 (a). Whether current methodologies for assessing RF-EMF exposure would be applicable even in 5G?

Q 1 (b). Whether new EMF exposure assessment methodologies or approaches would be required for 5G which may have significant changes from previous generation technologies in terms of deployment scenarios, new spectrum bands, antenna technologies etc.?

Please justify your response in (a) and (b) with rationale and suitable examples or best practices.

CHAPTER 3

RF EMF ASSESSMENT METHODOLOGY

3.1. RF-EMF compliance assessment for telecom networks requires careful analysis of the design and configuration of the site to be evaluated, along with the accessibility conditions possible at a particular site.

3.2. The purpose of the assessment is typically to determine the size of the RF-EMF compliance boundary (exclusion zone) for the general public and workers around the antennas, and to verify that this zone is not accessible. Alternatively, calculations or measurements are also conducted close to a base station site, in areas which are accessible for the general public, to verify that the RF-EMF exposure levels are below the applicable limits.

General Principles

3.3. There are many national and international standards or guidelines that provide safety limits for human exposure to EMFs. These include the use of basic limits and reference levels, the use of two-tier exposure limits, averaging times etc.

3.4. Most administrations or international guidelines, for example ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields[5] specify safety limits in terms of basic limits and reference (or derived) levels. The basic limits address the fundamental quantities that determine the physiological response of the human body to electromagnetic fields. Basic limits apply to a situation with the body present in the field. For instance, the basic limits for human exposure are expressed as the Specific Absorption Rate (SAR), Specific Absorption (SA) and Current Density.

3.5. As the basic quantities are difficult to measure directly, a set of derived (reference) levels for electric field, magnetic field and power density are also considered for RF-EMF assessment.

3.6. Further, most international documents use a two-tier limit structure where lower levels are specified for uncontrolled/general public exposure than for controlled/occupational exposure.

[5] https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf

3.7. The EMF exposure norms (limits on the unperturbed rms values of reference levels i.e. Electric Field, Magnetic Field and Equivalent Plane Wave Power Density) prescribed by the Department of Telecommunications for the general public exposure are reproduced in Table II below:

Table II: EMF exposure (reference levels) limits in India[1]

Type of Exposure	Frequency range	Electric field strength (V/m)	Magnetic field Strength (A/m)	Equivalent Plane Wave Power Density S_{eq} (W/m^2)
General Public	400-2000 MHz	**$0.434f^{1/2}$**	**$0.0011f^{1/2}$**	**f/2000**
	2-300 GHz	**19.29**	**0.05**	**1**

where, f is the frequency of operation in MHz.

Exposure from Multiple Sources with multiple frequencies

3.8. Due to the different physiological effect of lower-frequency sources and higher-frequency sources, it may also be required to consider low frequency and high frequency sources separately while assessing RF-EMF exposure. To consider the effects of multiple sources, most international standards require that the sources be considered in a weighted sum, where each individual source is pro-rated according to the limit applicable to its frequency. This very concept has been applied in the RF-EMF compliance assessment for shared sites, as provided in TEC Test Procedure document.

3.9. Further, the exposure limits are defined in terms of quantities averaged over a time period called the averaging time. For instance, both ICNIRP guidelines and TEC Test Procedure document recommend averaging time of six minutes for measurement of reference levels (electric field, magnetic field or power density).

3.10. The detailed method of EMF measurement and compliance assessment of Mobile Base Stations is given in TEC Test Procedure document.

Achieving compliance to EMF safety limits for telecommunication installations

3.11. For achieving compliance to EMF safety limits for Mobile Base Stations, the following steps should be taken[6]:

- Identify appropriate compliance limits.
- Determine if EMF exposure assessment for the installation of equipment in question is needed.
- If the EMF exposure assessment is needed, it may be performed by calculations or measurement.
- If the EMF exposure assessment indicates that pertinent exposure limits may be exceeded in areas where people may be present, mitigation/avoidance measures should be applied.

Exposure level assessment procedure

3.12. International standards/best practices take into account methods for RF exposure evaluation for three main applications:

- **Base station (BS) compliance:** Determination of compliance boundary information for BS before it is placed on the market.
- **BS installation compliance:** Determination of the total RF exposure levels in accessible areas from a BS and other relevant sources before the product is put into service.
- **In-situ RF exposure assessment:** Measurement of RF exposure levels in the vicinity of a BS installation after the product has been installed and is operating.

In order to allow for accurate and efficient assessments, different routes are possible depending on the characteristic of the Base Station (BS) or on the installation type. Same is depicted in Figure 4.

[6] ITU-T Recommendation K.52 'Guidance on complying with limits for human exposure to electromagnetic fields'

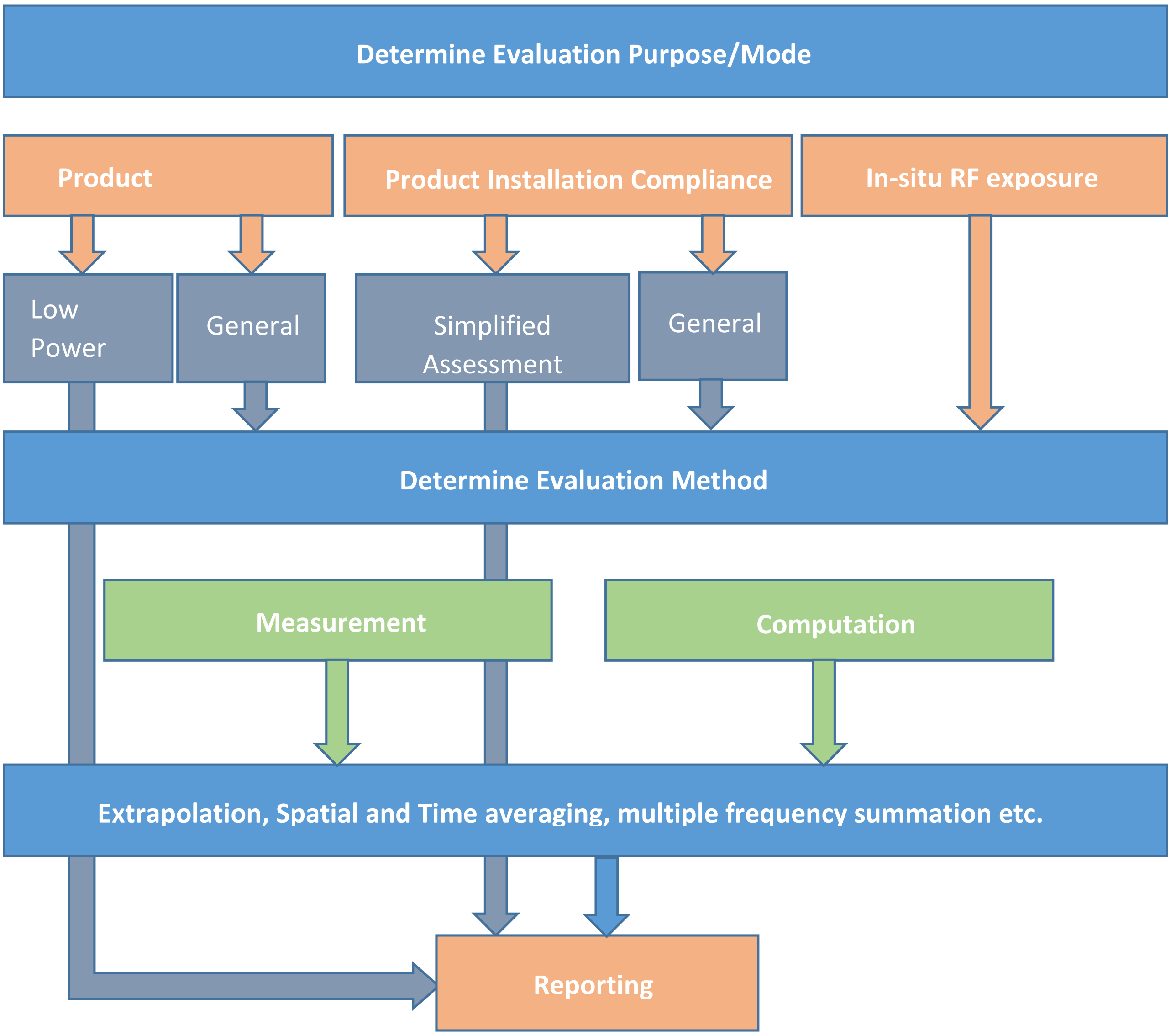

Figure 4: RF EMF exposure Evaluation Methods

A. Base Station (Product) Compliance

3.13. In Base Station (Product) compliance approach, the manufacturer or other legal entity that will place the BS in the market is typically required to provide RF exposure information, including relevant compliance boundaries (exclusion zones), to the end user of the product. The compliance boundary shall be established for applicable RF exposure limits using assessment methods for RF field strength, power density or SAR. As per IEC 62232 standard[7], compliance boundary information is normally determined for a number of selected typical configurations (frequency band, number of transmitters, bandwidth, antenna, feeder, etc.) of the BS product, assuming free-space conditions, and at the maximum power for each configuration.

3.14. Further, IEC 62232 considers SAR or power density (depending on the frequency range) measurements as the most appropriate evaluation technique to determine accurate compliance boundary (CB) information for equipment designed for small stand-alone equipment/devices and multi-element base station antennas shorter than or equal to 1.5 m. Examples of this type of equipment include medium range, local area, or home BS, pico-cell and microcell equipment. Alternatively, SAR can be calculated using estimation formulas or using advanced computational methods.

3.15. For all BS products, in particular, macro-cell equipment but also small coverage area equipment, field strength or power density evaluations are applicable. International standards suggest that either laboratory measurements or computations may be used. In some specific cases, compliance with relevant exposure limits can be assessed without the necessity to conduct measurements (e.g., because of the low power transmitted)[8].

3.16. The reporting of the product compliance may be required for evaluation or audit purposes. IEC 62232 prescribes that RF exposure evaluation report used for product compliance shall contain at least the following:

- Description of product/ Base station
- Description of Evaluation Method and exposure metric
- Description of compliance boundary

[7] IEC 62232: 2017 'Determination of RF field strength, power density and SAR in the vicinity of base stations for the purpose of evaluating human exposure'
[8] ITU-T Recommendation K.100 'Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service'

- Description of installation guidelines, where relevant.

3.17. Further, before putting the BS into service, product compliance approach may be complemented with subsequent requirements of installation compliance and in-situ measurement, depending upon the type of BS and its installation.

Q 2. Can product compliance approach be used for demonstrating RF-EMF exposure compliance in case of 5G Base stations? If yes, what criteria and which physical quantities may be used for EMF assessment in such case(s)? Also, what kind of laboratory measurements or computations will be required in such scenario? Please corroborate your response with rationale, suitable examples and global best practices, if any.

Q 3. What may be an appropriate definition of small cell? Can product compliance approach be adopted for demonstrating RF-EMF exposure compliance in case of small cells? If yes, how? Please support your response with rationale, suitable examples and best practices, if any.

Q 4. What are the possible benefits, risks and challenges foreseen in using product compliance as a complementary approach for EMF exposure evaluation in case of Mobile Base stations, specifically low powered/small cell base stations? Please support your response with rationale and suitable global examples, if any.

B. Product (Base Station) Installation Compliance

3.18. In this approach, a network operator or other legal entity intending to put a BS into operation usually needs to evaluate the RF field strength levels. Typically, these evaluations are performed in accessible areas and in the vicinity of the base station, to verify compliance with relevant RF exposure limits and regulations. In such an evaluation, contributions from other relevant sources and possible effects of the environment need to be considered.

3.19. International standards by IEC, ITU etc. indicate that the RF exposure levels from BS and other relevant sources shall be determined at maximum transmit power of the equipment (theoretical or actual) using measurements or computations. Also, since other RF sources may also be present in the vicinity of the BS being considered or in case of shared site, contributions from multiple sources shall be determined using summation formulas.

3.20. Just like product compliance, general methods of product installation compliance include actual measurements and/or computations. These depend on the characteristics of the BS to be installed and the accessibility conditions. ITU-T K.52 Recommendation and TEC Test Procedure document prescribe assessment of installation compliance by way of calculation of ratio ($EIRP / EIRP_{Threshold}$) for various accessibility conditions.

3.21. Further, Simplified assessment procedures is also used to identify a Base station that is known to be in compliance with relevant exposure limits without the necessity to follow general or comprehensive exposure assessment processes. Simplified Assessment Criteria (SAC), are typically based on maximum Effective Isotropic Radiated Power (EIRP) supported by the Base station and depend on antenna installation characteristics, such as mounting height, main lobe direction and distance to other ambient sources. ITU-T K.100 and TEC Test Procedure document prescribe SAC requirements in terms of minimum height and minimum distance (from nearest publicly accessible point) for Cellular Radio Base Stations for different values of EIRP and frequencies.

3.22. Since, 5G is expected to be deployed over a range of cellular frequencies in Low, Mid and High frequency band and with a range of small cell base stations, there seems to be a need to devise installation classes of base stations for small cells and corresponding Simplified Assessment Procedures.

3.23. ITU-T K.100 Recommendation prescribes SAC on the basis of Installation class of Base station, identified on the basis of EIRP. An indicative segregation of Base station installation classes is given in Table III below. The exact classification may be finalized with stakeholder consultation.

Table III : Installation classification of Mobile Base Stations- *Indicative*

Installation Class	EIRP (Watt)	Simplified Installation Criteria
Class I	N/A	Touch compliant product i.e. Product compliance boundary dimensions are zero. No specific requirement for installation.
Class II	To be finalized	Compliance with the exposure limits is generally obtained at zero distance or within a few centimetres.

		No specific requirement for installation.
Class III	To be finalized	EUT installed so that: (i) the lowest radiating part of the antenna(s) is at prescribed minimum height above the general public walkway; (ii) the minimum distance to areas accessible to the general public in the main lobe direction is prescribed; (iii) no other radio frequency (RF) sources are located within a prescribed distance.
…	…	…
…	…	…

Q 5. What criteria could be adopted for defining the installation classes for small cells? Also, what kind of Simplified Assessment Criteria could be adopted for such installation classes so as to demonstrate RF-EMF exposure compliance with respect to Indian EMF limits/norms? Please illustrate your response with examples and global best practices or international standards, if any.

3.24. The reporting of the installation compliance, whether demonstrated through general measurements or computation, or using Simplified Assessment Criteria, may be required for evaluation or audit purposes. IEC 62232 prescribes that RF exposure evaluation report used for Base Station installation compliance shall contain at least the following:

- Description of the product
- Maximum transmitted power for each transmit frequency band of the base station as installed.
- Antenna characteristics
- Description of installation configuration for the product, including installation height etc.
- Implementation of the Simplified Evaluation Method, if applicable.
- If Simplified Evaluation is not applicable, additional information regarding description of evaluation method and the exposure metrics
- Description of general public access restrictions

Q 6. Is the Simplified Assessment Criteria prescribed in the TEC Test Procedure document directly applicable to 5G Base stations, specifically in the light of identification of new frequency bands? If yes, please demonstrate the applicability with suitable examples. If no, what kind of modifications are required in the given criteria? Please justify your response with rationale and suitable examples, if any.

Q 7. Which methods, other than already suggested in TEC Test Procedure document, can be used for assessment of installation compliance (by measurement or calculation) for 5G Base stations? Please support your response with rationale, international precedents or best practices, if any.

Q 8. Can installation compliance approach be utilized for demonstrating RF-EMF exposure compliance in case of 5G small cells, indoor Base stations and street furniture Base station sites? If yes, what criteria may be used to categorize the accessibility and deployment conditions? Please justify your response with rationale and suitable examples or best practices, if any.

Q 9. Can an installation manual be created for indoor and street furniture Base stations on the basis of Base Station (product) compliance report and installation/accessibility conditions? If yes, how? Please support your response with rationale and suitable examples or best practices, if any.

C. Evaluation processes for in-situ RF exposure assessment

3.25. The in-situ RF exposure evaluation or assessment is performed by field measurement of RF field strength or reference levels using measurement antenna or field probe.

3.26. The objectives of in-situ measurements are:

- to determine if the RF exposure levels are in compliance with applicable exposure limits and regulations, e.g. in the vicinity of an operating BS installation, or
- to obtain the RF exposure data, typically required for communication purposes.

3.27. The process includes identifying fixed and permanently emitting RF source installations in the surrounding area and subsequent measurements of the RF field strength with spatial and time averaging.

3.28. A typical flow of in-situ measurement is given in Figure 5.

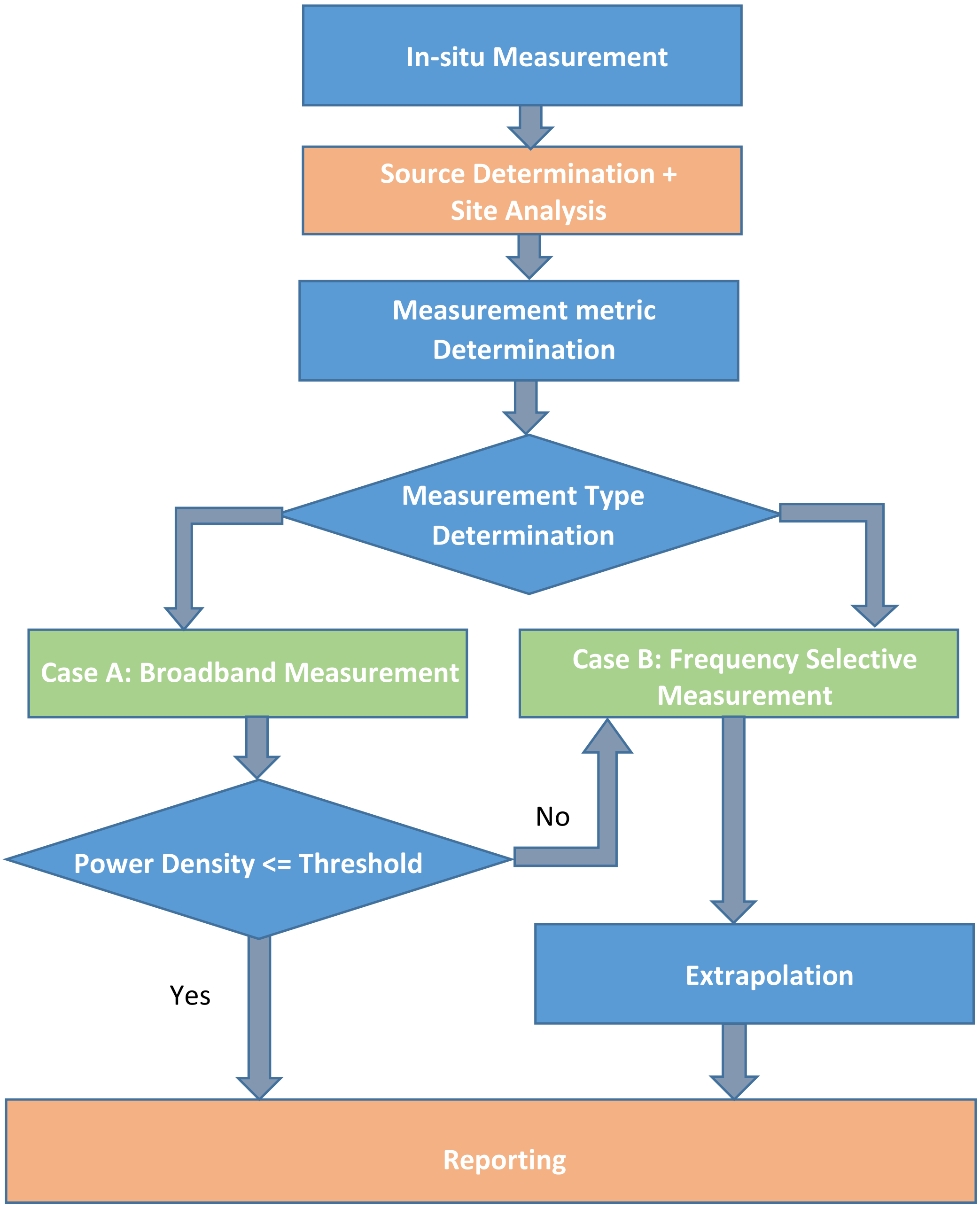

Figure 5: Alternate Routes to evaluate in-situ RF exposure

3.29. IEC 62232 prescribes for the measurement system(s) and the post processing to cover the RF emissions from the Base Station and all relevant ambient sources between at least 100 kHz and 300 GHz as determined by the site analysis. In India, the in-situ measurement for RF EMF exposure assessment is presently carried out at the Mobile Base Station sites only and covers frequency range 700 MHz to 3 GHz.

3.30. The approach suggested in Case A in Figure 5 is adopted in the TEC Test Procedure document wherein Broadband Measurements are done for first stage audit verification. **A threshold of 50% of DoT prescribed limits in terms of power density value corresponding to the lowest frequency radiated at the site is chosen for going ahead with next step i.e. Frequency Selective Measurement (FSM).** In case of breach of above threshold, Frequency Selective Measurement is required to assess the contribution of each source/base station on the site for determination of compliance to limits prescribed for exposure to the general public.

3.31. For mobile communications systems using adaptive power control, including GSM, WCDMA and LTE, the BS does not transmit at a constant power level; the emitted power varies with time depending on factors such as traffic variation and dynamic power control. Overall, the comprehensive exposure assessment is conducted in order to obtain a conservative estimate of the exposure level, when Base station/site operates at maximum output power. This requires measurement of time-invariable/pilot channel of each RF source at the site, followed by extrapolation to obtain total radiated power by the source. Such extrapolation is technology dependent. Various International standards issued by IEC, ITU prescribe extrapolation factors for GSM, UMTS, LTE etc. TEC Test Procedure document provides a detailed account on extrapolation of FSM measurements for these technologies.

3.32. However, due to identification of new frequency bands for cellular mobile use in India, especially with the deployment of 5G networks, the frequency range of in-situ measurement may require revision in the TEC Test Procedure document. Office of Communications (OFCOM) United Kingdom, in its Technical Report on 'Electromagnetic Field (EMF) measurements near 5G mobile phone base stations' has considered frequency range of 420 MHz to 6 GHz for in-situ measurements. However, this frequency range does not cover FR2 or millimetre wave frequencies expected to be use in 5G.

3.33. Similarly, extrapolation factors, which are technology dependent, also need to be identified for 5G technology.

Q 10. What should be the frequency range for in-situ measurement after identification of new frequency bands for cellular mobile (as per aforementioned Notice Inviting Tender)? Please support your response with rationale, capabilities of the measuring equipment available in the market, and international examples, if any.

Q 11. How should Broadband Measurement be carried out to cover both mid band (FR1) and high band (FR2) in 5G? Also, what should be the extrapolation factor for Frequency Selective Measurement (FSM) for 5G technology? Please support your response with rationale, supporting standard(s) and global best practices, if any.

Q 12. Whether any other changes are required in the current methodology of in-situ measurement and post processing (as provided in TEC Test Procedure document) in the light of new frequency bands and higher channel bandwidths anticipated to be used by IMT technologies? Please justify your response with rationale, supporting standard(s) and global best practices, if any.

CHAPTER 4

5G and mMIMO SPECIFIC CONSIDERATIONS IN RF-EMF ASSESSMENT

Determination of the actual maximum power for RF-EMF compliance assessments of 5G networks

4.1 Typically, RF-EMF exposure assessment is carried out in the worst case conditions corresponding to time averaged maximum transmitted power and maximum traffic load conditions. This worst case scenario estimation is captured in the extrapolation done over FSM results or consideration of time averaged maximum transmitted power for computation based compliance.

4.2 However, another approach, based on ‘Actual Maximum Transmitted Power or EIRP’, also finds mention in ITU Recommendations. Some standards prescribe that the method based on actual maximum transmitted power or EIRP provides for more accurate assessment of the real maximum exposure from a base station using the parameters of the site [8]. It avoids the unrealistic over-estimation of other approaches.

4.3 ITU-T Recommendation [4] suggests that the transmitted power averaged over time periods of relevance for RF-EMF exposure assessments, e.g., six minutes, is significantly lower than the rated maximum transmitted power for the equipment in 5G networks. Consequently, using the rated maximum power may lead to overly conservative RF-EMF exposure values and compliance boundaries, especially in the case of several different technologies and antennas at the site. Further, 5G networks deploy massive MIMO base stations which transmit a number of simultaneous beams to the connected devices. These beams vary rapidly in both time and space, which could lead to no transmission in a certain direction at the rated maximum power for long time periods.

4.4 To address this issue, both ITU-T Recommendation [4] and IEC 62232 standard open up the possibility of using 'actual maximum power', which can be determined from measurements of the base station's real output power from measurements of a large number of representative base stations in the network, or by using statistical models or network simulations.

4.5 The configuration of a massive MIMO 5G site vary depending on the operator network design and implementation of the applicable 3GPP standards. Further, with Base Station using mMIMO, the transmitted power is spread in different directions to provide service to different user equipment in different geographic locations. Therefore, beamforming involves additional variability in the determination of the power contributing to the actual maximum exposure. The power variation of a Base Station using mMIMO can be described by two factors[7]:

- the traffic variation and
- the time averaged spatial distribution of transmitted power or EIRP.

4.6 Further, the calculation of actual maximum transmitted power and actual maximum EMF exposure from a mMIMO 5G antenna array requires a number of factors to be considered, including[9]:

- total maximum transmitted power;
- fraction of power used for traffic beams and broadcast/synchronization beams;
- beam steering ranges and half-power beamwidths;
- antenna radiation pattern (envelope of all traffic beams);
- maximum gain for traffic beams and broadcast/synchronization beams;
- number of possible simultaneous traffic beams;
- installation environment;
- distribution of connected devices;
- time division duplex (TDD) or frequency division duplex (FDD).

4.7 IEC Technical Report 62669[9] mentions the following regarding the use of transmitted power:

- As a conservative approach, the actual maximum EIRP (directly or derived from the actual maximum transmitted power) can be used to determine the RF compliance boundary provided that the operator is implementing tools ensuring this threshold is not exceeded over time during service.
- These tools can be based on Base Station counters and features developed by manufacturers to monitor and control the EIRP (directly or derived from the RF transmitted power) and other relevant characteristics of the Base Station.
- This applies to Base Station sector or subdivisions of a Base Station sector for massive MIMO.
- This applies to all types of Base Stations, whether they are using fixed beams or steerable beams like with massive MIMO.

[9] IEC TR 62669: 2019 'Case studies supporting IEC 62232 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure'

4.8 An indicative process flow chart for assessing compliance for a Base Station is shown in Figure 6 and an example of implementation of compliance based on actual max EIRP is depicted in Figure 7.

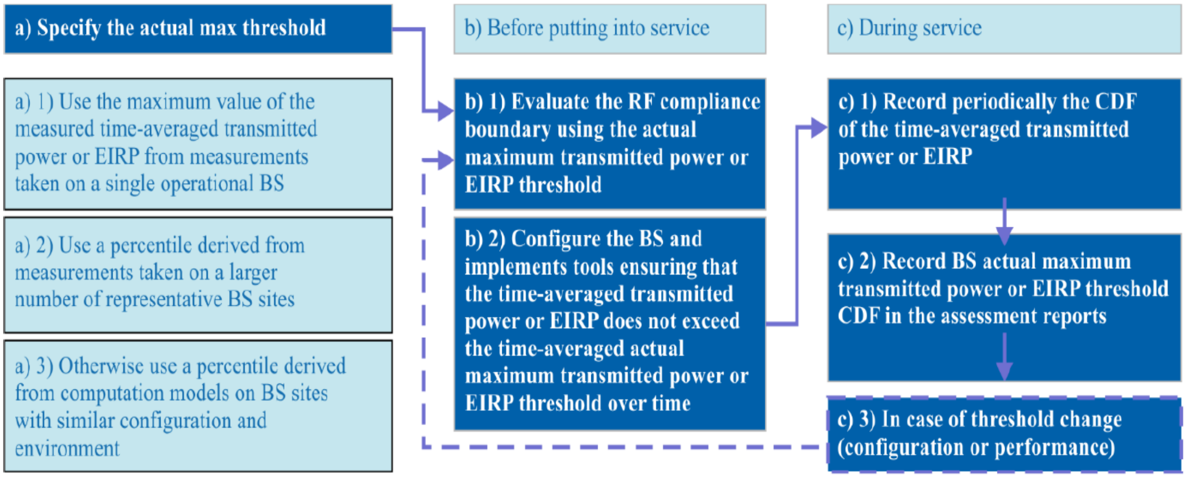

Figure 6: Flow chart for assessing compliance for a BS site sector or sub-division of a BS site sector[8]

Figure 7 shows an example of BS site sector based on the actual max EIRP. The RF exposure compliance boundary is defined based on the actual max EIRP threshold configured by the BS. The BS is implementing monitoring and control tools ensuring that the actual EIRP does not exceed this EIRP max threshold during service. The recording of the actual EIRP over time is summarized in a cumulative distribution function (CDF) that provide the actual max EIRP (100th percentile) and other lower percentiles (95th or 99th).

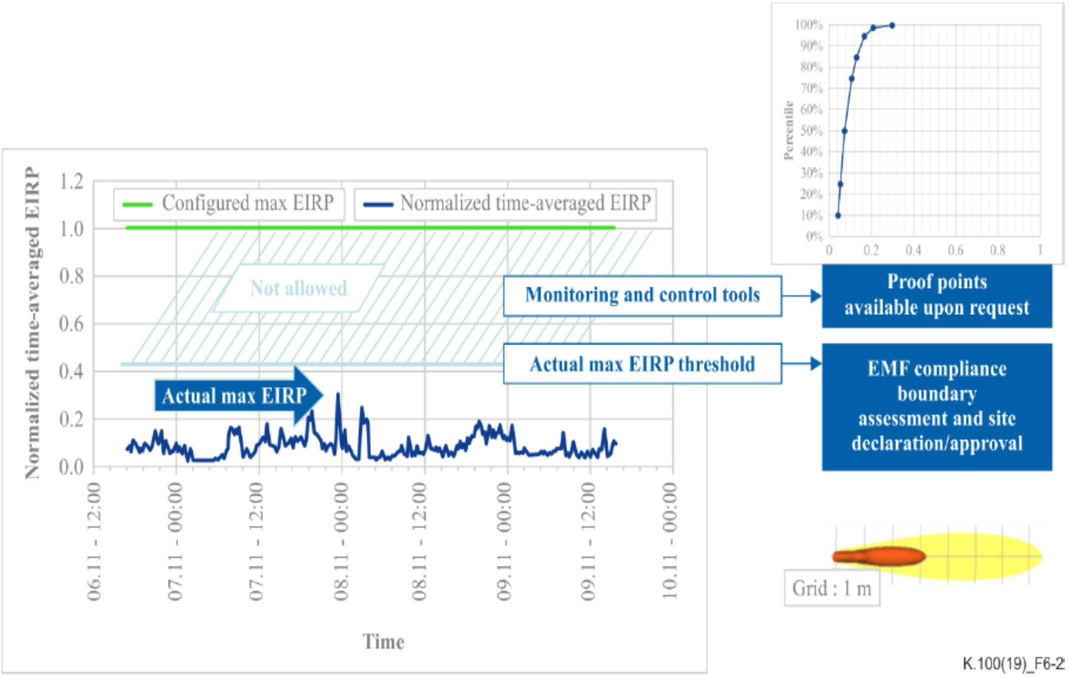

Figure 7: Example of implementation of compliance based on actual max EIRP[8]

Q 13. What is the maximum transmitted power and EIRP of the 5G Base Stations for different configurations, frequencies and channel bandwidths? Please support your response with international standards, equipment availability in the market or suitable examples if any.

Approaches for estimation of Transmitted Power in 5G

4.9 **Approach 1:** One possible approach for estimation of transmitted power may include measurement of power of time-invariable signal, such as signalling channel, which can be extrapolated to obtain total transmitted power by multiplication with a static extrapolation factor. This extrapolation factor depends on number of factors including the type of IMT technology deployed on the base station, number of sectors, antennas, number of beams etc. Similarly, for computational method, maximum value of the time-averaged transmitted power or EIRP may be used.

4.10 **Approach 2:** Another possible approach for estimation of transmitted power, as suggested in IEC Technical Report 62669 includes statistical analysis of the downlink transmitted power for single cell or multiple cell sites distributed over a very large geographical area. Such statistical analysis may be carried out using Mobile network management systems in a cyclical manner for various traffic profiles, ultimately leading to development of Cumulative Distributive Function (CDF) of extrapolation factors for various technologies, as well as for combined exposure assessment. Such statistical models could be derived from measurement as well as computational models.

Q 14. Which approach (Approach 1 or 2) may be adopted for determination of transmitted power for 5G base stations? Please justify your response with rationale, supporting standard(s) and global best practices, if any.

Q 15. In case of Approach 2, how can statistical analysis of network be carried out for EMF compliance? What are the benefits, risks and challenges foreseen in using such approach? Please support your response with rationale and suitable examples or best practices, if any.

Q 16. Please provide examples of EMF exposure assessment methodologies used in the countries where 5G networks have already been deployed. Please justify your inputs with supporting documents.

Q 17. Any other issues which are relevant to this subject? Please suggest with justification and supporting standards or best practices.

CHAPTER 5

ISSUES FOR CONSULTATION

Q 1 (a). Whether current methodologies for assessing RF-EMF exposure would be applicable even in 5G?

Q 1 (b). Whether new EMF exposure assessment methodologies or approaches would be required for 5G which may have significant changes from previous generation technologies in terms of deployment scenarios, new spectrum bands, antenna technologies etc.?

Please justify your response in (a) and (b) with rationale and suitable examples or best practices 1 (a). Whether current methodologies for addressing EMF concerns would be applicable even in 5G?

Q 2. Can product compliance approach be used for demonstrating RF-EMF exposure compliance in case of 5G Base stations? If yes, what criteria and which physical quantities may be used for EMF assessment in such case(s)? Also, what kind of laboratory measurements or computations will be required in such scenario? Please corroborate your response with rationale, suitable examples and global best practices, if any.

Q 3. What may be an appropriate definition of small cell? Can product compliance approach be adopted for demonstrating RF-EMF exposure compliance in case of small cells? If yes, how? Please support your response with rationale, suitable examples and best practices, if any.

Q 4. What are the possible benefits, risks and challenges foreseen in using product compliance as a complementary approach for EMF exposure evaluation in case of Mobile Base stations, specifically low powered/small cell base stations? Please support your response with rationale and suitable global examples, if any.

Q 5. What criteria could be adopted for defining the installation classes for small cells? Also, what kind of Simplified Assessment Criteria could be adopted for such installation classes so as to demonstrate RF-EMF exposure compliance with respect to Indian EMF limits/norms? Please illustrate your response with specific examples and global best practices or international standards, if any.

Q 6. Is the Simplified Assessment Criteria prescribed in the TEC Test Procedure document directly applicable to 5G Base stations, specifically in light of identification of new frequency bands? If yes, please demonstrate the applicability with suitable examples. If no,

what kind of modifications are required in the given criteria? Please justify your response with rationale and suitable examples, if any.

Q 7. Which methods, other than already suggested in TEC Test Procedure document, can be used for assessment of installation compliance (by measurement or calculation) for 5G Base stations? Please support your response with rationale, international precedents or best practices, if any.

Q 8. Can installation compliance approach be utilized for demonstrating RF-EMF exposure compliance in case of 5G small cells, indoor Base stations and street furniture Base station sites? If yes, what criteria must be used to categorize the accessibility and deployment conditions? Please justify your response with rationale and suitable examples or best practices, if any.

Q 9. Can an installation manual be created for indoor and street furniture Base stations on the basis of Base Station (product) compliance report and installation/accessibility conditions? If yes, how? Please support your response with rationale and suitable examples or best practices, if any.

Q 10. What should be the frequency range for in-situ measurement after identification of new frequency bands for cellular mobile (as per aforementioned Notice Inviting Tender)? Please support your response with rationale, capabilities of the measuring equipment available in the market, and international examples, if any.

Q 11. How should Broadband Measurement be carried out to cover both mid band (FR1) and high band (FR2) in 5G? Also, what should be the extrapolation factor for Frequency Selective Measurement (FSM) for 5G technology? Please support your response with rationale, supporting standard(s) and global best practices, if any.

Q 12. Whether any other change(s) is required in the current methodology of in-situ measurement and post processing (as provided in TEC Test Procedure document) in the light of new frequency bands and higher channel bandwidths anticipated to be used by IMT technologies? Please justify your response with rationale, supporting standard(s) and global best practices, if any.

Q 13. What is the maximum transmitted power and EIRP of the 5G Base Stations for different configurations, frequencies and channel bandwidths? Please support your response with international standards, equipment availability in the market or suitable examples if any.

Q 14. Which approach (Approach 1 or 2) may be adopted for determination of transmitted power for 5G base stations? Please

justify your response with rationale, supporting standard(s) and global best practices, if any.

Q 15. In case of Approach 2, how can statistical analysis of network be carried out for EMF compliance? What are the benefits, risks and challenges foreseen in using such approach? Please support your response with rationale and suitable examples or best practices, if any.

Q 16. Please provide examples of EMF exposure assessment methodologies used in the countries where 5G networks have already been deployed. Please justify your inputs with supporting documents.

Q 17. Any other issues which are relevant to this subject? Please suggest with justification and supporting standards or best practices.

References

[1] Website: https://dot.gov.in/journey-emf

[2] Test Procedure For Measurement of Electromagnetic fields From Base station antenna (TEC 13019:2018) https://tec.gov.in/pdf/GR3/TSTP%20EMF%20Measurement.pdf

[3] Notice Inviting Applications for Auction of Spectrum in 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500 MHz, 3300 MHz, and 26 GHz Bands. https://dot.gov.in/sites/default/files/NIA%202022.pdf?download=1

[4] ITU-T Recommendation Series K Supplement 16 'Electromagnetic field compliance assessments for 5G wireless networks.

[5] ICNIRP guidelines For limiting exposure to Electromagnetic Fields (100 kHz to 300 GHz) https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pdf

[6] ITU-T Recommendation K.52 'Guidance on complying with limits for human exposure to electromagnetic fields.

[7] IEC 62232: 2017 'Determination of RF field strength, power density and SAR in the vicinity of base stations for the purpose of evaluating human exposure.

[8] ITU-T Recommendation K.100 'Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service.

[9] IEC TR 62669: 2019 'Case studies supporting IEC 62232 - Determination of RF field strength, power density and SAR in the vicinity of radio communication base stations for the purpose of evaluating human exposure.

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