GTI 5G mmWave Spectrum White Paper

GTI 5G mmWave SPECTRUM WHITE PAPER

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Contents

Annex A: Document History

Date	Meeting #	Revision Contents	Old	New
2018.12.28		Draft White Paper skeleton		
2019.01,25		First Version of the Draft White Paper completed		
2019,01,30		Second Version of the Draft White Paper completed		

Abstract

1 Introduction

Overall demand of 5G shows that the business needs of 5G will be diversified, no matter from the business needs of enhanced mobile broadband, massive machine type of communication and the communication demand of ultra-reliable/low-latency services. It inevitably brings new design for 5G NR radio interface to extend their spectrum used to meet the different requirements for the future, such as the need for a large amount of spectrum, very wide bandwidth and different delay requirements.

At the WRC-15, based on the feasibility study of high frequency band for IMT in ITU-R WP 5D, a new agenda item AI 1.13 of WRC-19 was established for additional spectrum allocation to mobile service and identification of additional frequency bands for IMT, to counteract the difficulties encountered in finding additional spectrum for IMT in the bands above 6GHz and allow IMT systems to meet the demand for greater capacity in the frequency bands in the range of 24.25-86GHz.

A number of Administrations are considering licensing spectrum within mmWave bands by 2020 while some countries have done so already. Several bands from these ranges have been specified

within 3GPP Release 15 (Rel-15) and products and ecosystems supporting different portions of these frequency ranges are available since 2018.

World Radio Conference-19 will be held this year on Oct, 28-Nov, 22 in Egypt. It is very critical for GTI to start the study and preparation taking into account the world wide mmWave spectrum development for 5G. This white paper will update the global situation regarding the 5G radio spectrum policy for mmWave, standardization progress, global industry development, operator trial and deployment. It will also promote a mobile industry view on how to protect the existing service used in the bands and provide appropriate technical requirement for coexistence with the existing services. Based on the study in the white paper, we also would like to conclude a GTI proposal of the future 5G mmWave spectrum strategy for developing the products and our view towards WRC-19 AI 1.13 as well.

1.1 Background

With large spectrum bandwidth available in the mmWave frequency ranges, mmWave spectrum will enable various 5G NR applications of very high data rates and low latency for indoor and outdoor scenarios, e.g. 5G eMBB(Enhanced Mobile Broadband) and URLLC (Ultra Reliable & Low Latency Communication) applications to be deployed at hotspots in metropolitan areas and/or for industrial usage.

A number of Administrations are considering licensing spectrum within these ranges by 2020 while some countries have done so already. Several bands from mmWave bands have been specified within 3GPP Release 15 (Rel-15) and products and ecosystems supporting different portions of these frequency ranges are available since 2018.

World Radio Conference-19 will be held this year on Oct, 28-Nov, 22. Its AI 1.13 will be focused on additional spectrum allocation to mobile service and identification of additional frequency bands for IMT above 6GHz and allow IMT systems to meet the demand for greater capacity in the frequency bands in the range of 24.25-86GHz.

1.2 Objectives of this white paper

The objective of this white paper will:

- Update the global situation regarding the 5G radio spectrum policy for mmWave, standardization progress, global industry development, operator trial and deployment.
- Promote a mobile industry view on how to protect the existing service used in the bands and provide appropriate technical requirement for coexistence with the existing services.
- Conclude a GTI proposal of the future 5G mmWave spectrum strategy for developing the products
- Deliver our view towards WRC-19 AI 1.13 to relevant administrations and regional regulatory bodies for lobbying

1.3 Terminology

Term	Description
ASMG	The Arab Spectrum Management Group (ASMG)
ATU	The African Telecommunications Union (ATU)
EESS	Earth Exploration Satellite Service
EIRP	Effective Isotropic Radiated Power
FSS	Fixed Satellite Service
ISS	Inter-Satellite Service
SCS	Subcarrier Spacing
TRP	Total Radiated Power

2 High Frequency Bands Requirements for 5G and Characteristics and Challenges of High Frequency

2.1 High Frequency Bands Requirements for 5G

High frequency bands provide large amount of spectrum and help mobile operator to increase their capacity with much wide bandwidth .e.g. continuous 1GHz amount of spectrum per operator. With such large spectrum bandwidth it can enable various 5G NR new applications for extremely high data rates, ultra-wide band and low latency for indoor and outdoor scenarios to establish extreme user experience for 5G eMBB and URLLC applications at hotspots in metropolitan (corporate buildings, campus, stadium, shopping mall, hotels, Arenas, airports, train stations and other transportation hubs, parks and city centers) and/or industrial usage areas.

To satisfy the various mobile operator 5G applications, accessing to different type of spectrum (low, mid and high frequency bands) and spectrum amount (narrow to very wide channel bandwidths) is needed. mmWave can be deployed in NLOS in clutter environment for the applications requiring very wide bandwidths in short ranges.

2.2 Characteristics of High Frequency Bands

mmWave band is operated in 30GHz-100GHz (see figure 2-1). Vast amount of spectrum will be available in these new bands and often they are contiguous spectrum. Operation in mmWave bands contains large frequency ranges and can offer very high data rate like Gbps speeds. Small wavelengths in millimeter-wave bands make massive antenna deployments possible and that will also help to provide high speed data transmission with more efficiency. The power in mmWave band is in the order of 10-20dBm for indoor and provide enhanced network energy efficiency

Figure 2-1 mmWave spectrum

Operators can provide dense deployment with access to very large bandwidth around 500MHz up to 2GHz. The use case can be indoor and very dense outdoor deployments. One access node can cover every room, lamp pole etc for the areas with high data rate or capacity needs, e.g. corporate buildings, campus, hotels, Arenas, shops, airports, train stations, parks and city centers. It can also offer the capability of in-band wireless self-backhauling with latency of around 1 ms for each hop in the self-backhaul. The self-backhaul can make low deployment cost and provide

operator deployment flexibility to meet traffic demand.

The ability to handle mobility as in cellular network is achievable as well.

2.3 Challenges of High Frequency Bands

According to the ITU-R Report ITU-R M.2376, the outdoor to indoor building penetration loss is showed in the Figure 2

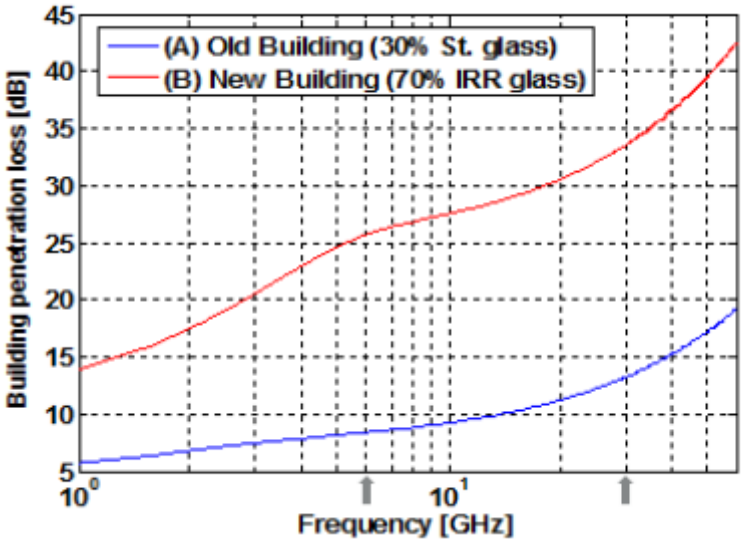


Figure 2-2: Outdoor-to-indoor building penetration loss

Figure 2-2 shows 30% building like old building with standard glass in blue color and 70% building like the new building with infrared reflective glass in red color. In standard glass mode, 5dB difference for frequency range from 6Ghz to 30GHz and for the IRR glass, 7.5dB difference between 6GHz and 30GHz.

And the propagation loss for different frequency bands also varies from low to high frequency bands. It will need a compensation to increase path loss as a function of frequencies beamforming using more antennas and densification of the network.

Fundamentals of radio propagation have different properties for high frequency bands e.g. free space propagation, penetration, reflection, diffraction, shadowing, blocking etc.

3 Global High Frequency Spectrum Development Updates

3.1 ITU Progress

In World Radiocommunication Conference 2015(WRC-15), WRC-19 agenda item 1.13 was

confirmed which is to consider identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 238 (WRC 15).

Resolution **238 (WRC-15)** calls for studies to determine the spectrum needs for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz, as well as sharing and compatibility studies, taking into account the protection of services to which the frequency band is allocated on a primary basis, for the frequency bands:

– 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and

– 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis,

And furthermore, the first session of the Conference Preparatory Meeting for WRC 19 (CPM19-1) , which was held in Geneva following the WRC-15, have made decision to establish Study Group 5 Task Group 5/1 (TG 5/1) and corresponding Terms of Reference on WRC-19 agenda item 1.13.

ITU-R WP5D conducted the spectrum needs studies and provided the studies' results to TG5/1 in February 2017.

TG 5/1 finalized its work including sharing and compatibility studies and draft CPM text for WRC-19 agenda item 1.13 at the sixth meeting in August 2018. Although different countries have different views on WRC-19 agenda item 1.13, it is anticipated that ITU will identify some of the candidate bands for IMT at WRC-19, 24.25-27.5GHz and 37-43.5GHz are the most promising frequency bands.

3.2 3GPP Progress

3GPP defined many spectrum bands below 6 GHz as well as mmWave bands up to 52.6 GHz in Release 15. Considering different testing methods to verify the Radio Frequency (RF) and Radio Resource Management (RRM) requirements in different frequency range, i.e., Over the Air (OTA) testing or conductive testing, two frequency ranges are categorized, i.e., Frequency Range 1 (FR1) 450 MHz–6 GHz and Frequency Range 2 (FR2) 24.25 GHz–52.6 GHz. mmWave bands defined in 3GPP are within the range of 24250 MHz – 52600 MHz.

3.3 U.S. Progress

On July 14, 2016, the US Federal Communications Commission (FCC) voted for the 10.85 GHz high-band spectrum for 5G wireless technology, including 28G (27.5-) 28.35 GHz), 39G (38.6-40 GHz), a total of 2.25 GHz licensed spectrum, 37G (37-38.6 GHz) total 1.6 GHz hybrid licensed spectrum, and 64-71 GHz total 7 GHz license-free spectrum[8]. In November 2017, the FCC issued the report and order and decided to add the 1.7 GHz band of 24.25-24.45 GHz, 24.75-25.25 GHz and 47.2-48.2 GHz for 5G wireless technology[9]. Up to January of 2019, the FCC has allocated total 13 GHz spectrum for the 5G wireless technology in the millimeter wave band.

In June 2018, the FCC officially approved Third Report & Order & Further NPRM[11]. A frequency management scheme shared between the 5G frequency licensing service and the FSS earth

station is provided at 24.75-25.25 GHz. For the coexistence of 24 GHz and EESS, the FCC tends to consider additional spurious limit requirements for IMT with reference to global protection guidelines. In addition, the FCC further sought advice on the opening of the frequencies 25.25-27.5 GHz and 42-42.5 GHz, as well as the sharing of the framework for the 37.0-37.6 GHz band.

In March 2018, the FCC issued a public notice [10], proposing an auction scheme for the 28 GHz and 24 GHz spectrum. The 28 GHz spectrum will be split into 2 licensed bandwidths each for 425 MHz, licensed for the county level, and the 24 GHz spectrum will be split for each license of 100 MHz bandwidth. The licenses will target 416 PEAs (local economic regions) across the United States. The 28 GHz spectrum was auctioned since November of 2018 and the 24 GHz spectrum auction would be slightly later than the 28 GHz spectrum auction. The FCC adopted the program on April 17, 2018. It is worth noting that most operators with fixed service licenses at 28GHz have converted their fixed service licenses into mobile licenses in 2016. The 28GHz license auction in November 2018 is a fixed service for FCC inventory because it has not met the deployment requirements. A small number of spectrum licenses are recovered, which are a small subset of all 28 GHz licenses. In December of 2018, the FCC approved the order setting the rules for the auctions[12]. The channel block is decided to be 100MHz in these ranges, including 37.6 to 38.6 GHz 39GHz, 38.6 to 40 GHz and 47.2 to 48.2 GHz. The auction will be an incentive auction to rearrange things in 39GHz frequency range. So up to the end of 2018, the FCC had a full slate of mmW auctions between the end of 2018 and the end of 2019: 28 GHz was underway. The 24 GHz would follow when the 28 auction ends. Then, by the second half of 2019, FCC would action these other mmW bands.

3.4 China progress

Using millimeter wave spectrum for 5G systems has become the trend. A lot of investment from government has been put on mmWave key technology R&D. the Ministry of Industry and Information Technology of China released a public consultation on June 8, 2017 to collect comments to use 24.75-27.5GHz, 37-42.5GHz or other millimeter wave bands for 5G systems. In July of the same year, the Ministry of Industry and Information Technology approved the frequency bands of 24.75-27.5 GHz and 37-42.5 GHz to be used in the 5G technology trial for 5G technology research and development.

MIIT Radio Regulatory Department issued a mmWave frequency plan questionnaire, companies were asked to officially feedback their key consideration for 5G mmwave, the urgency of 5G mmWave spectrum planning, deployment scenarios and plan and also the equipment capability of bandwidth, output power and spurious emission.

3.5 EU progress

Europe Commission published the EC 5G Action Plan in September 2016. It presents an action plan for timely and coordinated deployment of 5G networks in Europe through a partnership between the Commission, Member States, and industry. It calls for coordination approach to help shape a global consensus as regards the choice of technologies, spectrum bands and leading 5G

applications effective and commercial 5G service launch. The Commission worked with Member States to work towards a recommended approach for the authorisation of the specific 5G spectrum bands above 6 GHz, taking due account of the opinions of BEREC and RSPG. An early indication of technical options and feasibility was available through CEPT studies by end 2017.

RSPG under European Commission published its Opinion on spectrum related aspects for next-generation wireless systems (5G) in November 2016. In particular, RSPG identified the pioneer bands spectrum bands for the initial launch of 5G services including above 6GHz: 24.25-27.5GHz to ensure all the performance targets of 5G, for example multi gigabit per second data rates. The RSPG recommends the 24.25-27.5 GHz as a pioneer band for 5G above 24 GHz and that Europe should develop harmonisation measures on the basis of the radio spectrum decision in this band before 2020 and Member states should make available a portion of this frequency band for 5G in response to market demand. In addition, the EU will continue to study the 32G (31.8-33.4GHz) and 40G (40.5-43.5GHz) bands, as well as other high frequency bands.

In December 2016, EC mandated to CETP to develop harmonized technical conditions for spectrum use in support of the introduction of 5G terrestrial wireless systems in the Union, including 5G usage scenarios and take into account needs for shared spectrum use with existing or prospective incumbent uses. After that CEPT finalized its report to the European Commission in response to the mandate to develop harmonised technical conditions for spectrum use in support of introduction of next generation (5G) terrestrial wireless systems in the Union and ECC decision was approved in July, 2018 for Harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band
24.25-27.5 GHz.

The European Commission issued regulatory requirements for the 5G use of the 26G band in the second half of 2018. At the same time, in 2018, European countries have also started to solicit opinions on the spectrum auction rules for the 5G spectrum, including 26GHz. Italy is the first EU member state to auction the 26 GHz band (26.5-27.5GHz) for 5G. Each of the five operators won one of the five lots of 200 MHz (TDD). France and Germany is ongoing for the public comments for 26GHz spectrum auction. Spain, Sweden and U.K have completed the public opinions on the 26GHz spectrum auction rules, the timing of the auction is now TBD.

3.6 Japan progress

MIC (Ministry of Internal Affairs and Communications) in Japan released a report for their radio policy 2020 in July 2016. This report covers several topics including 5G spectrum and 5G trials. Japan targets to commercially launch 5G by July, 2020. MIC established their radio policy vision towards 2020s and set up their new goals for frequency allocations to mobile communication systems. The key element of their strategy to secure necessary spectrum for 5G for Above 6GHz is that:

- 24.25GHz-86GHz (11bands*), *Frequency considered in WRC-19 (IMT-2020): Promote comprehensive consideration in accordance with international harmonization,

domestic/international R&D trends and frequency sharing with existing systems

- 27.5GHz-29.5GHz: Promote comprehensive consideration in accordance with U.S and Korea etc.

MIC disclosed a draft 5G spectrum allocation plan and policy on Nov. 2, 2018 for public consultation. After the consultation, it will be finalized in Jan. 2019, applications for beauty contest in Jan. to Feb., and spectrum awarded in March. For 5G high band, MIC allocates 28GHz (27.5-29.5GHz), they allocate 400MHz × 4 for operators, each operator can apply for up to 1 × 400MHz. The final spectrum award will be in March, 2019.

3.7 Korea progress

Korea Ministry of Science, ICT and Future Planning (MSIP) issued '**K-ICT Spectrum Plan**' which is an official roadmap for pioneering domain of future frequencies in Korea including 5G spectrum on January 18, 2017. According to the K-ICT Spectrum Plan, The Korean regulator plans to provide 300MHz bandwidth in the band 3.4-3.7GHz and 3 GHz bandwidth in the band 26.5-29.5 GHz by 2018 when 5G systems are available, at the latest by 2021 and additional 1 GHz bandwidth in the band above 24.25 GHz will be allocated by 2026 taking into account WRC-19 results.

Korea auctioned their 5G spectrum in June 2018 including the high band 26.5-29.5GHz, 800MHz each operator (SKT: 28.1GHz-28.9GHz, KT: 26.5GHz-27.3GHz and LG Uplus： 27.3GHz-28.1GHz). The license is a 5 year license from Dec, 1st, 2018. The obligation of 5G deployment will be 15% in 3 years of the basis (100000).

4 Standardization and Product Availability

4.1 Standardization Requirement

A list of 3GPP mmWave bands is provided in Table 4-1 below. These bands are defined only for NR and have been selected based on operators' requests (subject to time available to complete all the UE/BS RF requirements of the band). Additional bands will be defined in later release but in release independent manner, if requested by operators.

Table 4-1: NR operating bands in FR2

(from TS38.101-2-f30)

Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD

Different from LTE which has a fixed subcarrier spacing (SCS) for 15 kHz, NR supports scalable numerology for more flexible deployments covering a wide range of services and carrier frequencies. Note that 60 kHz, 120 kHz and 240 kHz are applicable to above 6 GHz carrier frequencies and 240 kHz SCS is used for SS/PBCH block in above 6 GHz bands.

For each operating band, limited number of channel bandwidth has been specified for each subcarrier spacing (SCS). For UE channel bandwidth in Release 15, it is further specified that all channel bandwidth below 200 MHz shall be mandatory supported by UE with a single component carrier in FR2, as in Table 4-2.

- **Table 4-2: Channel bandwidths for each NR band**

Operating band / SCS / UE channel bandwidth					
Operating band	SCS kHz	50 MHz	100 MHz	200 MHz	400 MHz
n257	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n261	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

More than 90% spectrum utilization has been specified in NR (except certain SCS) as maximum transmission configuration for each SCS and each channel bandwidth in implementation agonistic manner. In order to meet the relative emission requirements, the minimum guard band for each UE channel bandwidth and SCS has been also defined, as Table 4-3 shows.

- **Table 4-3: Minimum guardband for each UE channel bandwidth and SCS (kHz)**

SCS (kHz)	50MHz	100MHz	200MHz	400 MHz
60	1210	2450	4930	N. A
120	1900	2420	4900	9860

For FR2 NR UE and some NR BS types, due to highly integrate antenna implementations, physical conductive testing interface may not exist anymore. To specify the radiated requirements, both RF performance and the test methods were considered. Overall, directional requirements, e.g., EIRP/EIS and non-directional requirements, e.g., TRP have been specified for corresponding RF requirements for UE and BS.

4.2 Product Availability Analysis

4.2.1 Chipset and Device availability

The leading chipset suppliers will release commercial 5G NR mmW products supporting n257, n258, n260 and n261 in 2019 as per 3GPP R15 compliance. And since 2020, most major chipset suppliers will release commercial 5G NR mmW products supporting 26GHz, 28GHz,39GHz, and so on, as per 3GPP R16 compliance.
In 2018, the mmWave antenna modules are ready which is fully-integrated mmWave RF solution for smartphones and other mobile devices that are engineered to open up spectrum and improve mmWave signal using 5G technologies.
Mobile devices to support mmW will be commercially launched in 2019.

4.2.2 BS equipment availability

B261 and B260 products have been available for Korea, American and Japanese market in 2018. B257 product will be supported in 2019. B258 product would be foreseen ready in 2020 after many administrations' decision made for this band.

5 Coexistence solutions

5.1 ITU Sharing Study Progress and Summary of the Conclusions

As invited by CPM19-1, ITU-R SG5 formed Task Group (TG) 5/1 which is responsible for conducting the sharing and compatibility studies for WRC-19 agenda item 1.13, and with developing the draft CPM text for this agenda item. The sixth and final meeting of ITU-R TG 5/1 was held in Geneva, Switzerland from 20-29 August 2018. TG 5/1 finalized its work at this meeting. Draft CPM text for agenda item 1.13 has been provided to the chapter rapporteur within the timeframe dictated by the CPM management team. Summaries of results of studies and spectrum regulation recommends of the candidate frequency bands are provided in the CPM text, for the decision-making of WRC-19. Because different countries have different standpoints, there is great discrepancy between studies' results in certain cases, and there are many different views on spectrum regulations.

Table 5-1 provides the summary of cased which have been studied in TG 5/1, including frequency band, services, major contributors, studies results and CPM methods. There are two methods to satisfy the agenda item for each of the frequency bands, one is no change to the Radio Regulations, and the other is identification to IMT under some conditions.

Table 5-1：Summary of ITU-R TG5/1 studies

Frequency band（GHz）		*services/ systems*	*Major contributors*	*Studies results*	*CPM methods*
24.25-27.5	*23.6-24*	*EESS passive*	*USA*、*Korea*、*ESA*、*France*、*GSMA*、*China*、*Brazil*、*Germany*、*Ericsson*、*Nokia*	*based on -13dBm/MHz unwanted emission, require additional isolation: 9-31dB*	Method 1: NOC Method 2: option 1：Add limitation in Resolution 750 (Rev.WRC-15) Option 2：develop an ITU-R Recommendation including limitation. Option 3：no condition

	23.6-24	*RAS*	*France、CRAF、China*	*based on -13dBm/MHz unwanted emission, protection distance: 17-52km*	Method 1: NOC Method 2: option 1：Recommendation for protection Option 2：Resolution for protection Option 3：no condition
	25.5-27	*EESS/SRS(S-E)*	*USA、China、ESA、UK、Korea、Brazil*	*protection distance: EESS:0.2-7km，SRS:0.8-92km*	Method 1: NOC Method 2: option 1：develop an ITU-R Recommendation and invited the administrations to adopt provisions Option 2：develop an ITU-R Recommendation and incorporate this Recommendation into the RR by reference Option 3：Protection of other services (in-band and/or adjacent band) by IMT should be contained in a WRC Resolution cross-referenced in the footnote in RR Article **5** in which the frequency band is identified for IMT. Option 4: No condition.
	25.25-27.5	*ISS*	*China、UK、France、USA、Russia*	*Addition margin: 8.2-25dB (only Russian results shows additional isolation is needed)*	Method 1: NOC Method 2: option 1：limitation on TRP, electrical tilt and mechanical tilt Option 2：Limitation on TRP, elevation

	24.65-25.25/27-27.5	*FSS(E-S)*	*Australia*、*Korea*、*Luxembourg*、*France*、*Japan*、*China*、*Brazil*、*Russia*、*Ericsson*	*All studies except Russia show that interference from IMT to FSS space station can meet the interference criteria.*	angle and antenna pattern. Option 3：limitation on TRP and combined tilt (electrical and mechanical) Option 4：limitation on main beam pointing and mechanical pointing Option 5：limitation on TRP, mechanical tilt and density Option 6: limitation on e.i.r.p. mask Option 7：epfd limit Option 8：TRP Option 9：no condition
	24.25-27.5	*FS*	*Germany*、*UK*、*Switzerland*、*Brazil*	*Protection distance：* In-band：0.5-70km Adjacent band：0-13km	\
31.8-33.4	*31.8-33.4*	*RNS*	*USA*、*France*、*China*、*Russia*	*protection distance:100km*	Only one method, NOC
37-43.5/45.5-50.2/ 50.4-52.6	*36-37*	*EESS passive*	*USA*、*China*、*GSMA*	*based on -13dBm/MHz unwanted emission, require additional isolation: 0-26.1dB*	Method 1: NOC Method 2: option 1：add limitation in Table 1-1 of Resolution **750** Option 2：add limitation in Table 1-2 of Resolution 750 Option 3：add limitation in IMT resolution. Option 4：no condition
	37-38、*40-40.5*	*SRS(s-E)*	*USA*、*ESA*	*protection distance: 24-100 km*	Method 1: NOC Method 2: option 1：develop Recommendation and invite administrations to adopt.

					option 2：Protection in a WRC Resolution and cross-referenced in the RR footnote. Option 3: No condition.
	37.5-42.5、*47.5-47.9*、*48.2-48.54*、*49.44-50.2*	*FSS/MSS/BSS (s-E)*	*China*、*Canada*、*USA*、*Brazil*、*Huawei Sweden*、*Luxembourg*、*GSMA*、*France*	*protection distance: 0.2-2km*	Method 1: NOC *Method 2:* *option 1：Considering balance between IMT and FSS, develop Recommendation and invite administrations to apply.* Option 2：Protection in a WRC Resolution and cross-referenced in the RR footnote. Option 3: Revise RR No. **5.516B** to provide 2 GHz spectrum to FSS. Option 4: develop Recommendation and invite administrations to apply, considering HDFSS；balance between IMT and FSS. Option 5：considering HDFSS, Option 6：no condition.
	42.5-43.5	*RAS*	*CRAF*、*Brazil*、*China*	*protection distance: adjacent band：5km-48km in-band：36-68km*	Method 1: NOC *Method 2:* *Option 1：update or develop Recommendation*

					; Option 2：Protection in a WRC Resolution and cross-referenced in the RR footnote. Option 3: No condition.
	42.5-43.5	*FSS (E-s)*	*Brazil、Russia、Luxembourg、UK、France、Ericsson*	*Addition margin:16-33dB* *Russia：* *GSO addition margin 2.9dB* *NGSO: interference exceed the protection criteria*	Method 1: NOC *Method 2:* *7 options, similar to 26GHz*
	47.2-50.2	*FSS (E-s)*	*USA、France、Luxembourg、Brazil、Ericsson、OneWeb*	*Addition margin: 6.5-26.6dB* *OneWeb: interference exceed the protection criteria*	Method 1: NOC *Method 2:* *7 options, similar to 26GHz*
	50.2-50.4/52.6-54.25	*EESS passive*	*USA、ESA、Ericsson、GSMA*	*based on -13dBm/MHz unwanted emission, require additional isolation:5-29.5dB*	Method 1: NOC Method 2: option 1：Add limitation in Resolution 750 and add a cross-reference in footnote and revise RR No. 5.338A; Option 2：Add limitation in Resolution 750. *Option 3：no condition*
	50.4-52.6	*FSS (E-s)*	*Luxembourg、USA、France*	*Addition margin：6.5-22dB*	Method 1: NOC *Method 2:* *7 options, similar to 26GHz*

66-71	*66-71*	*ISS*	*UK*	*Single entry addition margin:38dB*	Method 1: NOC *Method 2: identify under conditions* *Method 3：continue to study* (USA and Europe: unlicensed spectru)
71-76/81-86	*71-76/81-86*	*FS*	*Nokia、China*	*separation distance:250-970m*	\
	71-76	*FSS(s-E)*	*One Web*	*separation distance: 250m*	Method 1: NOC *Method 2:* *option 1：develop recommendation,* Option 2：Protection in a WRC Resolution and cross-referenced in the RR footnote. Option 3: No condition
	81-86	*FSS(E-s)*	*One Web*	*Interference from IMT to satellite can meet the interference criteria.* Interference from earth station to IMT BS need 250m separation distance.	Method 1: NOC *Method 2:* *Option 1：TRP and combined tilt;* Option 2：e.i.r.p. mask Option 3：no condition.
	79-92	*RAS*	*China、CRAF*	based on -13dBm/MHz unwanted emission, separation distance: in-band: 21-49km, adjacent band: 2-29km	Method 1: NOC *Method 2:* *option 1：update or develop Recommendation.* *Option 2：Protection in a WRC Resolution and cross-referenced in the RR footnote.*

	86-92	*EESS passive*	*ESA、USA、China*	*based on -13dBm/MHz unwanted emission, require additional isolation:8.2-29.9dB*	Method 1: NOC *Method 2: option 1： Add limitation in Resolution 750* *Option 2： no condition*
	76-81	*RLS*	*Huawei Sweden、Germany/Switzerland*	*study A: addition isolation is up to 15dB based on -13dBm/MHz unwanted emission* study B: an unwanted emission limit more stringent than -30 dBm/MHz is nnecessary.	Method 1: NOC *Method 2: Add limitation in Resolution.*

5.2 CEPT Sharing Study Progress

CEPT finalized its report to the European Commission in response to the mandate to develop harmonised technical conditions for spectrum use in support of introduction of next generation (5G) terrestrial wireless systems in the Union and ECC decision was approved in July, 2018 for Harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz. In the ECC decision, they define:

- Protection of EESS(passive) in 23.6 – 24.0 GHz
  - -42 dBW/200 MHz for BS
  - -38 dBW/200 MHz for UE
- Second order harmonics (interference into EESS(p) above 50 GHz): General spurious limit (-30 dBm/MHz) accepted as protection for these two EESS bands
- No TRP limit and EIRP elevation mask defined to protect satellite
  - Conditions applying to the elevation of the main beam from 5G AAS outdoor base stations
    - When deploying outdoor base stations, it shall be ensured that each antenna is normally transmitting only with main beam pointing below the horizon and in addition the antenna shall have mechanical pointing below the horizon except when the base station is only receiving
- No communications from BSs to UAVs (the opposite direction to be studied)

5.3 China Sharing Study Progress

ITU-R Task Group 5/1 meeting has finalized its sharing and compatibility studies on key services. The results of the studies are captured in working document attached to Chairman's report, as below Table 5-2.

Table 5-2： Summary of China sharing studies

Frequency bands (GHz)		Services	Input Doc# from China	Output Doc# in Chairman's Report
24.25-27.5	23.6-24	EESS passive	5-1/148, 220, 333, 453,	5-1/478 Annex 03 Part 2
	23.6-24	RAS	5-1/216, 332	5-1/478 Annex 03 Part 2
	25.5-27	EESS/SRS (s-E) (in-band)	5-1/60, 150, 217, 218, 334, 335, 451, 452	5-1/478 Annex 03 Part 1
	25.25-27.5	ISS	5-1/58, 151, 219, 337, 455	5-1/478 Annex 03 Part 4
	24.65-25.25/27-27.5	FSS (E-s)	5-1/61, 152, 221, 336, 454	5-1/478 Annex 03 Part 3
31.8-33.4	31.8-33.4	RNS	5-1/59, 153, 222	5-1/478 Annex 04 Part 1
37-42.5	36-37	EESS passive	5-1/149, 223, 338, 456	5-1/478 Annex 05 Part 3
	37.5-42.5	FSS (s-E)	5-1/62, 154, 224, 339, 457	5-1/478 Annex 05 Part 1
	42.5-43.5	RAS	5-1/340	5-1/478 Annex 05 Part 5
71-76	71-76	FS	5-1/155, 225	5-1/478 Annex 12 Part 1
81-86	81-86	FS	5-1/156, 226	5-1/478 Annex 13 Part 2
	79-92	RAS	5-1/227, 342	5-1/478 Annex 13 Part 4
	86-92	EESS passive	5-1/228, 341, 458	5-1/478 Annex 13 Part 1

6 Key consideration for the protection requirement to existing satellite systems

6.1 Protection Requirement of adjacent EESS(passive) band in the 24.25-27.5 GHz band

The frequency band of 23.6-24.0 GHz is allocated to EESS (passive) globally, and a number of studies have been carried out in ITU-R Task Group 5/1 to determine the technical conditions for protection/compatibility of passive services in 23.6-24.0 GHz, leading to a range of 5G unwanted emission levels that would be necessary to protect the EESS (passive). While some of the studies were performed on all sensors in Recommendation ITU-R RS.1861 operating in the 23.6-24.0 GHz frequency band, the results summary in draft CPM report (section 2/1.13/3.2.1.2) are based on the most sensitive and restrictive Sensor F3.

The differences in the results are due to differences in the assumptions for aspects such as:

1) Antenna patterns
2) Apportionment of interference between services
3) IMT station densities
4) Interpretation of EESS (passive) protection criteria
5) Multi-operator factor
6) Margins (not applied in all studies)

Related to the last point on margins, it is a very important aspect that should be taken into account when the regulatory limit for 5G unwanted emissions is defined. Margins are necessary to manage the measurement uncertainties, variation in the production and deployment of 5G equipment, and temperature fluctuations and ageing. It is not realistic to assume that all devices emit exactly according to the given protection level (especially when this level is not allowed to be exceeded). So in practice, to ensure that this level is not exceeded, products need to be manufactured well below the limit which then results in an additional protection margin beyond the specified level thereby reducing the interference even further. The following margin diagram shows the actual interference and margin in Figure 6-1.

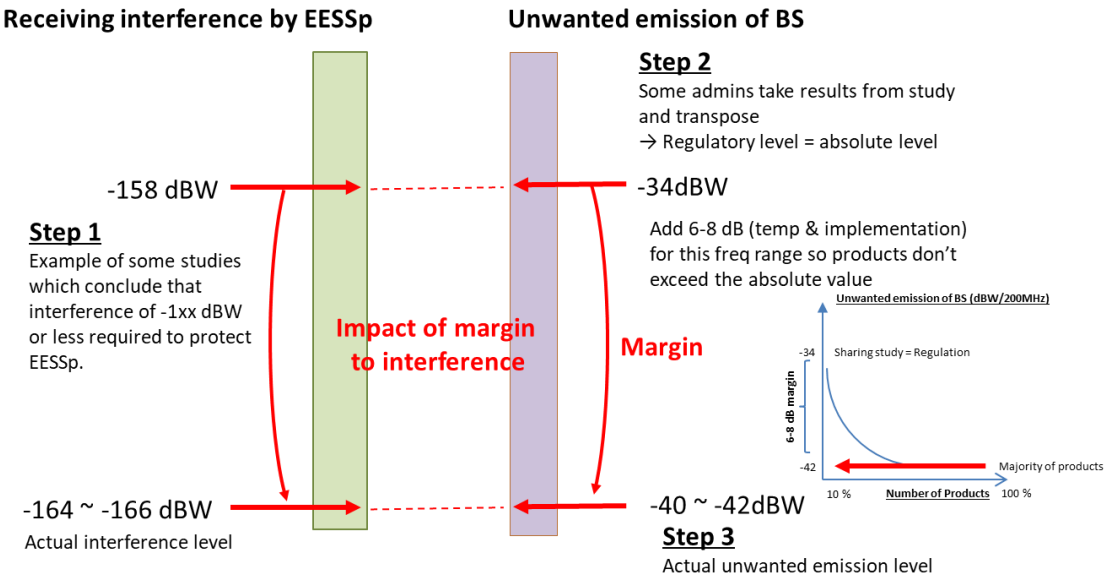


Figure 6-1 Illustration of Actual interference and Margin

The African Telecommunications Union (ATU) recently adopted an African preliminary position which specifies the IMT-2020 unwanted emission levels within the following ranges:

- BS: -32 to -37 dB(W/200 MHz)
- UE: -28 to -30 dB(W/200 MHz)

The Arab Spectrum Management Group (ASMG) at its 24th meeting in Amman, Jordan in December 2018, decided to support no strict measures and restrictions on the use of IMT in 26 GHz band, with possibility of a new ITU-R Recommendation to include the following values of OOBE limits to the band 23.6-24 GHz from the BSs and UEs operating in the band 24.25-27.5 GHz, in case of need for these additional measures as appropriate:

- BS: - 32 dB(W/200 MHz)
- UE: - 28 dB(W/200 MHz)

CEPT has decided in ECC Decision 18(06) [2018-10-26] on restrictions as stringent as -42 dB(W/200 MHz) for unwanted emissions from 5G BS. These unwanted emission limits are not workable for the IMT industry. This will seriously hamper the performance of network and in practice, can make a large part of the 26 GHz band unusable. 3GPP has been studying the feasibility of meeting more stringent unwanted emission limits than their baseline requirement. Preliminary results from these studies indicate that, for example, with an emissions limit for base stations of -37 dB(W/200 MHz) there would be a substantial impact on performance, throughput and costs of 5G networks and services in the 26 GHz band. This would also require a large frequency separation of around 1 - 1.5 GHz between the mobile transmissions and the EESS (passive) band, resulting in the lower part of the 26 GHz band not being usable for outdoor 5G

base stations. While advances in technology and filter design may improve over time it is still anticipated that a significant guard band will be required for outdoor 5G deployments with such stringent requirements such as -42 dB(W/200 MHz).

In addition, US will likely auction the 24 GHz (24.25-24.45 & 24.75-25.25 GHz) in early 2019, which goes down to 24.25 GHz with same EESS(p) issue and the current limit considered by FCC is -13 dBm/MHz, i.e. -20 dB(W/200 MHz), which is 22 dB more relaxed than CEPT. Auction is expected to happen with this relaxed limit. The FCC will later on, if necessary, consider through notice and comments whether any modification of their current out-of-band limits may be needed. Even if they change the limit, it may not be as stringent as CEPT. Also in Korea, the limit for the 28 GHz band (26.5-29.5 GHz) is same as in FCC (-13 dBm/MHz).

The Protection level proposed by different regions were shown in the following Figure 6-2

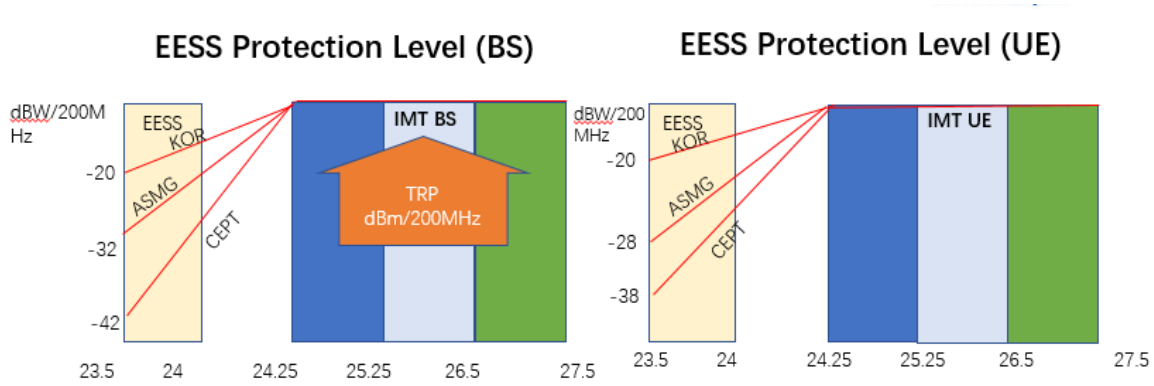


Figure 6-2 Protection level proposed by different regions

Although there is clearly a need to protect EESS (passive) operations in 23.6-24 GHz, it is important not to over-protect EESS in such a way that would unnecessarily restrict 5G networks and services. GTI companies support that most studies indicated that a value in the range -32 to -37 dB(W/200 MHz) is sufficient, and is supported by compatibility study results from both administrations and industry. And we suggest that the following IMT unwanted emission limsts shall be the most restrictive values needed to protect the EESS (passive) service in the 23.6-24.0 GHz frequency band (see Annex for detailed calculation):

- BS: -33.5 dB(W/200 MHz)
- UE: -29.7 dB(W/200 MHz)

6.2 Protection Requirement of FSS (Earth-to-space)/ISS in the band 24.25-27.5GHz and 42.5-43.5GHz

In Region 3, the frequency bands 24.65-25.25 GHz and 27-27.5 GHz and 42.5-43.5 GHz are allocated to FSS (Earth-to-space), and the frequency bands 24.45-24.75 GHz and 25.25-27.5 GHz are allocated to ISS.

Sharing studies between IMT and FSS/ISS in the 26 and 40 GHz bands, conducted as part of the work of TG 5/1, give clarity on co-existence between these services. These studies show there is a sufficient protection margin between the level of emissions that would be expected from a 5G network and the level that could potentially cause interference to FSS/ISS space stations.

For the 26 GHz band, for the case of aggregate long-term interference from IMT stations into FSS space stations in a geostationary orbit, results showed that the calculated I/N ranged from -40.62 dB to -19 dB for the baseline case, all below the protection criteria agreed by WP 4A. When considering short term interference, all studies provided results that showed maximum I/N values ranging from -28.3 dB to -15.8 dB for the baseline case, which again satisfy the agreed short-term protection criteria. Similar results are found in study results concerning the 42.5-43.5 GHz band. For the 26 GHz band, for the case of aggregate interference from IMT stations into ISS, results showed that the calculated I/N ranged from -35dB to -22.2dB for the baseline case, all below the protect criterion agreed by WP 7B .

Despite this, certain conditions are nevertheless being proposed which include an EIRP mask (based on elevation angle), an TRP limit per base station, and/or antenna tilting limits. Any such conditions would have a negative impact on the deployment, operation and performance of 5G networks and services. They are not required given that results of baseline studies show sufficient margins.

The imposition of a strict EIRP mask, TRP limits and/or electrical and mechanical tilting limitations on IMT-2020 base station would be unnecessary and impractical, and would further restrict the development and implementation of 5G in the 26 GHz and 40 GHz bands. In an IMT-2020 network, beamforming will be used to direct the main beam from a base station in the direction of each user equipment (UE) to be served, and a restriction on emissions at positive elevation angles is likely to be impractical to implement. The vast majority of UEs will be located below the height of the base station to which they are connected, and hence elevation angles greater than 0° will be atypical and are unlikely to have any significant impact on interference into other services. Imposition of an EIRP mask would place unnecessary constraints on a 5G network operator's ability to provide 5G services in an efficient and effective manner and raise costs of connectivity for consumers.

It should also be noted that almost all of the sharing studies that have been conducted on the potential interference from 5G networks into satellite space station receivers indicate that there is a significant margin between the level of interference calculated and level that could potentially cause interference at the satellite receiver.

GTI member companies believe that there is no technical justification for incorporating any regulatory provisions related to technical conditions, i.e. EIRP mask, TRP limits, epfd and/or electrical and mechanical tilting limitations on IMT-2020 base stations, for identification of the bands 24.25-27.5 GHz and 42.5-43.5 GHz in the Radio Regulation.

In addition, IMT is the victim of interference from FSS earth stations in these two bands, but no conditions to ensure the co-existence between the FSS transmitting earth stations and IMT receiving base stations and terminals operating within frequency bands of 24.25-27.5 GHz and 42.5-43.5 GHz are needed to be specified in Radio Regulation, including development of any ITU-R Recommendation, as this is a matter for the national authority.

6.3 Unwanted emission level in 40GHz

The frequency band 36-37 GHz is allocated on a primary basis to both EESS (passive) and the MS and FS with coexistence conditions currently addressed in Resolution 752 (WRC-07). The unwanted emission level of −13 dB(m/MHz), i.e. −43 dB(W/MHz), for an IMT station, which is equivalent to −13 dBW/GHz in the frequency band 36-37 GHz, satisfies the conditions described in Resolution 752 (WRC-07) (where the sharing criteria for stations in the mobile service is −10 dBW) to coexist with the EESS (passive). From this perspective, there is no need to define additional OOBE limit for IMT systems operating in the frequency band 37-43.5 GHz to ensure coexistence with the EESS (passive) systems operating in the frequency band 36-37 GHz.

In addition, passive services in the frequency band 36-37 GHz share the band with active MS and FS, so the frequency band 36-37 GHz is not a pure passive band and is not listed in Footnote **5.340**. Thus, EESS (passive) observations in this frequency band already currently have to accept a certain level of interference and that situation would not change through the use of the 37-43.5 GHz band by IMT systems.

GTI member companies is of the opinion that it is not appropriate to include this frequency band 36-37 GHz in any revision to Resolution 750 (Rev.WRC-15).

7 Above-6GHz bands development progress

This white paper intents to study and follow up the development of above-6GHz band for 5G NR. In this section, it will summarize the different above-6GHz bands development situation from various regions, countries and investigate the possible operator deployment plan for these bands showing in the following Figure 7-1.

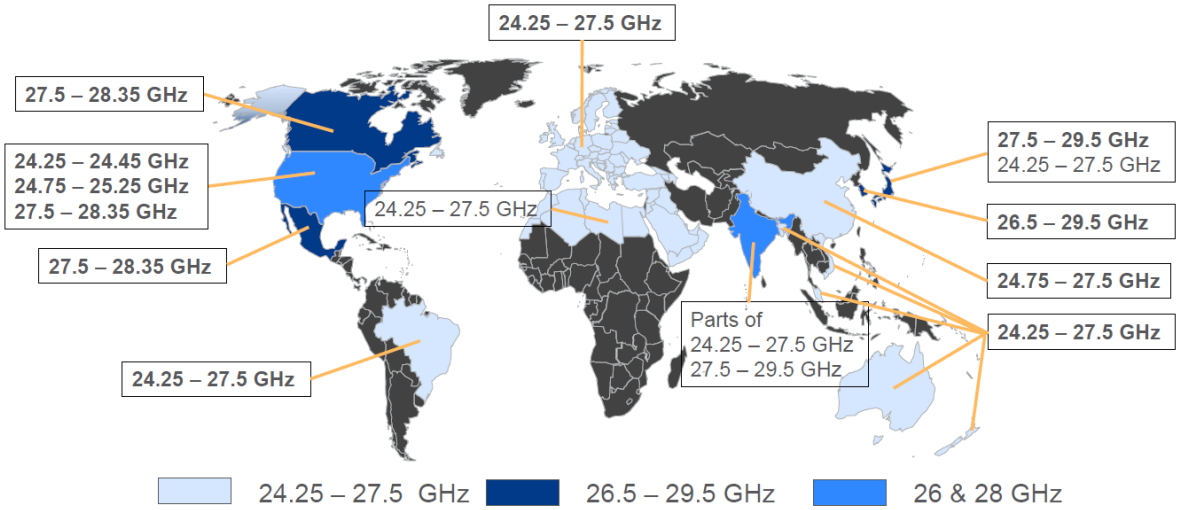


Figure 7-1 Above 6GHz development from different regions

7.1 26GHz

Several regions pay attention to the allocation of 26GHz to develop 5G services.

Europe RSPG confirmed in its 2nd opinion on "Strategic Spectrum Roadmap Towards 5G for Europe" issued in January 30th 2018 that 26 GHz (24.25 -27.5 GHz) is the pioneer band for 5G in Europe above 24 GHz, that the focus of 5G authorizations in the 26 GHz band should be on individual license regime and that Member States should make by 2020 a sufficiently large portion of the band, e.g. 1 GHz, available for 5G in response to market demand.

Currently many European regulators seem likely to move point to point licences out of bands like 26 GHz then re-assign that spectrum for 5G services. Mr. Eric Fournier chair of CEPT's Electronic Communications Committee (ECC) has clearly indicated that the 26GHz seems to be presenting "an advantage" for 5G services and there is a high possibility that 26 GHz fixed links will move to 32 GHz frequencies in order to allocate 26GHz for 5G.

Early allocation of 26GHz in Europe has been triggered in Italy in 10-2018.

In a 5G roadmap published by the ARCEP on July 16, 2018 it was revealed that the ARCEP plans to hold a consultation in October 2018 on the planned assignment of spectrum in the 26GHz band. The ARCEP plans to assign spectrum in the 26GHz band by the end of 2020

In 07-2018 Poland's spectrum regulator the UKE has opened a consultation on the use of spectrum in several bands including 26GHz bands.

ASMG region is committed to use 26GHz band for developing 5G services in hotspot areas. In past years ASMG has actively engaged with various industry players in the region for preparing the allocation of 26GHz in coming years. Several ASMG member countries (e.g. Saudi Arabia, United Arab Emirates) have already expressed interests in allocating 26GHz for 5G services.

The 24.25-27.5 GHz frequency band is also now part of the APT preliminary views because of the unanimity of support. In 09-2018 Cristian Gomez, director of spectrum policy and regulatory affairs at industry group GSMA for the APAC region has indicated that several trials of mmWave in

the 26GHz and 28GHz bands leave that spectrum in solid shape.
China P.R. has already indicated that 26GHz is part of the overall 5G services roadmap to be implemented in China.
On July 26, 2018 Hong Kong's Secretary for Commerce and Economic Development (SCED) and the Communications Authority (CA) have jointly launched a public consultation on proposals to assign spectrum in the 26GHz and 28GHz bands. The SCED together with the CA are proposing to assign 4,100 MHz of spectrum in the 26GHz (24.25 – 27.5GHz) and 28GHz (27.5 – 28.35GHz) bands through an administrative process which will also include 400MHz to 800MHz of spectrum being set aside for use on a shared basis. As part of these proposals the SCED and CA are looking to levy a spectrum utilisation fee based on supply and demand for spectrum in the 26GHz and 28GHz bands as well has how the spectrum is used.
Several other countries in Asia are considering 26GHz band as a candidate for future 5G services rollout e.g. in Indonesia the 26GHz band is one of 3 bands the government is eyeing for 5G, along with C-band and 28 GHz, because it is favoured globally.

Globally the 26GHz band represents a consensus across several countries in Region 1 and Region 3 and it could easily accommodate several operators in each country due to its (extra) large bandwidth.

Finally thanks to 3GPP standardization efforts the 26GHz band is fully part of 3GPP R15 (and being identified as "n258" in 3GPP specifications) which has been already frozen in 2018.

7.2 28GHz

Some countries mainly in North America and Asia – including the US, Japan, South Korea and Canada–are all looking to 28GHz for 5G services.

North America is definitely the front runner when it comes to the use of 28GHz band for 5G services. Some US operators (e.g. AT&T, Verizon) are actively developing their 5G services in using 28GHz. Indeed USA is the first country to commercially use 28GHz for 5G services.
In 12-2018 Canada Minister of ISED (Innovation, Science and Economic Development) has mentioned plans to launch a public consultation on spectrum in the 28GHz, 37-40GHz, 64-71GHz used for the development and deployment of 5G wireless networks.

In Asia South Korea has officially allocated 28GHz to all 3 mobile operators; each of them having secured a bandwidth of 800MHz in 06-2018. Operators are planning to conduct 5G field trials based on 28GHz in 2019.
Other countries in Asia market are still mainly performing trials and evaluating the performance of 28GHz band. For example ahead of deployment in 2022, Indonesia has showcased various 5G applications in the 28 GHz band at Jakarta Palembang 2018, the Asian games running from 18 August to 2 September 2018 in the 2 Indonesian cities of Jakarta and Palembang.
In May 2018, Docomo Japan achieved "what is believed to be the world's first successful 28GHz wireless data transmission between a 5G base station and a 5G mobile stations in 5G field trials

using a car moving at 305 km/h".

The following Table 7-1 lists major countries pushing 28GHz adoption for 5G services.

USA: 27.5 – 28.35GHz	Korea: 26.5 – 29.5GHz	Japan: 27.5 – 28.28GHz
Early adoption of commercial 5G FWA services in 2018/19 in selected cities	Pre-commercial 5G trials during 2018 Winter Olympics in South Korea Allocation in 2018	5G system trials kick-off in 2017 in major cities Target allocation in 2019 for 5G services

Table 7-1: Key Countries Planning for 28GHz Adoption for 5G Services

The 28GHz band is part of 3GPP R15 and has been approved under 2 versions:

- 26.50 – 29.50GHz ("n257")
- 27.50 – 28.35GHz ("n261"; standardized for USA market)

7.3 37-42GHz

The 37~42GHz frequency range is structured around 2 sub-bands "39GHz" and "42GHz".

The US has allocated 37-40GHz for mobile usage and is used by Tier-1 operators like AT&T and Verizon. They focus on delivering 5G FWA services.

Most administrations in the APT region are positive about the 37-43.5GHz range and have a preference in prioritizing considerations for IMT identification in the 37-43.5GHz frequency bands, or portions thereof, subject to satisfactory results of sharing and compatibility studies.
In Japan in 05-2018, Huawei and Docomo "marked another milestone in their joint 5G trials" by completing a trial of integrated access backhaul technology using the 39GHz band. The trial showed that IAB can significantly boost mmWave coverage and capacity.

In Europe the main interests are focused on 42GHz band. However the allocation has not taken place yet in any European countries for 42GHz.

The ATU has designated the 40 GHz band (37-40.5; 40.5-42.5; 42.5-43.5GHz frequency range) as a priority candidate for IMT identification under Resolution 238 (WRC15).

3GPP R15 has approved 37.0 – 40.0GHz frequency range as "n260".

7.4 Other Candidate Bands in ITU-R list

32GHz

Europe RSPG is of the opinion that the 31.8-33.4GHz band should no longer be considered as a priority for the following reasons:

• The preliminary results of sharing studies at the international level show the incompatibility with the use of this band for radio navigation, including for systems which would permit, in poor visibility conditions, landing where it would not be safe otherwise (in particular for airport not equipped with ground landing assistance systems such as ILS).
• The industry interest in this frequency band appears to be declining.
• The size of this band, only 1.6 GHz appears limited, also taking into account that there could be stringent requirement to protect the passive service allocation which is immediately adjacent which would likely require a guard band that would further reduce the available spectrum for IMT in the band.
• There is some interest in keeping this frequency band for backhauling fixed links, taking into account the need to migrate fixed links from the 26GHz in order to make it available for IMT in the most efficient way.

Europe CEPT has also excluded the 31.8-33.4 GHz band from the priority bands for studies for 5G under AI 1.13 of WRC-19.

66~71GHz

66-71GHz has the potential as a primary European band for 5G services. CEPT is working on different options for its position on the 66-71GHz band towards WRC-19, including the identification for IMT.

Some APT Members are also considering candidate bands such as the 66-71GHz, 71-76GHz and 81-86GHz frequency bands or portions thereof, for possible identification for IMT towards WRC-19. This is subject to satisfactory results of sharing and compatibility studies,

The cellular industry position on the above is the following:
• 66-71GHz: spectrum above 60GHz important for 5G
• IMT identification of 71 – 86GHz.

8 High Interested Operator deployed 5G-NR high frequency bands

The following table lists the positioning of several key countries with regards to mmWave bands for allocation to 5G services. USA is the first country to have already deployed mmWave for 5G services and Italy is the first European country having allocated mmWave band up to now. New allocations of mmWave bands for 5G should take place in 2019/20.

Region	Country	24 - 28GHz	Current Allocation Status
Asia-Pacific	**China**	**24.5 – 27.5GHz**	**To be allocated**
	South Korea	**26.5 – 29.5GHz**	**Already allocated (KT, LG U+, SK Telecom)**

	Japan	**27.5 – 29.5GHz**	**To be allocated in 2019/20**
	Australia	**24.25 – 27.5GHz**	**To be allocated**
	Malaysia	**26GHz**	**To be allocated**
Europe	**Italy**	**26GHz**	**Already allocated (Fastweb, Iliad Italy, TIM Italy, Vodafone Italy, Wind Tre)**
	UK	**26GHz**	**To be allocated**
	Germany	**26GHz**	**To be allocated**
	France	**26GHz**	**To be allocated in 2020**
Middle East	**Saudi Arabia**	**26GHz**	**To be allocated**
	UAE	**24.2 – 27.5GHz**	**To be allocated**
North America	**Canada**	**27.5 – 28.35GHz**	**To be allocated in 2019/20**
	USA	**27.5 – 28.35GHz**	**In Used (AT&T, Verizon)**

Table 8-1: List of Key Countries Positioning to Allocate mmWave Bands for 5G Services

8.1 26GHz

APAC Region

Australia: It is also considering the auction of spectrum at 26 GHz (24.25–27.5GHz) for 5G in Q3/4 2020 / Q1/2 ACMA FY2020–21), subject to consultation. Telstra Australia has performed 5G trial in using 26GHz.

China: The country is also expected to use the 24.75–27.5GHz band and has recently initiated a stakeholder consultation on these bands. During China IMT-2020 project some tests have been conducted in using 26GHz band.

Hong Kong / China: Hong Kong OFCA has announced it would be making spectrum at 24.25–27.5GHz and 27.5-28.35GHz available for mobile services (specifically including 5G services) with the spectrum allocated through an administrative process. Applications for spectrum issued through the administrative process are due in December 2018 with a target to announce assignment results in March 2019 and to assign the spectrum in April 2019. In May 2018, 3 Hong Kong received a temporary permit from Hong Kong's Communications Authority (CA) to conduct 5G network trials in the 26 GHz and 28 GHz bands from the third quarter in 2018.

India: 26GHz is among the spectrum bands being considered for 5G NR services.

Indonesia: The Ministry of Communications and Informatics of Indonesia (BRTI)) has given initial indications that Indonesia will license 5G spectrum by 2022. Current bands under consideration for allocation include 24.25–27 GHz, 27–29.5GHz.

New Zealand (Commerce Commission): According to the Radio Spectrum Management's 'Road map to 5G' in New Zealand, the 24.25–28.35GHz range is also to be considered for 5G use.

Singapore: lnfocomm Media Development Authority (IMDA) is considering several bands for future 5G deployments including 24.25–29.5GHz.

Thailand: In December 2018, Thai NBTC has published its plans for 2019. Both 26GHz and 28GHz are being considered.

Vietnam: Specifically for 5G, the Ministry has stated that the 24.25–27.5GHz and 27–43.5GHz bands are of interest and (whole or partly) could be made available for 5G services pending international developments.

EUROPE Region

Belgium: Belgian Institute for Post and Telecommunications (BIPT) has indicated some interests in allocating 26GHz from 2021 and 31.8–33.4GHz and 40.5–43.5GHz from 2022 to 2027.

Bulgaria: Communications Regulation Commission (CRC) is defining conditions for releasing at least 1 GHz between 24.25–27.5GHz to support the introduction of 5G networks.

Czech Republic: Czechia (Czech Communications Office (CTU)) has stated its future intention to issue spectrum at 26GHz for 5G services

France: In a 5G roadmap published by the ARCEP on July 16, 2018 it was revealed that the ARCEP plans to hold a consultation in October 2018 on the planned assignment of spectrum in the 26GHz band. The ARCEP plans to assign spectrum in the 26GHz band by the end of 2020

Poland: In 07-2018 Poland's spectrum regulator the UKE has opened a consultation on the use of spectrum in several bands including 26GHz bands.

Germany: German Bundesnetzagentur is drawing up application procedures for use of the 26GHz band (for local or regional 5G services or improving rural mobile coverage).

Greece: In October 2018, Hellenic Telecommunications and Post Commission (EETT)) has launched a public consultation on the granting of rights to use spectrum between 3400–3800MHz and 24.25–27.5GHz for 5G testing.

Finland: In Q3-2018 Telia has launched a 5G trial in Helsinki in using 26GHz.

Hungary: Hungary (National Media and Infocommunications Authority) has stated that it has been formely considering plans to auction spectrum at 26GHz.

Italy: Auction in 10-2018 of 26GHz to 5 operators incl. Fastweb, Iliad Italia, TIM Italy, Vodafone Italy and Wind Tre.

Portugal: ANACOM is currently holding a public consultation on a proposed spectrum auction of various bands for 5G including 26 GHz.

Romania: Romania (National Authority for Management and Regulation in Communications (ANCOM)) has launched 2 consultations. The first (open until 21 December 2018) concerns the national strategy for the implementation of 5G, planned for 2020, including plans to make additional spectrum at 700 MHz and 3400– 3800 MHz available in 2019, plus spectrum at 26 GHz (24.25–27.5GHz) in 2021.

Russia: (The Minister of Digital Development, Communications and Mass Communications) The Russian Ministry of Communication has previously awarded test licences for 5G trials in the 3400–3800MHz and 25.25–29.5GHz bands. Then in December 2018 the State Commission on Radio Frequencies allocated regional licences for use of frequencies at 25.25GHz and 27.5GHz for various 5G tests.

Slovakia: Slovakia Office for Regulation of Electronic Communications & Postal Services (RU) has launched a consultation on the 26GHz and 29GHz bands for 5G.

Sweden: Swedish Post and Telecom Authority (PTS) has also initiated consultations on the demand for 5G **frequencies in the 24.25–27.5 GHz bands.**

UK: UK Office of Communications (Ofcom) issued an update to its 5G strategy, saying that would continue its work to free radio spectrum in several bands including 26GHz

MIDDLE EAST Region

Qatar: Qatar (Communications Regulatory Authority (CRA)) is considering auctioning multiple bands including 26 GHz band (26.5–27.5 GHz) for 5G mobile services.
UAE: Telecommunications Regulatory Authority (TRA) is considering deployment of 5G in the following bands: 1427–1518 MHz, 3300–3800 MHz and 24.25–27.5 GHz. In addition, the 40 GHz range will be considered for 5G beyond 2020.

8.2 28GHz

The following lists operators having spectrum assets on 28GHz for 5G services and their corresponding strategy:

- **AT&T USA,** looking for 5G FWA services
- **KT Korea,** having secured a block of 800MHz during auction in 06-2018
- **LG U+ Korea,** having secured a block of 800MHz during auction in 06-2018 and planning for field trials in 2019
- **SK Telecom Korea,** having secured a block of 800MHz during auction in 06-2018
- **Verizon USA,** launching 5G FWA

Japan should allocate 28GHz in 2019/20 for 5G NR services.

First commercial 5G NR CPEs supporting 28GHz are available since the end of 2018.
Current commercial 5G networks supporting 28GHz are available in few cities in USA (based on "n261") as of today.

APAC Region

India: 28GHz is among the spectrum bands being considered for 5G NR services
Indonesia: The Ministry of Communications and Informatics of Indonesia (BRTI)) has given initial indications that Indonesia will license 5G spectrum by 2022. Current bands under consideration for allocation include 24.25–27 GHz, 27–29.5 GHz,
Hong Kong China: 3 Hong Kong is working on a 5G testing in using 28GHz band.
Japan: Ministry of Internal Affairs and Communications (MIC) is formally considering the 28GHz (27–29.5GHz) among the bands for 5G and plans to assign spectrum in these bands by March 2019. Japanese tier-1 operator (Docomo, KDDI, Softbank, Rakuten) have all performed 5G testing based on 28GHz.
Singapore: Infocomm Media Development Authority (IMDA) is considering several bands for future 5G deployments including 24.25–29.5GHz. M1 Singapore has performed 5G testing in using 28GHz band.
South Korea: In 2018 28GHz band has been already allocated in Korea for 5G services to all 3 local operators: KT, SK Telecom and LG U+. Tests have been performed in 2017/2018

for this band and will continue in 2019.
Thailand: In December 2018, Thai NBTC has published its plans for 2019. Both 26GHz and 28GHz are being considered.
Vietnam: Specifically for 5G, the Ministry has stated that the 24.25–27.5GHz and 27–43.5GHz bands are of interest and (whole or partly) could be made available for 5G services pending international developments.

EUROPE Region
Russia: In 2018 MTS has announced that it held a virtual reality gaming demonstration with terminals hooked up to an Ericsson base station using 28GHz frequency.

LATAM Region
Argentina: Movistar Argentina has conducted 5G trial in using 28GHz.
Chile: In July 2018 Chile (Under-Secretary of Telecommunications (Subtel) opened a consultation on use of the 3.4–3.8GHz and 27.5–28.35GHz bands for 5G.
Colombia: Claro Colombia and Telefonica Colombia have performed 5G tests in using 28GHz band.

NORTH AMERICA Region
Canada: There are discussions for allocating 28GHz in Canada. Bell Canada, Rogers, Shaw Communications and Telus have already conducted 5G trial in using 28GHz.
USA: Both AT&T and Verizon have already deployed 5G services using 28GHz band. Other US operators like Charter, C-Spire USA, and T-Mobile USA have performed 5G trials in using 28GHz.

8.3 37-42GHz

The 39GHz band (n260) is currently used for 5G services in few US cities (AT&T, Verizon).
First commercial 5G NR CPEs supporting 39GHz are available since the end of 2018.
There are no commercial 5G NR terminals supporting 40~42GHz as of today.

APAC Region
China: The country is also expected to use the 37–43.5 GHz band and has recently initiated a stakeholder consultation on these bands.
India: 37~42GHz is among the spectrum bands being considered for 5G NR services.
Vietnam: Specifically for 5G, the Ministry has stated that the 24.25–27.5GHz and 27–43.5GHz bands are of interest and (whole or partly) could be made available for 5G services pending international developments.

EUROPE Region
Belgium: Belgian Institute for Post and Telecommunications (BIPT) has indicated some interests in allocating 26GHz from 2021 and 31.8–33.4GHz and 40.5–43.5GHz from 2022 to 2027.

MIDDLE EAST Region

UAE: Telecommunications Regulatory Authority (TRA) is considering deployment of 5G in the following bands: 1427–1518 MHz, 3300–3800 MHz and 24.25–27.5 GHz. In addition, the 40 GHz range will be considered for 5G beyond 2020.

NORTH AMERICA Region

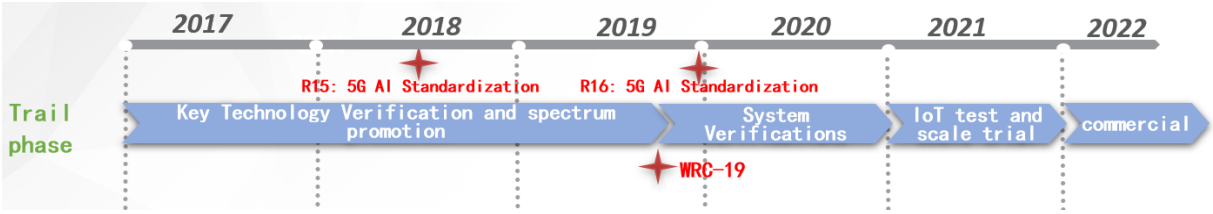
USA: Some US operators (Verizon USA) are looking for 39GHz to deliver 5G services.

9 GTI Operator Plans of 5G trial and schedule

The use of the mmWave spectrum is very compelling as the available large bandwidth at these high frequency bands enable extremely high data rates and significant increase in capacity. 5G NR mmWave could meet the ever-increasing demands for faster, better connectivity, which enables the mobile devices continue to grow with advancements such as higher-resolution camera, 4K video, always-connected cloud computing, and virtual/augmented reality. In addition, 5G NR mmWave could also offer the capability of in-band wireless self-backhauling with latency of around 1 ms. The self-backhaul can make low deployment cost and provide operator deployment flexibility to meet traffic demand.

To date, the main 5G NR mmWave commercial deployment scenarios are urban high-traffic hot spots and self-backhauling:

- Outdoor hot spots: shopping street, station, square, pleasure ground, view spot, and the small area private networks, etc
- Indoor hot spots: shopping mall, gymnasium, airports, hospitals, subway platforms, etc
- WTTx: B2H (business to home), public safety, e.g. public surveillance camera, etc
- BH(back haul): mmWave can be used to support other RAT data backhaul, e.g. IAB



To accelerate 5G mmwave commercialization, China Mobile released 5G high frequency overall schedule, which consists of four stages:

1. Key technology trial and spectrum promotion: 2017 - 2019 Q3

To assess the feasibility of potential key technology trial and the high-frequency mmWave propagation model, the key technology trial was conducted in 2017 with the small cell coverage deployment scenario, focusing on 24.25-27.5GHz and 37-42.5GHz. The key technology trial included an analysis and verification of the following key technology: Digital-analog hybrid architecture, massive MIMO, massive users, beamforming management, new frame structure and system parameters, etc.

2. System performance and standardization scheme trial: 2019 Q4 – 2020 Q4

WRC-19 held in Egypt on October 28th -November, 22nd, 2019 will be focused on additional spectrum allocation to mobile service and identification of additional frequency bands for IMT, which will help to promote the 5G commercialization. Based on the Rel-16 5G mmWave standardization finished in 2019 Q4, China Mobile launched the system performance and standardization scheme trial to prepare for the coming large scale trial. The details of the trial component are shown below:

1) mmWave standardization promotion
2) Verification of standardization performance and scheme
3) Devices specification and prototype development
4) building of the trial environment and methodology
3. Large scale trial: 2021 Q1 – 2021 Q4

China mobile will be committed to the inter-vendors inter-operation trial and high-low frequency networking trial to build the pre-commercial network. In addition, mmWave services will be further enhanced and the final commercial service specification will be released.

4. Commercialization: 2022

China mobile expects to launch the 5G mmWave commercialization in 2022.

10 WRC-19 AI 1.13 View

International Telecommunication Union (ITU) World Radiocommunication Conference in 2019 (WRC-19) will be held in Egypt on October 28th -November, 22nd, 2019. GTI, working together with other industry associations such as the GSA, GSMA, actively supports the identification of new spectrum for IMT (5G) under agenda item 1.13:

24.25 – 27.5 GHz and 37.0 – 43.5 GHz:

GTI support identification for IMT globally in these 2 bands. Spectrum within these two ranges provides the opportunity for very high data rates indoor and outdoor hot-spot deployments.

45.5 – 50.2 GHz and 50.4 – 52.6 GHz:

GTI support an identification for IMT globally for these 2 bands for WRC-19 AI 1.13. The range 47.2 – 48.2 GHz is already allocated to 5G NR in the USA which is anticipated to stimulate market demand in other countries and regions. There are challenges due to the passive services on both sides of 50.2 – 52.6 GHz and its limited size.

For 31.8 – 33.4 GHz: GTI does not support the band for identification for IMT. The band does not have sufficient global support and is less suitable for mobile broadband use due to its moderate size and challenges from sharing with incumbent services (e.g. aeronautical radars) and adjacent (passive) services which might further reduce the size of band. It is preferred for general backhaul solutions under the Fixed Service (FS) allocation.

11 Recommendations

Transparent and in advance spectrum planning would enable operators to build a more solid business model and facilitate development toward 5G. As development momentum may vary across regions, this section aims to summarize the discussion in previous chapters.

Key findings for mmWave 5G spectrum

MmWave spectrum brings new design for 5G NR radio interface to extend their spectrum used to meet the different requirements for operators needs for very large amount of spectrum, very wide bandwidth and different delay requirements for their future diverse applications.

MmWave 5G ecosystem maturity

BS, device and chipset products are ready to support the 5G commercial deployment in mmW bands in 2019. Some operators have already deployed mmW for 5G service.

Candidate 5G mmWave bands

Based on the analysis in the previous sections, at the current stage GTI supports the following candidate bands: 24.25-27.5GHz, 27.5-29.5GHz and 37.0-43.5GHz as the kick-off bands for 5G deployment in above 6GHz.

Protection requirement for sharing with other incumbent services

- Protection requirement of adjacent EESS (passive) band in 24.25-27.5GHz band: GTI companies support the following IMT unwanted emission limits to protect the EESS (passive) service in the 23.6-24.0 GHz frequency band.

- BS: -33.5 dB(W/200 MHz)
- UE: -29.7 dB(W/200 MHz)

Protection Requirement of FSS (Earth-to-space)/ISS in the band 24.25-27.5GHz and 42.5-43.5GHz: GTI member companies believe that there is no technical justification for incorporating any regulatory provisions related to technical conditions, i.e. EIRP mask, TRP limits, epfd and/or electrical and mechanical tilting limitations on IMT-2020 base stations, for identification of the bands 24.25-27.5 GHz and 42.5-43.5 GHz in the Radio Regulation.

Protection Requirement of EESS (passive) in the band 36-37 GHz

There is no need to define additional OOBE limit for IMT systems operating in the frequency band 37-43.5 GHz to ensure coexistence with the EESS (passive) systems operating in the frequency band 36-37 GHz.

WRC-19 AI 1.13 View:

GTI support identification for IMT globally in the bands of 24.25-27.5GHz and 37.0-43.5GHz. Spectrum within these two ranges provides the opportunity for very high data rates indoor and outdoor hot-spot deployments.

GTI support an identification for IMT globally for 45.5 – 50.2 GHz and 50.4 – 52.6 GHz:
for WRC-19 AI 1.13.

12 Reference

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