Commission for
Communications Regulation

26 GHz Band 5G Study

A study by Plum Consulting and IDATE regarding the future use of the 26 GHz Band.

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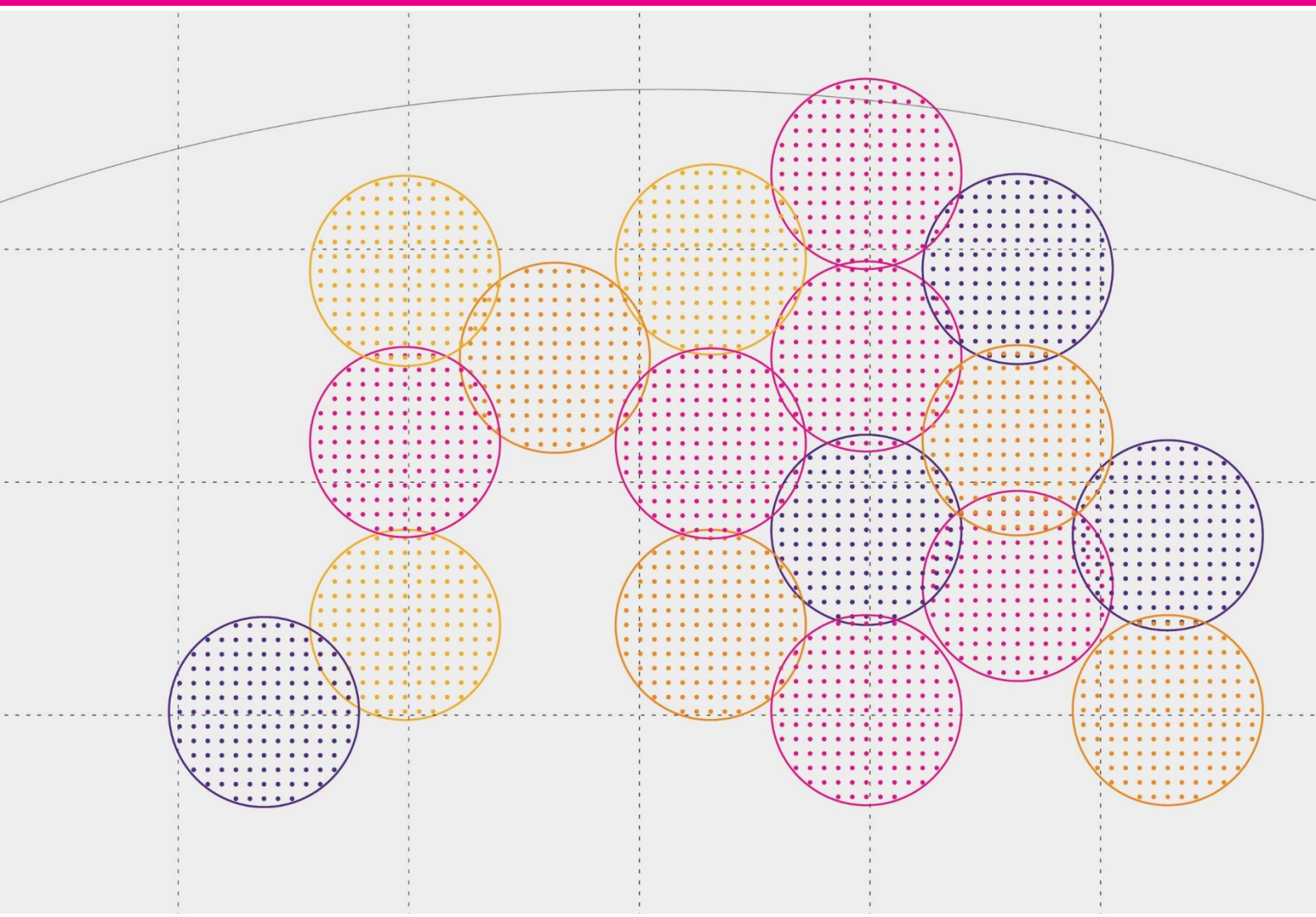

About Plum

Plum is an independent consulting firm, focused on the telecommunications, media, technology, and adjacent sectors. We apply extensive industry knowledge, consulting experience, and rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial, and technology domains.

About IDATE

Since 1977, IDATE DigiWorld has delivered consultancy services, market intelligence solutions & networking opportunities to provide an in-depth understanding of the digital world and enhance our clients' strategic decision-making. We are proud that every year more than 400 public bodies & multinational companies all over the world renew their trust in our services.

About this study

This study for ComReg assesses the potential demand for WBB ECS in the 26 GHz band, possible licensing approaches and technical conditions taking into account incumbent and other innovative uses of the band in Ireland.

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1 Introduction

1.1 mmWave bands background

This report is provided to inform the Commission for Communications Regulation's (ComReg) consideration of how best to organise and effectively manage the 26 GHz (24.25 – 27.5 GHz) band in line with its statutory objectives, including ensuring the efficient use of the radio spectrum resource. This report considers the requirements to ensure the continued provision of existing services, as appropriate, while also seeking to facilitate "5G" deployments, if and when required, through the introduction of appropriate licensing framework(s) for terrestrial wireless broadband (WBB) electronic communications services (WBB ECS).

It considers the range of 5G services originally envisaged, use of the 26 GHz band internationally, the situation in Europe relating to the award of the 26 GHz band, and how these matters and potential demand currently reflects on the future use of the 26 GHz band in Ireland.

1.2 Overview of 5G developments, uses and business cases

5G developments and associated frequency bands

There are three frequency ranges and multiple frequency bands within these ranges that have been identified for 5G WBB ECS:

- Low band below 1 GHz to provide coverage (e.g. the 700 MHz, 800 MHz and 900 MHz bands);
- Mid band below 6 GHz - can be used for both capacity and coverage purposes (e.g. the 1.4 GHz, 1.8 GHz, 2.1 GHz, 2.3 GHz, 2.6 GHz and 3.6 GHz band); and
- High band above 6 GHz - typically in millimetre wave bands ("mmWave bands") to provide ultra-high capacity (e.g. the 26 GHz band).

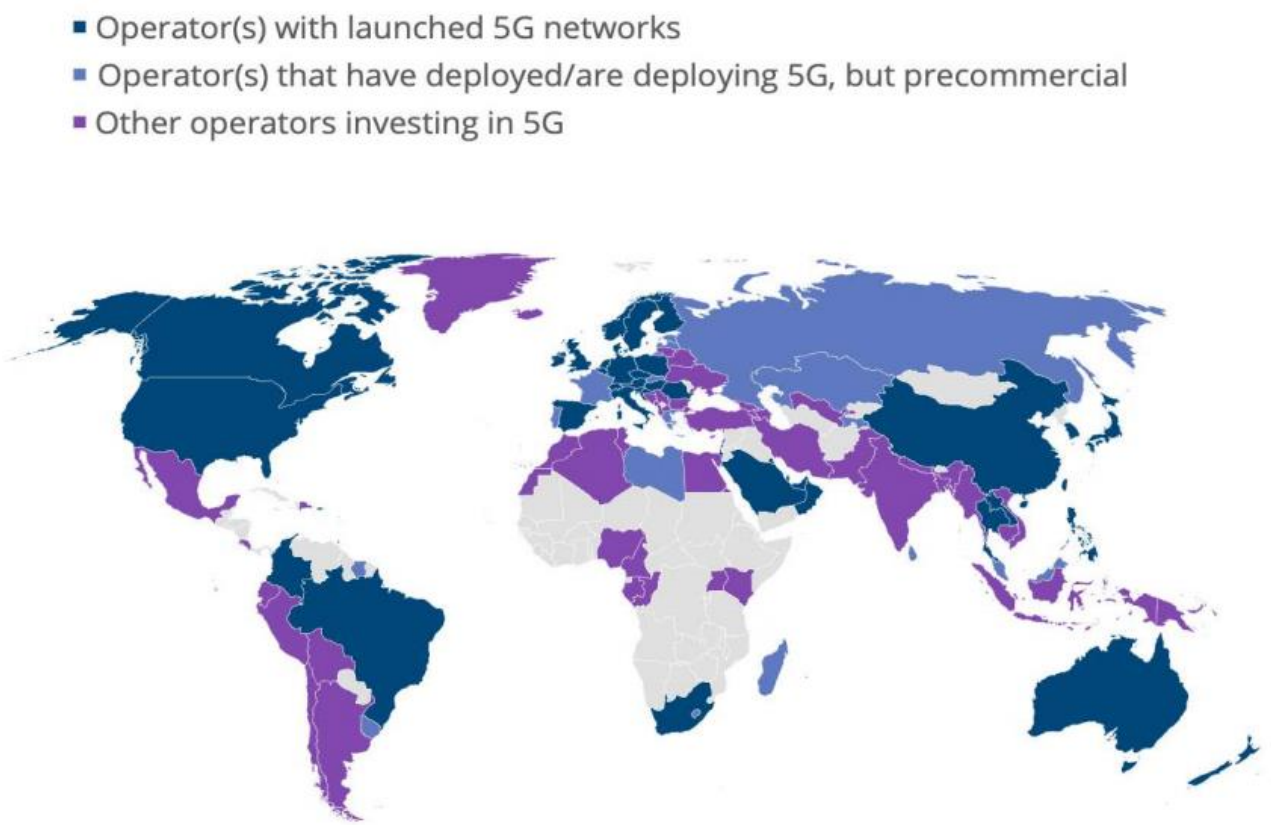
Frequency bands within the mid band and high band ranges can usually provide more contiguous spectrum than frequency bands in low band range and are therefore ideal to meet capacity requirements. The mmWave bands provide very limited coverage ranges in comparison with lower frequency bands. For example, base station densities in the range 10 – 30 / km^2 for hotspots and / or 40 m separated indoor base stations as compared to a single base station covering 1 km^2 with a cell radius of 500 m and inter-site distances of 660m for urban deployments in the 2.6 GHz band[1]. However, limited coverage range means base stations can often be deployed below roof tops and their physical size (smaller antenna arrays compared with lower bands) can provide advantages for site acquisition. The mmWave bands also have limited potential to provide indoor coverage from outdoor base stations due to building losses but this means they have unlimited potential for indoor use.

According to the Global mobile Suppliers Association (GSA) there are now over 120 commercial 5G networks worldwide[2]. Figure 1.1 shows global operator investment in 5G. The C-band spectrum (3300 – 4200 MHz) has been the main focus for operator investment to date, which has been supported by the number of available devices[3]. There is an increasing number of devices for the mmWave spectrum bands – the GSA had identified 18

[1] ECC Reports 174 and 308
[2] 5G Market Snapshot November 2020. https://gsacom.com/technology/5g/
[3] According to the GSA by August 2020 they had catalogued 278 devices for Bands n78 and n77. 183 were phones and 28 non-industrial CPEs. Further information is provided in 0 .

devices (commercial and precommercial) for Bands n257[4] and n258[5] of which 5 were phones[6]. There is now increasing focus on 5G in the frequency range 24.25 to 29.5 GHz with investments from over 127 operators. Further details on equipment availability are provided in 0.

Figure 1.1: Global operator investment in 5G



Source: GSA 5G Market Snapshot November 2020

Potential Services

In 2015 the International Telecommunications Union (ITU) finalised a global vision[7] defining the framework and overall objectives of the future development of technologies and systems beyond 4G. This ITU Recommendation envisaged that 5G would support diverse usage scenarios and applications and that a broad variety of capabilities would emerge within the range of these usage scenarios.

Since 2015, according to the tests and announced plans from around the world, 5G services using mmWave bands have consolidated into the following four usage scenarios:

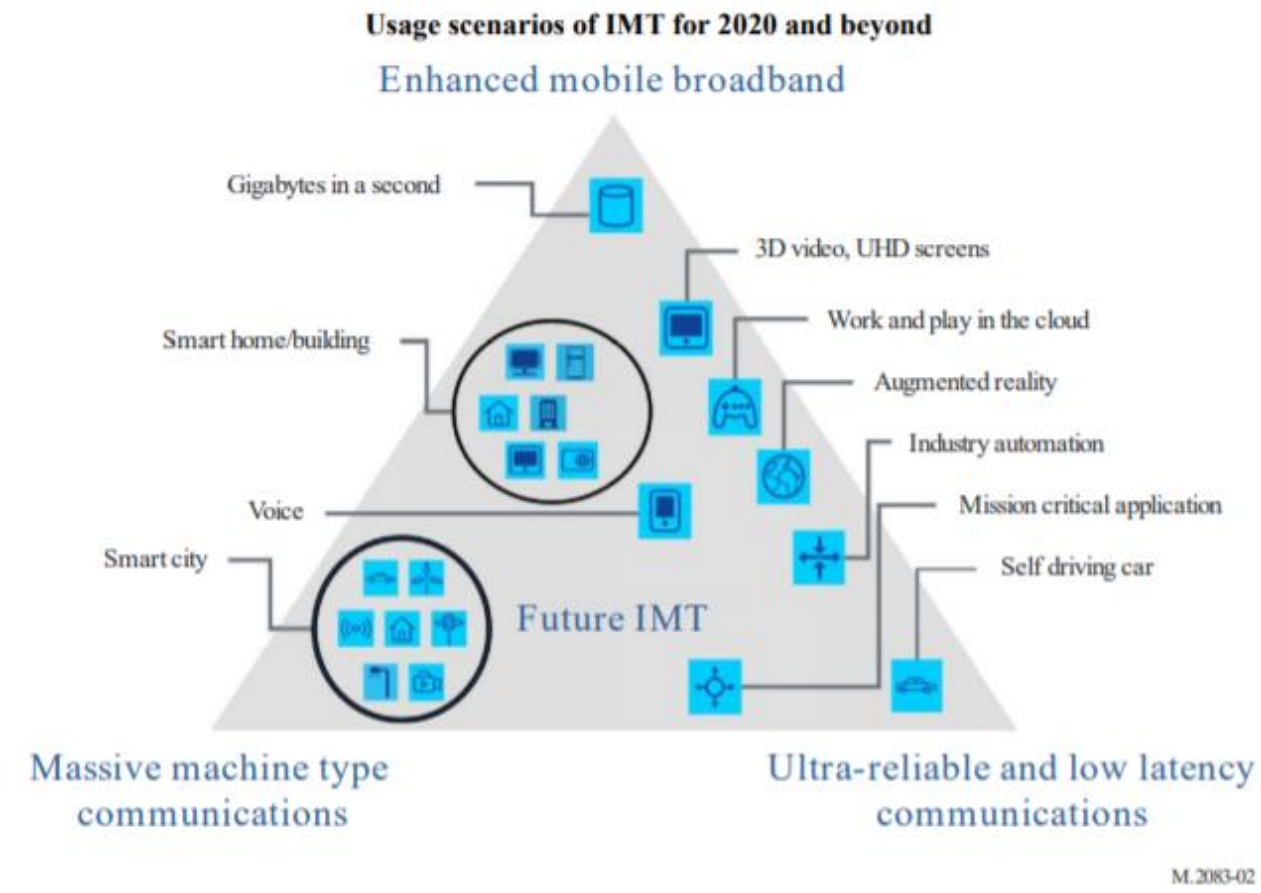
- Enhanced Mobile Broadband (eMBB) services for very high data rates and high capacity;
- Services to support the specific requirements of vertical sectors;

[4] The band designated as n257 is known as the 28 GHz band and covers the range 26.5 – 29.5 GHz.
[5] The band designated as n258 is known as the 26 GHz band and covers the range 24.25 – 27.5 GHz.
[6] The five phones listed utilise n257 but not n258.
[7] ITU Recommendation M.2083 https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

- Critical communications which have their own unique requirements; and
- Fronthauling / backhauling in addition to any of the three scenarios above.

Figure 1.2 provides examples of these services that may be supported by 5G as envisaged by the ITU[8].

Figure 1.2: Services supported by 5G



Source: ITU-R Rec. M.2083[9]

Enhanced Mobile Broadband (eMBB) services

Enhanced Mobile Broadband (eMBB) based-services for high capacity are the first commercial 5G services offering mobile services and Fixed Wireless Access (FWA) which is significantly faster than ADSL (around 100 Mbps) but slower than FTTH. It has been targeted at:

- Locations not covered by a fixed network (emerging countries, rural areas);
- Very densely populated areas, competing with fixed services (fibre and cable access) in particular;
- For operators without a fixed network in order for them to compete in a triple or quad play market;
- On demand for areas that occasionally attract large crowds (e.g. festivals, stadiums, etc).

[8] ITU 2018 5G policy paper "Setting the Scene for 5G: Opportunities & Challenges" https://www.itu.int/pub/D-PREF-BB.5G_01
[9] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

Many industry reports[10] expect that mmWave bands will be used to provide higher speeds and capacity in hot spots such as airports, railway stations, malls, stadiums/arenas and other indoor venues with a very high to ultra-high density of users.

Massive Machine Type Communications (mMTC)

Massive machine type communications are defined by a very large number of connected devices (up to 1 million per square km) typically transmitting a relatively low volume of non-delay sensitive data. Devices are required to be low cost and have a very long battery life.

Ultra-reliable and low latency communications (URLLC)

URLLC targets use cases with stringent requirements for capabilities such as throughput, latency and availability. Some examples include wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.

Services for vertical sectors

Spectrum bands are generally not the most important factor for vertical users of 5G except if they need very large bandwidth that only mmWave can offer. The most important factors for vertical users are quality of service, coverage and privacy of data.

Vertical industries targeting the use of 5G for their own needs include automotive, media & entertainment, manufacturing, logistics, agriculture, energy and utilities, financial services, public services, trade, mining, education and healthcare[11].

Various industries[12] have expressed a view that mmWave bands will be required for the provision of 5G services in vertical sectors such as manufacturing/industrial automation, automotive, other transportation (trains and buses for direct access from the 5G network), energy grid communications, smart cities, and medical applications.

Figure 1.3: Potential 5G services using mmWave bands – Summary

Sector/ Application	5G use cases	Global use of mmWave bands (% of total 5G traffic for each application) 2020/2025
eMBB-mobile (local)	Use of mmWave bands in hot spots (indoor and outdoor small cells)	++
eMBB-FWA	Use of FWA driven by HD video	++ to +++
Automotive	Hotspot backhaul, V2V, V2X	+
Trains and buses	Access and hotspot backhaul	+
Medical applications	Tactile Internet, remote healthcare	- /+
Transport Backhauling	For in-vehicle (moving) hot-spots	++
Manufacturing / industrial automation	Robotics, Tactile Internet, localized real-time control, security, process automation	+

[10] https://www.comreg.ie/publication/future-mobile-connectivity-in-ireland/
[11] https://www.gsma.com/futurenetworks/ip_services/understanding-5g/the-5g-ecosystem/
[12] See session E of the CEPT workshop on 5G held in Mainz, 2-4 Nov 2016 and the CEPT workshop on new spectrum solutions for industry sectors held in Copenhagen, 2-3 May 2019.

Sector/ Application	5G use cases	Global use of mmWave bands (% of total 5G traffic for each application) 2020/2025
Energy distribution	Smart metering concentrator connection, smart grid	-
Smart cities	Digital signage, video surveillance	+
Public safety	Real time video and high-quality pictures	-
Cell-site Backhauling/ Fronthauling	In-band Backhauling (IAB)	+++

Legend: "+++": 100% use of mmWave bands, "++": important use of mmWave bands, "+": limited use of mmWave bands, "-": very limited use of mmWave bands

Source: IDATE

For example, in the railway sector, mmWave bands could be used to support backhauling for trains[13], enable high bandwidth backhaul links between a base station on the trackside and/or an access unit on the carriage. Distribution within the train via Wi-Fi and/or small cells then enables users to get very fast broadband access services.

Services for critical services

Critical services are part of 5G standardisation. Very high reliability and low latency networks enabled by 5G unlocks the ability to control critical services and infrastructure. New opportunities for public safety, government, city management and utility companies will appear soon.

Fronthauling / backhauling

In places where fixed links do not offer sufficient bandwidth or where fibre optic networks are too expensive to build, wireless fronthauling/backhauling will become a viable option with the standardisation of in-band backhauling enabling mobile operators to use the same spectrum for access and backhaul.

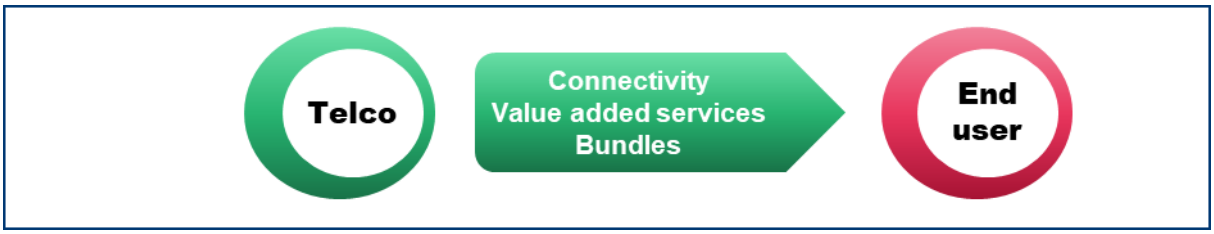
With the standardisation of the Integrated Access Backhaul (IAB) capability in 3GPP Release 16, large portions of spectrum will make it possible in many locations to use part of the spectrum for backhauling/fronthauling purposes as mobile and FWA operators will be able to split the spectrum resource easily between access and backhauling/fronthauling.

Value chain

Today, 5G services are offered on a Business to Consumer (B2C) basis with eMBB services (including FWA) providing higher data rates. The consumer market value chain remains standard, with direct potential for operators to sell 5G as the natural progression of 4G or dedicated 5G products, such as on demand Quality of Service (QoS).

[13] See for instance a 5GPPP project demo: https://www.5g-picture-project.eu/news.html

Figure 1.4: B2C value chain



Source: IDATE DigiWorld, 5G Monetisation, September 2019

In the coming years, many 5G operators have indicated[14] that they intend to implement Business-to-Business (B2B) and Business-to-Business-to-Consumer (B2B2C) offers.

- The technological advancements that 5G brings, in particular network slicing, opens the way for new business models and for new players to enter the value chain, either as telcos' customers or suppliers, along with a host of customisation possibilities for solutions marketed to vertical sectors.
- For example: a stadium hosting an event[15] would be able to obtain a dedicated network partition to guarantee the supply of additional, live camera angles to viewers. These services could be sold with tickets to the event.
- This value chain can bring in other players such as tower companies, content owners, Internet service and content providers.

Figure 1.5: B2B2x value chain

Source: IDATE DigiWorld, 5G Monetisation, September 2019

There is currently a lot of activity[16] in the industry for the provision of 5G services for automotive plants for communications, process control, telemetry, security, etc.

Private networks

5G operators are already working with industry verticals[17] in order to adapt their offers to industry needs. There is also interest from verticals in acquiring spectrum rights of use[18] and deploying their own tailored stand-alone networks. Facilitating the needs of traditional MNOs and verticals would perhaps require a range of appropriate spectrum licensing approaches within the one band.

[14] See https://fr.idate.org/produit/5g-for-industrials-dataset-and-report/ and https://www.ericsson.com/en/5g/5g-for-business
[15] https://www.telecompetitor.com/verizon-5g-stadium-service-will-put-mm-wave-5g-edge-computing-to-the-test/
[16] See https://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/
[17] https://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/
[18] https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/LokaleNetze/lokalenetze-node.html

2 Approaches to award the 26 GHz band internationally

In this section we have included the 28 GHz band in our analysis as the 26.5 – 29.5 GHz band (n257) is the more advanced ecosystem, driven by the US and Asia, and is used in some regions of the world in place of, or in addition to, the 26 GHz band of 24.25– 27.50 GHz (n258).

The status of the 26/28 GHz bands for WBB ECS in the USA and Asia Pacific is provided in the following sections where we indicate:

- Frequency bands and amount of spectrum assigned.
- Licensing framework for assigning the 26/28 GHz spectrum including competitive award process, national/local area licences, geographical restriction (indoor only, etc.).
- Licensees assigned the spectrum (and spectrum allocated/assigned for vertical sector).

Further detailed information is provided in Appendix B.

2.1 USA

In the USA a number of mmWave frequency bands have been awarded as summarised in Figure 2.1. The 28 GHz and 39 GHz (37-40 GHz) bands are currently used in the USA for 5G commercial services by AT&T and Verizon Wireless. Verizon Wireless is using the 28 GHz band to provide fixed wireless access services and mobile services. Given the limited number of 5G base stations deployed by the US operator, coverage is restricted to specific high population density sub-urban/urban areas in a limited number of cities. However, recent measurements by OpenSignal[19] show that the use of mmWave bands enables Verizon Wireless to provide very high throughputs, close to 500 Mbps. Licence duration is typically 15 years.

Figure 2.1: mmWave bands use in the USA

USA	Characteristics	Comments
Frequency bands	24 GHz (24.25–24.45 GHz and 24.75–25.25 GHz) 28 GHz (27.5–28.35 GHz) 37 GHz (37.6-38.6 GHz) 39 GHz (38.6-40 GHz) 47 GHz (47.2-48.2 GHz)	

[19] https://www.opensignal.com/reports/2020/06/usa/mobile-network-experience-5g

USA	Characteristics	Comments
Assignment date	24-28 GHz band spectrum auctioned in Q1 2019 37-39-47 GHz band spectrum auctioned in March 2020	24 GHz: Twenty-nine bidders won 2904 licences after bidding 2.02 billion USD in an auction. 28 GHz: 2,965 of the 3,072 available Upper Microwave Flexible Use Service (UMFUS) licences were acquired with bidders committing 702.6 MUSD in the award. 37 GHz, 39 GHz, and 47 GHz bands: 14,142 of the 14,144 licences on offer were acquired after bidders committed 7.6 billion USD (6.9 billion EUR) in the award.
Quantum of spectrum assigned	24 GHz band: seven 100 MHz blocks. 28 GHz band: two 425 MHz blocks by county (27.500 – 27.925 GHz and 27.925 – 28.350 GHz). Upper 37 GHz and 39 GHz bands: 2,400 megahertz licensed as 24 100-megahertz blocks. 47 GHz band: 1,000 megahertz licensed as ten 100-megahertz blocks.	
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	The 24 GHz band auction employed a clock auction format, beginning with a clock phase that allowed bidding on generic blocks in each Partial Economic Area in successive bidding rounds. There was then an assignment phase to allow winners of the generic blocks to bid for frequency-specific licence assignments. The auction of the licences in the 28 GHz band employed the standard simultaneous multiple round auction format. 37GHz, 39GHz, and 47GHz bands: clock phase auction and an assignment phase. Partial Economic Area concessions.	For the 24 GHz band (Auction 102), Partial Economic Area (PEA) licences. Auction 103 for upper 37 GHz, 39 GHz, and 47 GHz also provided Partial Economic Area (PEA) licences. Auction 101 for the 28 GHz band: county-based licenses. The Partial Economic Areas divide Economic Areas into 416 service areas.
Licensees assigned the spectrum	24 GHz: AT&T, T-Mobile, US Cellular. 28 GHz: Verizon, US Cellular, T-Mobile. 37 GHz, 39 GHz, and 47 GHz bands: Verizon, AT&T, T-Mobile, and T-Mobile	
Services being provided and planned for the coming years	Fixed Wireless Access Mobile services	
Use cases being served		Expected use cases: Media & Entertainment, Automotive & Transport, AR/VR, Industry 4.0, logistics, Agriculture

USA	Characteristics	Comments
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	AT&T is using the 39 GHz band for 5G services. T-Mobile and Verizon also launched 5G services in the 28 & 39 GHz.	

Source: IDATE/PLUM

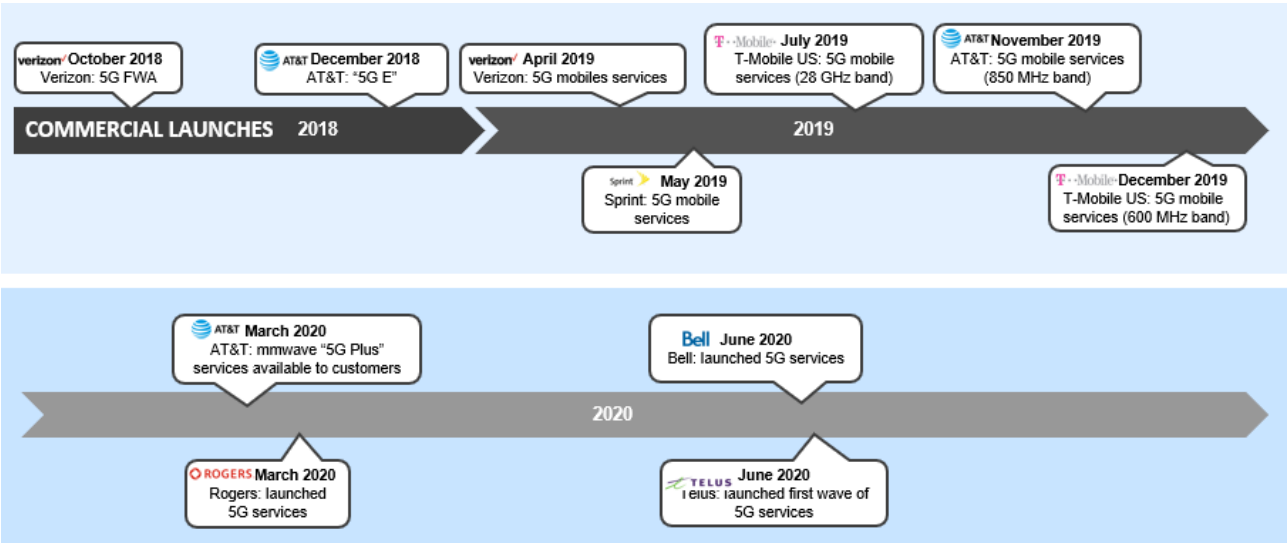
Figure 2.2 provides further detail on the available bandwidth and prices paid by frequency band. Figure 2.3 provides a timeline for commercial launches in the USA and Canada. Further information on the services can be found at Appendix B.1.3.

Figure 2.2: Summary of licensing arrangements and available bandwidth

Frequency band	Bandwidth (MHz)	Total price (EUR)	Price (EUR) / MHz /pop. (for 10 years)
27.500-27.925 27.925-28.350	850	623 462 755	0.22
24.25-24.45 24.75-25.25	700	1 793 471 140	0.77
37.6-38.6 38.6-40 47.2-48.2	3400	6 740 000 000	0.85

Source: IDATE DigiWorld, 5G markets in North America, July 2020

Figure 2.3: 5G commercial launches in the US and Canada



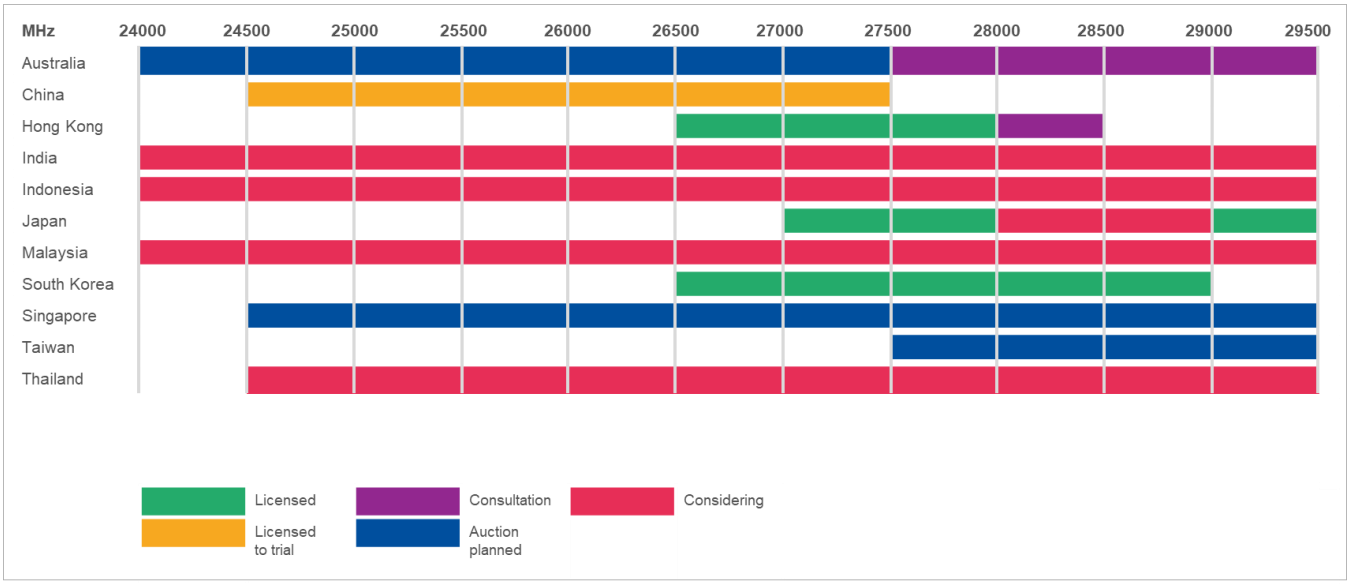
Source: IDATE DigiWorld, 5G markets in North America, July 2020

2.2 Asia Pacific

5G services were launched in South Korea in April 2019 with an emphasis on enhanced broadband services and also some specific services based on augmented reality and virtual reality. China is by far the world's leading 5G market in terms of subscribers. The rate of adoption has been very lively since launch in November 2019. In Japan, some spectrum in the 28 GHz band has been reserved for local licences.

Figure 2.4 shows expected use of the 26 and 28 GHz bands in the Asia-Pacific region in September 2019:

Figure 2.4: National spectrum in the 24-29.5GHz bands in Asia-Pacific



Source: IDATE DigiWorld, 5G markets in Asia-Pacific, September 2019

In Figure 2.5 we provide an overview of the different approaches to award mmWave spectrum. Further information is provided in Appendix B.

Figure 2.5: Overview of awards in Asia Pacific

	Australia	China	Hong Kong	Japan	Singapore	South Korea	Thailand
Award status	Auction planned for April 2021 for spectrum licences[20]	Not assigned. No date for award Testing ongoing	Administrative approach[21] Completed in March 2019	Completed in April 2019 (Beauty contest)	Completed in June 2018 (CFP[22] approach) 26 GHz spectrum awarded with 3.5 GHz spectrum.	Completed in June 2018 (auction with 3.5 GHz band)	Completed in February 2020 (auction with 2.6 GHz band)

[20] The first tranche of area wide apparatus licences (AWL) allocations was announced in December 2020. There were 15 applicant companies. There will be further allocations in January 2021. The 24.25 – 25.1 GHz band will be un-licensed.
[21] There are no spectrum utilisation fees payable. Performance bond to guarantee compliance with network and service rollout obligations https://www.ofca.gov.hk/en/media_focus/press_releases/index_id_1891.html
[22] Call for Proposals

	Australia	China	Hong Kong	Japan	Singapore	South Korea	Thailand
Award / licence conditions							
Frequency range	25.1-27.5 GHz	24.75-27.5 GHz 37-43.5 GHz	26.55-27.75 GHz	27.0-28.2 GHz 29.1-29.5 GHz		26.5-28.9 GHz	
Total amount of spectrum	2.4 GHz[23]	n.a.	1.2 GHz	1.2 GHz	1.6 GHz	2.4 GHz[24]	2.6 GHz[25]
Duration	15 years					5 years	
Roll-out / coverage obligations		n.a.	OFCA imposes a minimum number of units to be deployed within five years.	Population coverage: 5 years after issuance of the licence: between 56% and 90%. MNOs also committed to a minimum investment in their 5G networks.			
Spectrum/ network sharing			Additionally 400 MHz in the 27.95-28.35 GHz band available for localised shared services				
Incumbent services	Fixed Satellite Service (FSS)						
Coexistence requirements							

2.3 Observations

The manner in which spectrum is released in each country reflects the demand and expected usage cases in each, as determined by factors such as population, population density, currently assigned spectrum, upcoming spectrum awards, demand for services and market competition. These factors differ widely between countries.

The USA continues to rollout some form of WBB ECS in a mobile and fixed offering but not in any particularly co-ordinated approach. It is more a set of ad hoc commercial manoeuvres which includes, in some cases,

[23] Allocation limits of 1 GHz per operator for this spectrum auction
[24] 1 GHz spectrum cap for the 26 GHz band
[25] Awarded in 100 MHz blocks

rebranding LTE as "5G" and reusing the 800 MHz and 2.5 GHz bands to cover areas with insufficient population density and using the 28 GHz band in economically viable (densely populated) areas.

While China has invested in a 5G national action plan the focus has been on the release and rollout of services using mid band spectrum and no timeline has been set to award the mmWave bands. The awards in Hong Kong, Japan and South Korea reflect the large population and population densities in many of the conurbations in these countries.

The outlier from a population and population density point of view is Australia. The Australian Communications and Media Authority (ACMA) determined that there was no short-term demand at the time to license the 26 GHz band on a national basis. Instead ACMA determined to make a part of the band available for class licensing for use by short range devices, another part for individual licensing and retaining some spectrum for national licensing which they have since decided to award in 2021.

We provide some quotes from an influential report for the European Parliament[26] that provides a number of conclusions on the state of play in the USA and in Asia and touches on Europe:

- *"Despite the hype around 5G, the benefits in terms of economic stimulation from new services and products in GDP and employment will not be seen in any country for some time"*.

- "*There is a growing recognition, especially in Asia, that 5G will need much more time to perfect before comprehensive rollout, perhaps with a ten-year timeframe. China has previously called attention to this and China Telecom at the Mobile World Congress, in February 2019 noted that 5G will cost three times more than previous generations[27]. Japan has implied this with recent emphasis on understanding the real depth of the challenges. 5G may happen more slowly than many in the industry may think*".

- "*A pragmatic assessment of 5G suggest that the marketing campaign too often ignores reality:*

  - *While not the strongest driver, the lack of convincing business models, in Europe and elsewhere, is notable.*

  - *On the technical side, the rush to use frequencies in "mmWave" bands (20-100 GHz) for early 5G is not borne out in the majority of deployments so far. Instead it is the much lower frequency UHF band (300-3GHz) or just above it at 3.6 GHz (the "mid-band") that is gathering attention in Japan, USA, China as well as Europe. The advantage is a much greater propagation range with radio technology that is more familiar than for higher frequencies in centimetric and millimetric bands. Lack of clarity of financial returns in technology costs and network capital costs are the consequence.*

  - *The consequence is that the level of enthusiasm in the operators is less than it might be if there were established technology ready to go and offer proven returns. Those who have to invest are unsure of the business case for solid revenues*".

[26] 5G Deployment, State of Play in Europe, USA and Asia – An in-depth analysis requested by the ITRE committee of the European Parliament, Policy Department for Economic, Scientific and Quality of Life Policies, Directorate-General for Internal Policies, Authors: Colin BLACKMAN and Simon FORGE, PE 631.060 – April 2019

[27] Streaming Media (2019), MWC 19: Operators promise the moon but won't shoulder the cost, 27 February, https://www.streamingmedia.com/Articles/ReadArticle.aspx?/ArticleID=130139.

3 Harmonisation of the 26 GHz band in Europe

3.1 Overview of harmonisation initiatives in Europe

This section provides an overview of CEPT, BEREC, RSPG and European Commission publications related to 5G spectrum harmonisation. Further detailed information is provided in Appendix D.

3.1.1 The European Conference of Postal and Telecommunications Administrations (CEPT).

Late in 2016, the European Commission mandated the CEPT to determine the harmonised technical conditions required to facilitate the use of 5G technologies in the 3.5 GHz and 26 GHz bands.

In response to this mandate, Project Team 1 (with responsibility for mobile (IMT) issues) of the Electronic Communications Committee (ECC) ("ECC PT1") developed CEPT Report 68 that addresses the sharing and compatibility conditions to ensure the protection of incumbent users of spectrum in the 26 GHz (24.25-27.5 GHz) and adjacent bands. These incumbent users include the Earth Exploration Satellite Service (EESS), the Space Research Service (SRS) and the Fixed Satellite Service (FSS) Earth Stations in the band and the passive EESS in the adjacent bands.

CEPT Report 68 notes that "*In the 26 GHz, 5G services will mainly target urban areas and suburban hotspot areas even if some few deployments in dedicated locations or along major roads and railway tracks could be foreseen in rural areas. This frequency band does not present the characteristics to support a national coverage objective and wide coverage areas. There is no expectation that the bands above 24 GHz will be used for contiguous nationwide coverage of wireless broadband electronic communications services (WBB ECS) networks. There may be a need for hotspots also in rural areas e.g. dedicated locations or along major roads and railway tracks. The deployment of WBB ECS will target only cells with a small range deployed indoor and/or outdoor*."

The technical conditions proposed in that CEPT report were developed assuming the use of an individual authorisation regime but caveated that individual authorisation (and hence the technical conditions) can be used for both nationwide licensing and licensing on a smaller geographic basis.

On the basis of this report, ECC PT1 developed ECC Decision (18)06 which establishes the common and minimal Least Restrictive Technical Conditions (LRTC) for the introduction of Mobile/Fixed Communication Networks (MFCN) in the 26 GHz band. This decision also urged CEPT administrations to "*make available by the end of 2020 at least 1 GHz for MFCN in this band, subject to market demand*" noting further that "*this Decision does not preclude the use of the band by other services to which the band is allocated*".

ECC Report 303 entitled "Guidance to administrations for Coexistence between 5G and Fixed Links in the 26 GHz band ("Toolbox")", approved in July 2019, provides assistance to administrations in the national decision process supporting the introduction of 5G systems in the 26 GHz band where there are Fixed Service (FS) in operation. It provides mechanisms which allow for continued FS operation. The results of all studies for the outdoor 5G network deployment scenarios show that coexistence between both services is possible but requires coordination (see Appendix F for more details). However, the amount of spectrum available for 5G systems at individual locations might be reduced by the existing FS usage. The feasibility of a successful outcome under such a coordination approach is a separate matter that would require further consideration based on national circumstances including the density of fixed link deployments.

ECC Report 303 also notes that one study shows that coexistence conditions between indoor 5G systems and outdoor FS improve significantly due to higher values of building entry signal loss at 26 GHz compared to lower bands[28].

3.1.2 BEREC

The Body of European Regulators for Electronic Communications (BEREC) has released studies and consultations dealing with 5G issues as outlined in Figure 3.1.

Figure 3.1: BEREC studies on 5G

Study / Consultation	Comments
Implications of 5G Deployment on Future Business Models, March 2018[29]	Amongst the key conclusions reached, the study considered that: • 5G was evolutionary compared to 4G and eMBB would be the main driver for early 5G deployment (but would not be a revenue growth opportunity). • Network slicing was key to allow differentiated services targeting different users by prioritising certain features. Additional revenues would come from those new added-value niche services and applications. There would be no killer application for 5G. • 5G could meet verticals'/user groups' specific requirements (QoS, jitter, latency, data throughputs and reliability), modify the usual mobile value chain by creating opportunities for new national or trans-national intermediaries and shake traditional pricing structures. New pricing structures could lead to inefficient outcomes. • Private networks should multiply within vertical industries, be encouraged to help solve the coverage issue and be coordinated. • To solve coverage issues and exploit mmWave frequencies, small cells should be deployed in many areas. Site owners may gain power due to small cells. Deployment of sites would be encouraged by Governments • Infrastructure sharing should thus be encouraged but should avoid excessive concentration • Edge computing might prove useful for some applications.
Public consultation on draft common position on mobile infrastructure sharing – BoR (19) 109 and 110 Summary Report on the Outcomes of Mobile Infrastructure Sharing Workshop – BoR (20) 240	Consulted on its draft position on infrastructure sharing including NRAs analysing agreements on a case-by- case. Following up on the 2019 Common position on infrastructure sharing, BEREC held a workshop in November 2020 to enable discussion with stakeholders on the BEREC work and on possible future evolutions of the Common Position.
Feasibility study on development of coverage information for 5G deployments – BoR (20) 33	BEREC investigated views on connectivity and coverage needs from operators and verticals and how they can be translated into KPIs through two consultations in 2019 and 2020. It was eventually decided that it was too early to set policy objectives to provide harmonised coverage and QoS information.

[28] Section 4.2 (https://docdb.cept.org/download/09bce05a-999a/ECC%20Report%20303.pdf)
[29] https://www.dotecon.com/publications/study-on-implications-of-5g-deployment-on-future-business-models-a-report-for-berec/

Study / Consultation	Comments
Report on the impact of 5G on regulation and the role of regulation in enabling the 5G ecosystem, December 2019 – BoR (19) 245	Key points include: • Information on new business models opened up by network slicing and accompanied by the emergence of new players coming in. Ensuring access to new players is key. In that sense, wholesale aspects on 5G will be central. • Issues around planning permission, notably on the 26 GHz, remain. • Backhaul studies can be extended to any-haul as increasing needs are expected for front-haul and mid-haul. The key point here is to ensure non-discriminatory backhaul commercial viability and costs • Obstacles to small-cell deployment should be eased.
BEREC 5G Radar BoR (20) 222 and 223	In August 2020, the Board of Regulators approved the draft BEREC Guide to the 5G Radar and 5G Radar for public consultation[30]. The aim of these documents is to anticipate any changes to regulation that may be required to keep pace with innovation. In December 2020, BEREC published a summary of all contributions received. After an evaluation of the submissions, BEREC did not make any significant changes to the 5G Radar. Only one additional topic was added to the radar on satellite communications in order to make the Radar illustration more comprehensive.

3.1.3 Radio Spectrum Policy Group (RSPG)

The RSPG published three opinions on 5G issues between November 2016 and January 2019 as follows:

- In its first opinion the RSPG resolved to deliver an early first opinion in order to give speedy guidance and provide an early input to other associated European activities, such as the development of the European Commission 5G Action Plan and industry more generally to enable the early development of 5G in Europe. Among other things, this opinion recommended the 24.25 – 27.5 GHz band as a 5G pioneer band above 24 GHz to offer ultra-high capacity for innovative new services, enabling new business models and sectors of the economy to benefit from 5G. In addition, the opinion called for Europe to develop harmonisation measures before 2020 and for Member States to make available a portion of this frequency band for 5G in response to market demand, taking into account that 5G deployment in this frequency range is likely to remain geographically limited until at least 2020.

- The RSPG, in its second opinion (February 2018), adopted further recommendations for policymakers on strategic issues related to 5G. The opinion notes that that Member States will need flexibility in the way they authorise access to spectrum. For example: appropriate geographical areas (e.g. national, regional, city or hyper-local, e.g. for use in a factory), individual licensing or under a general authorisation framework. Directly addressing the 26 GHz band the opinion noted that:

  - The focus of 5G authorisations in the 26 GHz band should be on an individual licence regime. However, the possibility of a general authorisation regime under sharing conditions that protect the other users of spectrum in this band (e.g. EESS/SRS) is not excluded;

  - 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, taking into account that 5G deployment in this frequency range is expected to be used for local coverage; and

  - Regulatory flexibility for the progressive release of the 26 GHz band will facilitate an efficient introduction of 5G without having an unnecessary negative impact on the current users of the band. To this end Member States should plan any migration of fixed links necessary for ensuring the

[30] https://www.discuto.io/en/consultation/33831.

availability of the band for 5G, taking into account the geographical dimension of the market demand for 5G.

- The third opinion addressed 5G implementation challenges including connectivity needs of verticals noting that:
  - 5G will play a significant role in providing a communications service that meets the specific requirements for verticals alongside other technologies;
  - connectivity for vertical industries could be provided by mobile operators, third-party providers and directly by verticals themselves in EU harmonised ECS bands or in dedicated spectrum for verticals; and
  - that Member States consider other spectrum solutions including dedicated or shared spectrum for the business/sectoral needs ("verticals needs") that may not be met by mobile operators. Such solutions could take advantage of economies of scale and ecosystem availability in spectrum bands with EU harmonised technical conditions.

3.1.4 European Commission (EC)

There have been a number of European Commission initiatives, including:

- The Public Private Partnership 5G PPP aimed to secure Europe's leadership in particular areas such as smart cities, e-health, intelligent transport, education or entertainment & media.
- The 5G action plan launched in 2016 to boost EU efforts for the deployment of 5G networks and launch 5G commercial services by year-end 2020. The 5G Action Plan involves stakeholders, private or public, small and large in all Member States. The 5G Action Plan asked all Member States to launch 5G services in at least one major city by year-end 2020 and to provide 5G services in all urban areas and along major transport paths by 2025.
- The 5G Observatory which provides regular updates on all of the latest market developments, including actions being undertaken by the private and public sectors in 5G. It also delivers an analysis of the strategic implications of the 5G Action Plan and other policy objectives.

3.2 Key harmonisation measures

The following sections highlight the key harmonisation measures in Europe. Further detailed information is provided in Appendix D.

3.2.1 European Commission (EC Decisions)

The European Commission has issued two 26 GHz band-specific decisions on spectrum harmonisation:

- 26 GHz: Implementing Decision EU 2019/784/EC of 14 May 2019; and
- 26 GHz: Amending Implementing Decision EU 2020/590/EC of April 2020 which updates the relevant technical conditions for the band following the decisions made at the World Radiocommunications Conference held in 2019 (WRC-19).

3.2.2 The European Electronic Communications Code (EECC, 2018)

The EECC is an EU directive which revises the framework for the regulation of electronic communications and services within the EU. It is a key legal measure coming out of the EU's Digital Single Market Strategy and transposing into national law by each Member States is required by December 2020.

In terms of enabling the take up of 5G services key measures in the EECC include:

- Common deadlines for licensing the identified pioneer 5G bands which includes 1 GHz of the 26 GHz band by 31 December 2020 - General exceptions apply including that sufficient demand exists to use the spectrum band and that incumbent and adjacent services are protected;
- A more convergent use and definition of elements of selection procedures through participation in a peer-review system;
- licence durations for harmonised spectrum rights which provide regulatory predictability over a period of at least 20 years regarding conditions for investment in infrastructure which relies on the use of such radio spectrum;
- Flexibility on spectrum authorisation, spectrum sharing, spectrum trading, infrastructure sharing and local roaming if required; and
- Lighter authorisation for small cells.

3.2.3 EC small-area wireless access points (implementing regulation (EU) 2020/991 of 30 June 2020)

Characteristics of small-area wireless access points (implementing regulation (EU) 2020/991 of 30 June 2020)[31]

In June 2020, the European Commission adopted an implementing regulation on small-area wireless access points or small antennas. This regulation is intended to simplify and accelerate 5G network installations, which should be facilitated through a permit-exempt deployment regime, while ensuring that national authorities keep oversight.

The regulation is not directly related to spectrum management but rather defines the physical and technical characteristics of small cells, which must be exempted from any individual town planning permit or other individual prior permits.

- The new small cells (antennas) will be less visible (either fully integrated and invisible to the public or, if visible, occupy a maximum space of 30 litres).
- Small cells will produce less electromagnetic emissions. Small cells will use lower power levels and therefore create lower exposure levels than existing 4G infrastructure. In fact, they could be compared to WiFi installations. The overall exposure with the rollout of 5G networks will, therefore, be comparable to existing levels – it will be well below the strict EU exposure limits, set out in Council Recommendation

[31] Implementing Decision of 30 June 2020 specifying the characteristics of small-area wireless access points pursuant to Article 57(2) of Directive (EU) 2018/1972 of the European Parliament and the Council establishing the European Electronic Communications Code

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0911

1999/519/EC, which sets exposure limits at 50 times lower than international scientific recommendations to ensure public safety.

3.3 Current allocation and use of the 26 GHz band in Europe.

Based on ITU and European Common Allocations information, which is outlined in detail in Appendix F, the following observations have been made:

- The primary use of the 26 GHz band in Europe is for fixed links. These are mainly point-to-point links, and the band is extensively used across Europe for this purpose. Therefore, sharing conditions defined for fixed links and 5G systems need to be considered to identify the potential for continued use of the 24.5 – 26.5 GHz band for fixed services.

- The band is also used by a range of licence-exempt short-range devices including automotive, industrial probing and tank level probing radars. Therefore, the co-existence between 5G and licence-exempt user needs to be taken into consideration.

- The ITU Radio Regulations indicate that satellite services including inter-satellite, fixed satellite (Earth to space), EESS (space to Earth) and Space Research (space to Earth) have allocations within the 26 GHz band. The use of fixed satellite earth station transmitters is restricted by a minimum diameter requirement of 4.5 metres. In the band 25.25-27.5 GHz, the use of inter-satellite service is limited to Space Research and EESS applications and transmissions of data originating from industrial and medical activities in space. EESS earth stations are not able to claim protection from the fixed and mobile services. Ireland is not in the list of countries where the same condition is also defined for Space Research earth stations. It is also noted that administrations operating EESS and Space Research earth stations are not allowed to claim protection from the fixed and mobile services operated by other administrations. The implications of these regulations may have to be considered when defining sharing constraints.

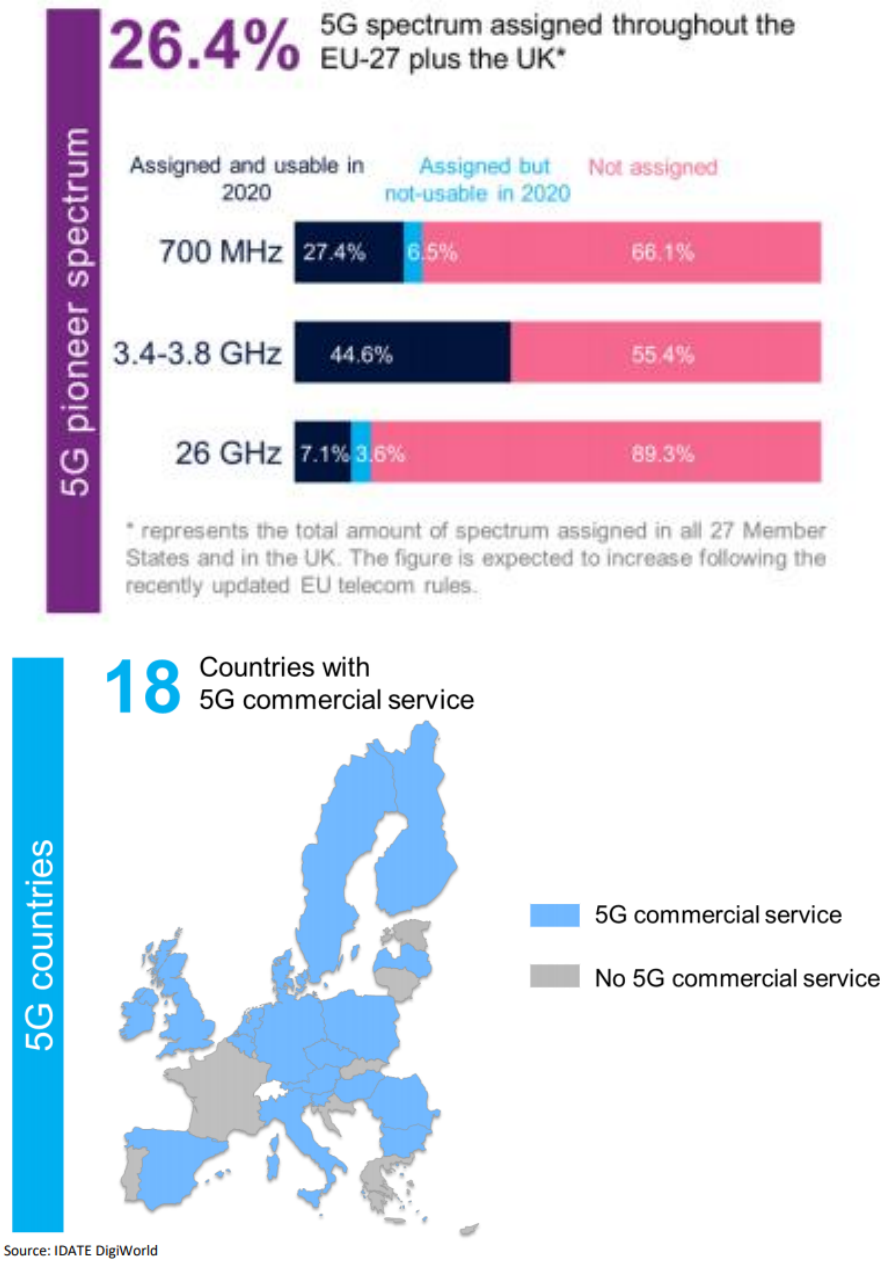
- Incumbent services operating in the adjacent bands need to be taken into consideration. Adjacent bands below the 26 GHz band have primary allocations for Radiolocation, Amateur, Amateur Satellite, EESS (passive), Radio Astronomy, Space Research (passive) and Fixed Service. Licence-exempt use is also allowed and includes ISM (industrial, scientific and medical), short range devices, industrial and tank level probing radars. Adjacent bands above the 26 GHz band are allocated to fixed and fixed satellite (Earth to space) services.

Reports, decisions and recommendations developed within CEPT and ECC provide information on the coexistence issues between the different co-channel and adjacent channel incumbent services as well as between WBB ECS systems. These are summarised in Appendix F.

4 European approaches to award the 26 GHz band

Figure 4.1 provides an overview of 5G development in the EU27 plus the UK as regards spectrum assignments and network deployments[32]. It can be seen that there is a significant amount of spectrum still to be assigned in the core (pioneer) bands.

Figure 4.1: 5G development in EU 27 plus the UK – September 2020



Source: IDATE DigiWorld

[32] See 5G Observatory Quarterly Report 9 http://5gobservatory.eu/wp-content/uploads/2020/10/90013-5G-Observatory-Quarterly-report-9-V2.pdf

In the following sections we specifically address the award of the 26 GHz band.

4.1 Benchmarking of awards, planned awards and licensing frameworks for the 26 GHz Band in Europe

Among the EU27 plus the UK, there have only been three awards of 26 GHz spectrum to date – in Greece, Italy and Finland. Other countries such as Luxembourg and Poland are at the initial stages of identifying whether there is demand for access to the 26 GHz band whereas others, such as Denmark and Slovenia, are more advanced with their preparation for licence award having determined the relevant spectrum, coexistence issues, method of award and potential demand.

The approach taken by Greece, Italy and Finland, and proposed by, Denmark and Slovenia, is to award national licences using an auction. It is important to note that often the award involves a number of different frequency bands including low band and mid spectrum in addition to the 26 GHz band. In Italy the regulator has adopted an innovative regulatory framework based on a "Club use" model[33] and under this framework licensees can share spectrum on a geographical basis when frequencies are not used, and each licensee would still have priority access to its own block. Plum understands that this model is still in the process of being implemented. In Denmark and Finland, consideration has been given to use a portion(s) of the 26 GHz band to license private networks and limiting licences to a local and regional nature.

The UK has adopted a different approach by initially issuing local licences for indoor use in the 24.25 – 26.5 GHz band. This approach seeks to enable deployment of new 5G indoor applications with little to no impact on existing services and without prejudice to future outdoor use of the band. Based on this approach, users will be allowed to apply for a 26 GHz Shared Access licence for indoor use. Once the licence is granted, licensees can deploy the required number of indoor base stations in a circular area with a 50-metre radius without requiring further individual base station authorisations. It is possible to apply for multiple licences to cover a larger area. The licence will also cover terminal stations and a licence fee of £320 will be applicable per licence[34].

Germany has proposed to award the 24.25 – 27.5 GHz band for local broadband[35] and licence applications have been accepted since 1 January 2021. Licences will be awarded on a first come first served basis and are technology and service neutral. It is expected that most users will request 800 MHz bandwidth and applicants will have to provide justification for the requested bandwidth. Operator agreements between neighbouring users are required to manage use of the local broadband frequencies (indoor and outdoor). Frequencies can be partially or wholly revoked after 12 months under use-it-or-lose-it licence conditions.

A summary of the currently available information on awards across Europe and the UK is provided in Figure 4.2 and further details, on a per country basis in Appendix C.

[33] This is a variant of the classic "club use" formula, as the club members and the access criteria are decided by the regulator, while the club "members" decide on their own rules of coexistence and management.
[34] Average of cost-based fee for other shared access bands Does not vary by bandwidth as Ofcom considered sufficient amount of spectrum available and low risk of interference.
[35] Consultation on Frequencies for local broadband in frequency range 24.25 – 27.5 GHz, 27.07.2020

Figure 4.2: Overview of 26 GHz awards in Europe

	Ireland	Czech Republic	Denmark	Finland	France	Germany	Greece	Italy	Poland	Slovenia	UK
Demographics											
Population (2019)	4,904,226	10,649,800	5,804,081	5,517,919	67,059,890	83,019,214	10,722,287	60,359,546	37,972,812	2,080,908	66,650,000
Total area (Km^2)	70,280	78,886	43,094	337,030	549,087	357,021	131,957	301,320	312,685	20,253	242,495
Pop. Density (people/km^2)	70	135	135	16	122	233	81	200	121	103	275
Award status		Experimental licences[36]	Auction planned for March 2021	Auction completed in June 2020	Consultation ended in July 2018	Local licensing	Auction completed in Dec 2020	Auction completed in Oct 2018	Ongoing consultation	Ongoing consultation	Local licensing[37]
Award / licence conditions											
Total amount of spectrum		1000 MHz	2850 MHz[38]	2400 MHz[39]	Not decided	Complete band	5 lots of 200 MHz	5 lots of 200 MHz		5 blocks of 200 MHz[40]	
Duration			20 years	13.5 years	Not decided	Until December 2040	15 + 5 years	19 years		15 years	[41]

[36] Following a consultation in August 2020 and talks with stakeholders CTU decided the market for services in the 26 GHz band was unclear and there was no demand for new services so they would offer experimental licences as a first step.
[37] The process started end of 2019 and applies to 24.25 – 26.5 GHz
[38] The lowest 400 MHz, i.e. 24.25-24.65 GHz is for private networks using TDD
[39] The lowest 850 MHz i.e. the 24.25-25.1 GHz band is reserved for local/regional vertical players and R&D or educational usage
[40] Spectrum cap of 800 MHz
[41] Local shared licences are for indefinite period but can be revoked with 1-month notice if break terms of licence. Can also be revoked if develop plans to repurpose band

	Ireland	Czech Republic	Denmark	Finland	France	Germany	Greece	Italy	Poland	Slovenia	UK
Roll-out / coverage obligations			✓[42]				✗[43]	✗[44]		✓[45]	
Spectrum/network sharing			✓[46]	✓[47]	✓[48]		✓[49]	✓[50]		✓[51]	
Incumbent services	Fixed Level probing radars	Fixed Level probing radars Automotive radars SAP/SAB No ISS, EESS and SRS	Fixed EESS FSS SRDs SRS	No EESS, SRS, FSS or RA	Fixed Satellite Military	EESS ISS Radio astronomy Satellite Fixed Military	Fixed SAP / SAB Satellite Note use of passive satellite in neighbouring countries	Fixed SRDs	Fixed Government users	Fixed	Fixed Satellite

[42] No coverage obligation. Have to install, no later than 4 years from date of licence antennas and transceivers connected to the network for at least 100 mast positions to provide service for at least one electronic communications service.
[43] Originally proposed at least 5 base stations in each municipality with greater than 50,000 inhabitants within 5 years of licence award except for Attika and Thessaloniki regions. Now no obligation.
[44] No coverage obligations but spectrum must be used in all Italian provinces within 4 years.
[45] Propose that within 5 years of spectrum availability must offer services to end-users in at least one major city. Provision of services means that the service is provided through base stations covering at least 75% population of an individual urban settlement.
[46] Network sharing arrangements not limited
[47] A licence holder has the right to share the use of mobile network base stations with another licence holder in frequencies for which the other licence holder has a radio licence. A licence holder must notify the Finnish Transport and Communications Agency of the use of the shared network and frequencies before deployment of the network. A licence holder must also notify the Agency if the use of the shared network ends partially or completely.
[48] Temporary licences (3 years) to companies willing to create "open-access" trials available for third parties
[49] Passive and active network sharing supported. Must negotiate with business verticals in good faith to provide access through, for example, leasing agreements. Also 200 MHz in the 26 GHz band is reserved for universities and start-ups to research and develop 5G-based services and applications.
[50] Club-use model: Each licensee can use all the awarded spectrum (up to 1 GHz) in areas where frequencies are not used by other licensees. Each licensee holder has pre-emptive rights on its assigned lots
[51] Sharing of frequencies and active equipment is permitted in the 26 GHz band between licensees

	Ireland	Czech Republic	Denmark	Finland	France	Germany	Greece	Italy	Poland	Slovenia	UK
Coexistence requirements		Future use by fixed services depends on sharing with 5G. 26.5 – 27.5 GHz non-civil band	After 1 December 2021 existing fixed links must cease operation if they cause interference			Allocation of frequencies require interference free co-existence with existing uses and users	In consultations proposed 2 different guard bands for fixed services (20 MHz and 30 MHz)		Consultation asks about coexistence with fixed and also about 28 GHz being the migration band.		No requirement for technical coordination between indoor 5G base stations and fixed links. 1 Km exclusion radius around EESS earth station and radio astronomy sites.[52]

[52] See https://www.ofcom.org.uk/__data/assets/pdf_file/0033/157884/enabling-wireless-innovation-through-local-licensing.pdf paragraphs 5.22 - 5.36.

4.2 Countries where there are currently no planned dates for 26 GHz band awards

There are a number of countries that have not yet set a date for the assignment of frequencies in the 26 GHz band. These are summarised in Figure 4.3.

Figure 4.3: Availability of 26 GHz spectrum in EU-27 (as of end September 2020)

Country	Frequencies	Comments
Austria	24.25 – 27.5 GHz	Public consultation on plans in June 2019
Bulgaria	24.25 – 27.5 GHz	
Croatia	24.25 – 27.5 GHz	
Czech Republic	26.5 – 27.5 GHz	
Cyprus	24.25 – 27.5 GHz	
France	26.5 – 27.5 GHz	
Hungary	26.5 – 27.5 GHz	Public consultation in July 2019, limited demand for 5G. Auction put on hold.
Poland	n/a	Depends on demand

Source: 5G Observatory – Quarterly Report #9

ComReg has consulted on the release of the 26 GHz band as part the current multi-band spectrum award[53]. ComReg's position and the view of some stakeholders justifying not including a number of bands in the current multi-band spectrum awards is detailed in ComReg document 19/124[54]. In relation to the 26 GHz band stakeholders noted that:

- the characteristics of the 26 GHz band are significantly different to those of the other bands in the Proposed Award;
- the 26 GHz network and device ecosystem is less advanced than other bands being included; and
- there are several issues to be considered in order to optimise the 26 GHz band before an award, reconfiguration might be necessary, and a separate consultation is required to resolve these matters.

ComReg agreed that the characteristics of the 26 GHz band are significantly different to those in the proposed award, and a separate consultation would be necessary to optimise an award process for the 26 GHz band.

4.3 Observations

There has been very limited release of the 26 GHz band across Europe for 5G. Momentum is slowly growing but a number of the large EU countries i.e. France have not seen the need to release the 26 GHz band or portions of the 26 GHz band at this time other than for trialling, while others, i.e. Germany and the UK, have sought to use portions of the band for indoor or local/regional use. The Czech Republic has adopted a different approach and decided to make the band available for experimental licences to inform future regulatory and technical considerations due to lack of demand.

[53] See ComReg Doc 20/122 Multi Band Spectrum Award – Response to Consultation and Decision – The 700 MHz Duplex, 2.1 GHz, 2.3 GHz and 2.6 GHz Bands | Commission for Communications Regulation (comreg.ie)
[54] See ComReg Doc. 19/124 – Proposed Multi Band Spectrum Award - Response to Consultation and Draft Decision- published 20 December 2019

The limited 5G use of the 26 GHz band across Europe is reflected in the recently released Apple iPhone 12 Pro not including the 26 GHz band[55]. It appears that Apple has chosen to focus on the 3.6 GHz band where there is far greater rollout across Europe. This is an important metric as 32% of smartphones in Ireland[56] are Apple iPhones and 36% of mobile phone owners hold onto their current models for at least 3 – 6 years.

The importance of this metric across Europe is reflected in a recent report[57] from Analysys Mason which notes that "*The iPhone is typically the single-most significant device launch and 5G operators around the world will have high expectations for the device*" and "*Apple's smartphones account for only 15% of the smartphone shipments worldwide, but the company has a much higher market share in many developed markets. For example, Apple accounts for over 40% of all smartphones in Australia, Japan, the UK and the USA. Apple has a strong presence among premium consumers who represent a large proportion of potential early adopters of 5G plans*".

There are five other phone manufacturers of 5G phones that utilise the 28 GHz n257 band (26500 -29500 MHz, see Figure 4.4. However, the 26 GHz n258 band (24250-27500 MHz)[58] does not appear to be available in any of the current models.[59]

Figure 4.4: 5G phones

Vendor	Model	Form Factor
Fujitsu	Arrows 5G F-51A for NTT DoCoMo	Phone
LG	V60 Thin Q LG-51A (Japan)	Phone
Samsung	Galaxy S10 5G (Variant 2)	Phone
Samsung	Galaxy S10 5G (Variant 1)	Phone
Sharp	Aquos R5G SH-51A	Phone

[55] See https://www.apple.com/ie/ and https://www.apple.com/iphone-12-pro/specs/.
[56] See ComReg (19)101 – Mobile Consumer Experience Survey of Customers - 2019
[57] See https://www.analysysmason.com/research/content/comments/iphone-12-5g-rdmd0-rdmm0/
[58] Information source https://gsacom.om/gambod/

5 The 26 GHz band in Ireland

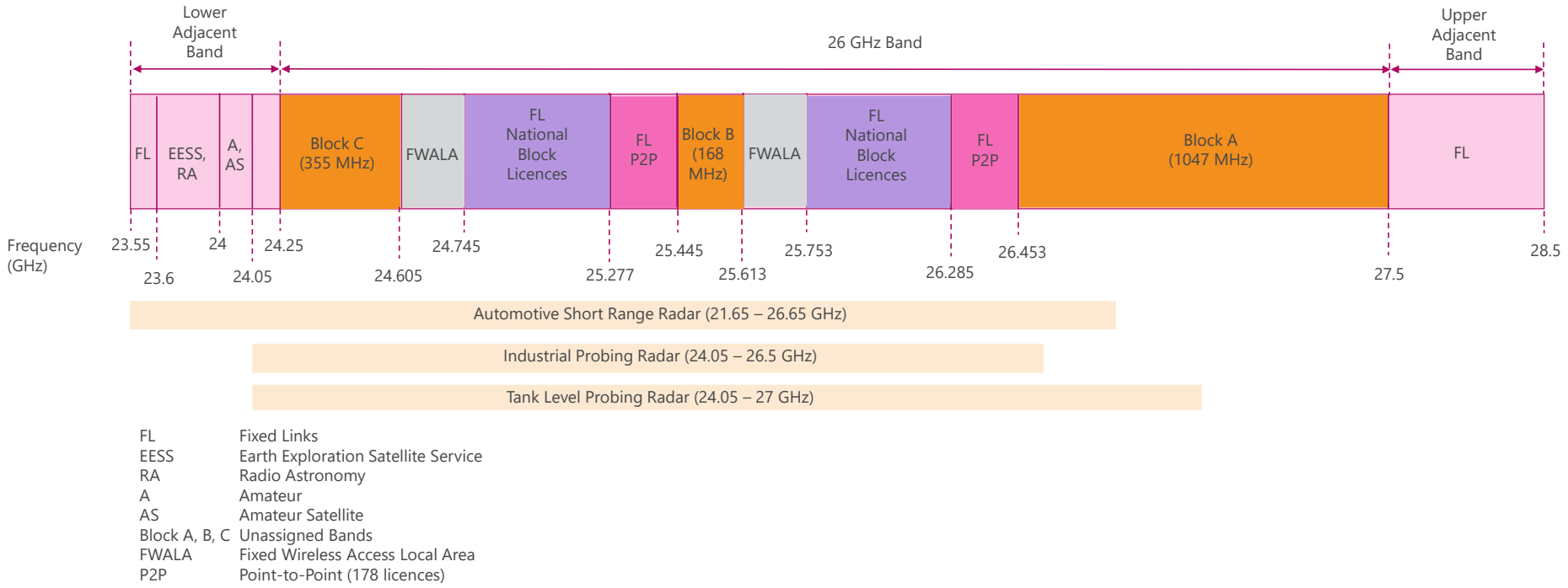
This section examines:

- The current use of the 26 GHz band in Ireland;
- The harmonised technical conditions under which WBB ECS can utilise the 26 GHz band;
- The use of the entire 26 GHz band for WBB ECS;
- The use of currently unassigned spectrum portions; and
- The options and consequence of the progressive clearing of one or more of the currently licensed portions of the 26 GHz band.

5.1 Current use of the 26 GHz band in Ireland

The current use of the 26 GHz band and allocations in the adjacent bands is illustrated in the following figure.

Figure 5.1: Current use of the 26 GHz band and allocations in adjacent bands in Ireland (Source: ComReg)



FL	Fixed Links
EESS	Earth Exploration Satellite Service
RA	Radio Astronomy
A	Amateur
AS	Amateur Satellite
Block A, B, C	Unassigned Bands
FWALA	Fixed Wireless Access Local Area
P2P	Point-to-Point (178 licences)

In common with many European countries the current primary use of the 26 GHz band in Ireland is by fixed services:

- There is a Fixed Wireless Access Local Area[60] allocation in 24.605 – 24.745 GHz / 25.613 – 25.753 GHz. As of January 2021 there are no assignments in this band;
- National block licences[61] enabling Point-to-point (PP) fixed link operation in 24.745 – 25.277 GHz / 25.753 – 26.285 GHz; and
- One hundred and seventy-eight (178)[62] individually co-ordinated PP link[63] licensees operate in 25.277 – 25.445 GHz / 26.285 – 26.453 GHz.

Other uses of the band under the licence exemption of short-range devices[64] are:

- automotive short-range radars (21.65 – 26.65 GHz);
- industrial probing radars (24.05 – 26.5 GHz); and
- tank-level probing radars (24.05 – 27 GHz).

Currently the unassigned portions of the band are:

- 26.453 – 27.5 GHz (1 047 MHz) – Block A;
- 25.445 – 25.613 GHz (168 MHz) – Block B; and
- 24.25 – 24.605 GHz (355 MHz) – Block C.

The bands adjacent to 24.25 – 27.5 GHz are allocated to / used by the following services / systems.

- Lower adjacent band (below 24.25 GHz):
  - Fixed links in 23.55 – 23.6 GHz;
  - Short-range devices (including automotive) in 21.65 – 26.65 GHz;
  - Earth Exploration Satellite Service and Radioastronomy Service in 23.6 – 24 GHz;
  - Amateur and Amateur Satellite Services in 24 – 24.05 GHz;
  - Industrial probing radars in 24.05 – 26.5 GHz; and
  - Tank-level probing radars in 24.05 – 27 GHz.
- Upper adjacent band (above 27.5 GHz)
  - Fixed links in 27.5 – 28.5 GHz.

[60] http://www.irishstatutebook.ie/eli/2003/si/530/made/en/print.
[61] http://www.irishstatutebook.ie/eli/2018/si/158/made/en/print
[62] As of 12th November 2020
[63] http://www.irishstatutebook.ie/eli/2009/si/370/made/en/print
[64] https://www.comreg.ie/publication/permitted-short-range-devices-in-ireland-2/

5.2 Harmonised technical conditions for WBB ECS in the 26 GHz band

The essential harmonised technical conditions under which WBB ECS can be used in the 26 GHz band are defined in **European Commission Implementing Decision (EU) 2019/784**[65] (published in May 2019) and amended by **European Commission Implementing Decision (EU) 2020/590**[66] (April 2020) (together the "EC Implementing Decision"). In summary, the general parameters[67] would be:

- The duplex mode shall be TDD.
- The assigned block size shall be a multiple of 200 MHz (although smaller blocks of 50, 100 or 150 MHz are possible adjacent to the assigned block of another spectrum user). This facilitates 16 blocks each of 200 MHz in the band.
- The upper frequency limit of an assigned block shall be aligned with or spaced at a multiple of 200 MHz from 27.5 GHz.
- Base station transmissions within the band are restricted by 'block edge masks' which assume synchronised operation and comprise base station transitional region power limit of 12 dBm/50MHz applicable up to 50 MHz below or above an operator's block and base station baseline power limit of 4 dBm/50MHz applicable to frequency offsets greater than 50 MHz below or above an operator's block.
- In order to limit interference into satellite receivers, the main beam of any Active Antenna System (AAS) outdoor base stations is only allowed to point below the horizon.
- For the protection of EESS in the band 23.6 – 24 GHz where all emissions are prohibited, 5G base station out-of-band emission limits (in terms of total radiated power a composite antenna radiates) are -33 dBW/200MHz for deployments before 1 January 2024 and -39 dBW/200MHz for deployments after 1 January 2024. For user terminals, the corresponding levels are -29 dBW/200MHz and -35 dBW/200MHz.

As required by the EC Implementing Decision, ComReg would also need to consider how:

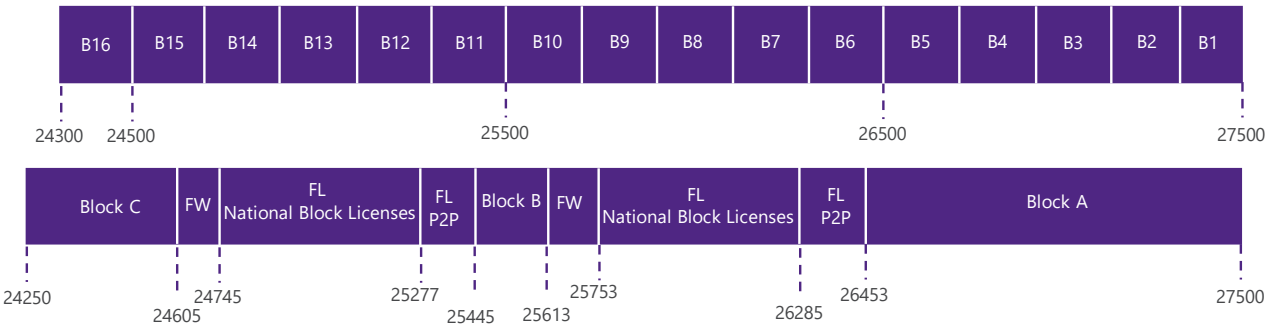
- it wants to deal with any new deployment, if allowed at all, of EESS (s-E), SRS (s-E) and FSS (E-s) earth stations in the band;
- to ensure the adequate protection of FSS satellite systems (E-s) in the portion 24.65 – 25.25 GHz if any such protection is warranted;
- to ensure the protection of an inter-satellite communications operating in the portions 24.45 – 24.75 and 25.25 – 27.5 GHz if any such protection is necessary.

5.3 Use of the entire 26 GHz band for WBB ECS

If the entire 26 GHz band was available for WBB ECS deployment, then the band plan would be as shown in the figure below which includes sixteen (16) blocks of 200 MHz bandwidth, and the essential technical conditions detailed in the two EC Implementing Decisions would be adequate.

[65] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019D0784
[66] https://eur-lex.europa.eu/eli/dec_impl/2020/590/oj
[67] This is not an exhaustive list - there are a few other requirements such as communications with unmanned aerial vehicles, earth stations, etc.

Figure 5.2: Band plan and current use



However, returning the band to a greenfield status does not appear very likely in the near to medium term. Further, we note that Member States are only permitted to designate and make the band available on a non-exclusive basis to WBB ECS and that Member States are obligated to consider if it is necessary to impose additional technical conditions in order to ensure appropriate co-existence of WBB ECS with other services in the band.

Therefore, we now consider if WBB ECS can make use of the currently unassigned spectrum portions of the band by analysing what technical conditions would apply to WBB ECS.

5.4 Potential use of the currently unassigned spectrum portions in the 26 GHz band

5.4.1 BLOCK A: Unassigned spectrum 26.453 – 27.500 GHz

In-band co-existence

The implications of co-existence with space services and licence-exempt devices needs to be considered. The space services referred to here are: EESS (space-to-Earth), SRS (space-to-Earth) and Inter Satellite Service (ISS).

In-band co-existence with space services

Although there is no current use of the band by earth stations in Ireland, relevant conditions have been outlined in this section in case of potential future deployments. More detailed discussions on the conditions are provided in Appendix F.

Case-by-case analysis with EESS and SRS earth stations could be necessary to introduce 5G systems in the same geographical area. It is worth noting that ITU RR includes a footnote (5.536B) stating that EESS earth station receivers cannot claim protection from fixed and mobile systems in Ireland in 25.5 – 27 GHz.

As mentioned earlier (in Section 5.2), to protect satellite receivers (including those operating in Inter Satellite Service, there is a harmonised technical condition in **EC Decision 2019/784** requiring that an outdoor base station antenna beam should normally be below the horizon and there should be no mechanical pointing above the horizon.

The impact of WBB ECS deployment in Ireland on earth stations deployed or planned to be deployed in neighbouring countries needs to be addressed in accordance with ITU-R procedures (e.g. Appendix 7 of Radio Regulations).

In-band co-existence with licence exempt devices

According to **CEPT Report 68**[68] and **EC Decision 2019/784**, the use of 24.25 - 26.65 GHz band by automotive short-range radars is no longer available since January 2018 and radar equipment already in use should be gradually phased out by 1 January 2022. There is a steady trend in the market for automotive short-range radars towards new deployments in the 77 - 81 GHz frequency band harmonised at Union level. Therefore, no co-existence issues with automotive short-range radars are identified.

CEPT Report 68 and **EC Decision 2019/784** also state that the 24.25 - 27 GHz portion of the 26 GHz frequency band is used for radio determination devices (i.e. level probing radars), which operate in 'underlay' mode based on ultra-wide band technology. In accordance with EC Decision 2019/784 "such use should be adaptable to the evolution of use of the 26 GHz frequency band for terrestrial wireless broadband electronic communications services".

ERC Recommendation 70-03[69] provides appropriate limits for enabling operation of level probing radars on a licence-exempt basis in the 26 GHz band. These limits are based on **ECC Decision (11)02**[70] which provides a reference to **ECC Report 139**[71] where detailed compatibility studies are presented for level probing radars deployed outdoor and indoor (covered) industrial environments. **ECC Report 139** concludes that level probing radars are installed and maintained in industrial environments by professionally trained personnel. They can be deployed on a licence-exempt basis subject to ensuring compliance with regulatory conditions which include the use of adaptive power control and limits associated with eirp[72], antenna orientation, antenna beamwidth and unwanted emissions.

In summary, technical conditions provided in **ERC Recommendation 70-03** and **ECC Decision (11)02** should be adequate for co-existence with licence-exempt level probing radars. As short-range automotive radars are migrating to the 76 – 81 GHz band no co-existence issues are expected.

Adjacent band co-existence

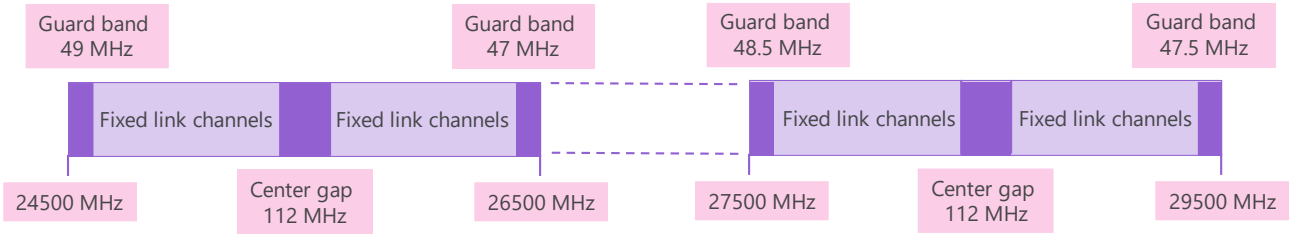
The primary use of the adjacent bands is fixed links. The implications of co-existence with licence-exempt devices and space services including the protection of passive band (23.6 – 24 GHz) also need to be considered.

Adjacent band co-existence with fixed point to point links

The licensing of fixed links in Ireland closely follows the CEPT recommended band plan as provided in **CEPT Recommendation T/R 13-02**[73]. The following figure illustrates the 26 GHz band fixed link band plan.

[68] https://www.ecodocdb.dk/document/3358
[69] https://www.ecodocdb.dk/document/845
[70] https://www.ecodocdb.dk/document/429
[71] https://www.ecodocdb.dk/document/247
[72] Eirp is the effective isotropic radiated power and is the maximum power that can be radiated from an antenna taking into account antenna gainand transmit power of the RF system.
[73] https://docdb.cept.org/document/869

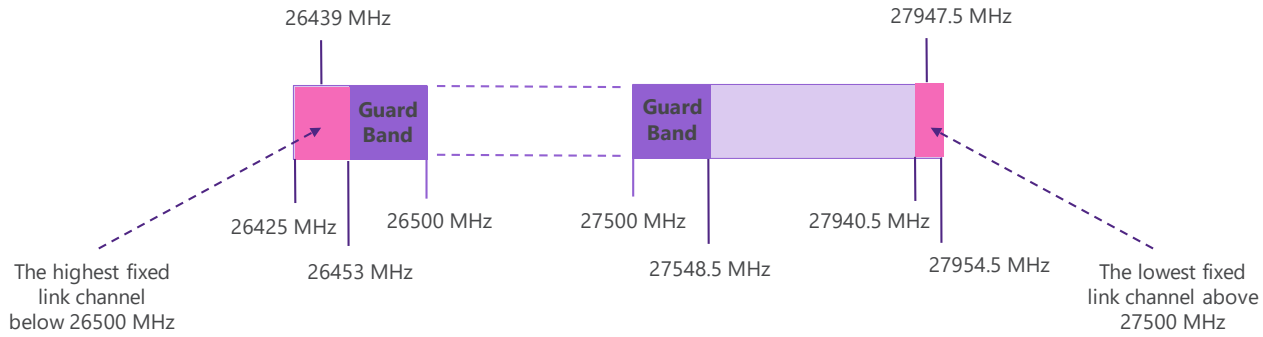
Figure 5.3: The 26 GHz fixed link band plan (Source: CEPT Recommendation T/R 13-02)



ComReg is currently undertaking a review of the Fixed Radio Links Licensing Regime and published two documents (20/109 and 20/109A)[74]. Fixed link data provided by ComReg indicates that:

- The lowest fixed link channel centre frequency currently in use above 27 500 MHz is 27 947.5 MHz and these links operate in 14 MHz wide channels.
- The highest fixed link channel centre frequency currently in use below 26 500 MHz is 26 439 MHz and these links operate in 28 MHz wide channels.

Figure 5.4: Fixed link channels operating adjacent to 26 500 – 27 500 MHz



The figure above suggests that there would be more than 400 MHz of guard band between existing fixed links operating above 27 500 MHz and the potential WBB ECS deployment in the 26 500 – 27 500 MHz band. The minimum guard band between existing fixed links operating below 26 500 MHz and the potential WBB ECS deployment in the 26 500 – 27 500 MHz band is 47 MHz (i.e. 26500 – (26439+28/2)).

As outlined in Appendix F, a number of CEPT and ITU-R studies have examined the implications of guard bands by assuming that a 20 MHz guard band exists between a fixed link receiver and a WBB ECS transmitter. These studies show that, with a 20 MHz guard band, a few hundred metres separation would be sufficient in most co-existence scenarios. As noted above, there would be a 47 MHz guard band[75] already available with respect to the Irish fixed link use below 26 500 MHz. Therefore, the adjacent band co-existence would be feasible with relatively small separations of WBB ECS transmitters from the fixed link receivers, a few hundred metres in most scenarios.

Scenarios involving 28 MHz and 56 MHz guard bands have also been considered in a few CEPT and ITU-R studies (see Appendix F). For example, the impact of a 56 MHz guard band has been analysed for fixed link receivers with large antenna heights (e.g. 60 m) and shown that in such scenarios separations up to 1 km would be sufficient for urban WBB ECS deployments.

[74] Publications - Commission for Communications Regulation (comreg.ie)
[75] This is the upper guard band of 47 MHz in the preferred channel arrangement for the 24.5 – 26.5 GHz band available in T/R 13-02, Annex 2

A 56 MHz guard band implies that there is a potential for a 9 MHz overlap between the guard band and 28 MHz wide fixed link receivers operating in a channel centred at 26 439 MHz. The analysis of ComReg fixed link data suggests that there are nine (9) 28 MHz wide fixed link receivers with a 9 MHz overlap in the 56 MHz guard band. The relevant site data are shown in the following figure.

Figure 5.5: Site and antenna height data for fixed links operating below 26 500 MHz with 9 MHz overlap in 56 MHz guard band

Site name	Location (Easting)	Location (Northing)	Site height (a.s.l.) (metres)	Antenna height (a.g.l.) (metres)
Site 1	078797	061947	74	15
Site 2	303675	239900	70	28
Site 3	315368	242132	64	16.2
Site 4	101207	072644	98	20.5
Site 5	321792	228366	25	19.5
Site 6	317936	223809	313	15
Site 7	169463	071816	4	43
Site 8	156816	071877	160	23.3
Site 9	318900	239890	40	17.7

As can be seen, most of the sites are highly elevated. The site locations are shown in the following figures.

Figure 5.6: Locations of fixed links operating below 26 500 MHz with 9 MHz overlap in 56 MHz guard band (Dublin Area)

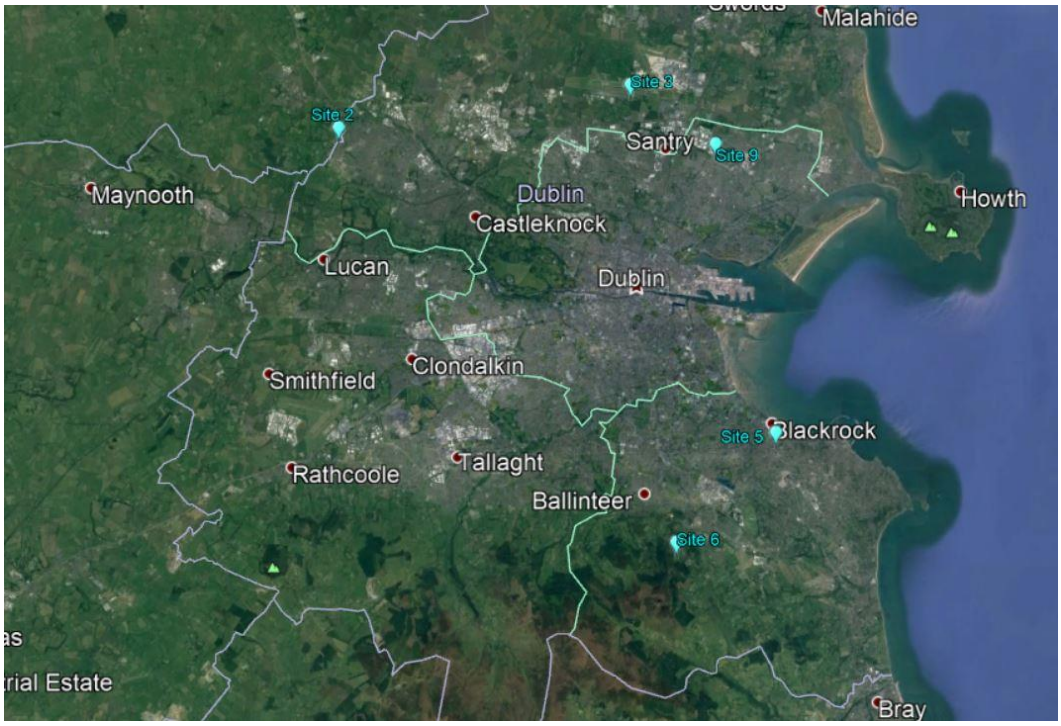
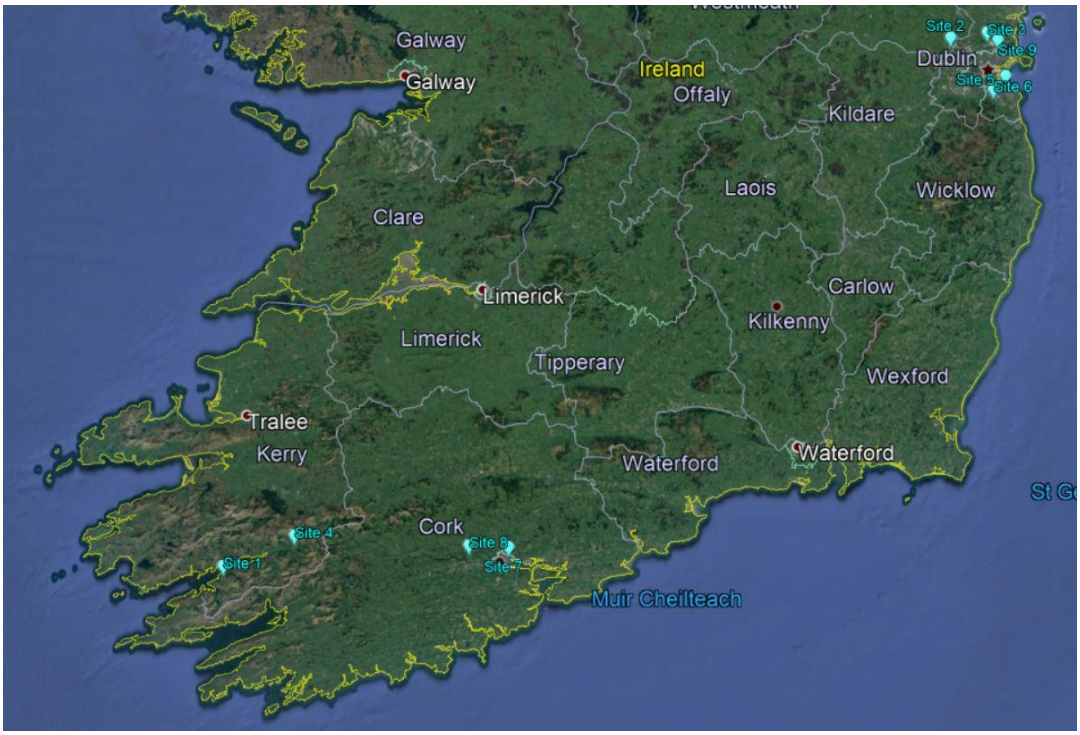


Figure 5.7: Locations of fixed links operating below 26 500 MHz with 9 MHz overlap in 56 MHz guard band (Ireland)



The analysis above indicates that the allocation of 1 GHz spectrum for WBB ECS in the 26.5 – 27.5 GHz band would be feasible. The 47 MHz guard band at the upper edge of the 24.5 – 26.5 GHz band should allow adjacent band co-existence without causing a major impact on existing fixed links. ComReg should consider avoiding the assignment of the upper most fixed link channel (regardless of bandwidth) as this will further minimise the impact on adjacent services. There is no impact for the fixed link band commencing at 27.5 GHz.

It is our opinion that WBB ECS can be deployed in the unassigned 26 453 – 27 500 MHz in line with the proposals outlined in **ECC Report 303**[76] without a restriction on existing fixed links in the adjacent bands.

Adjacent band co-existence with licence exempt devices and space services

The co-existence conditions provided above for the in-band co-existence with licence exempt devices (i.e. short-range devices and level probing radars) and space services (i.e. EESS, SRS and ISS) are also applicable for adjacent band co-existence scenarios. The additional space service to be considered is FSS (Earth-to-space) operating above 27.5 GHz and the protection of FSS satellite receivers is based on the principle of limiting the outdoor base station antenna beam below the horizon as described in **EC Decision 2019/784**.

The protection of the passive band 23.6 – 24 GHz is ensured by base station and user terminal out-of-band emission limits defined in **EC Decision 2020/590**. Although there is no current Radio Astronomy Service use in Ireland, specific measures (e.g. exclusion areas) could be required to protect potential future Radio Astronomy sites using the 23.6 – 24 GHz band. We have identified several recent references relating to the establishment of exclusion areas for the protection of Radio Astronomy sites in the UK. The relevant key points are summarised below.

[76] https://docdb.cept.org/document/12612

- *OfW 590 Technical Frequency Assignment Criteria for Shared Access Radio Services*[77], published in April 2020, provides an exclusion area of 1 km radius around Harwell Earth Exploration Satellite Service earth station (Oxfordshire); Jodrell Bank Observatory (Cheshire) and Cambridge Radio Astronomy Site (Cambridgeshire) to protect their operation in 23.6 – 24 GHz band with respect to low power devices (TRP=23 dBm/200MHz) licensed to operate indoors in the band 24.25 – 26.5 GHz.

- *IR 2030 – UK Interface Requirements 2030 for Licence Exempt Short Range Devices*[78], published in May 2020, prohibits the use of level probing radars in the band 24.05 – 26.5 GHz within 4 km radius of Radio Astronomy sites located in Cambridge, Darnhall, Jodrell Bank, Knockin and Pickmere. A further restriction based on limiting antenna height to 15 m up to 40 km from these sites is also defined. These conditions are referenced to ETSI EN 302 729.

- *Ofcom Statement on short-range devices and railway level crossing radar sensor systems*[79], published in June 2020, revokes the licence exemption for the operation of railway level crossing radar sensor systems operating in the band 24.1 – 24.350 GHz with a maximum power limit of 500 mW e.i.r.p. Originally, these systems were required to operate outside 20 km exclusion areas established to protect sites in Cambridge, Defford, Darnhall, Jodrell Bank, Knockin and Pickmere. In 2015, the exclusion area requirement was replaced with a coordination area requirement where the deployment of radars would be possible within 20 km zones providing that a coordination agreement is in place with the Radio Astronomy user. These devices are now authorised via a licence to enable Ofcom to manage their deployment at locations previously excluded under the licence exemption regime. The power limit of these systems has been changed to 5W.

5.4.2 BLOCK B: Unassigned spectrum 25.445 – 25.613 GHz

In-band co-existence

The in-band co-existence conditions related to space services (including ISS, EESS and SRS) and licence-exempt use (including level probing and automotive short-range radars) defined in Section 5.4.1 are applicable.

Adjacent band co-existence

The adjacent band co-existence conditions defined in Section 5.4.1 related to the level probing and automotive short-range radars as well as the protection of the passive band (23.6 – 24 GHz) are applicable.

There is currently spectrum allocated for FWALA in the upper adjacent band and point-to-point fixed links operating in the lower adjacent band.

Adjacent band co-existence with fixed point to point links

ComReg fixed link data indicates that a total of twenty-one (21) fixed link receivers with 28 MHz channel bandwidth centred at 25 403 MHz and 25 431 MHz would be operating within an assumed 56 MHz guard band below 25 445 MHz. [80]The relevant site data are shown in the following figure.

[77] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/183744/Shared-Access-technical-frequency-assignment-criteria.pdf
[78] https://www.ofcom.org.uk/__data/assets/pdf_file/0028/84970/ir-2030.pdf
[79] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/196245/statement-870-and-rlc-radar.pdf
[80] Note in CEPT/ITU studies various guard bands of 20, 28 and 56 MHz have been considered with 56 MHz being the largest considered for co-existence.

Figure 5.8: Site and antenna height data for fixed links operating below 25 455 MHz within an assumed 56 MHz guard band

Site name	Location (Easting)	Location (Northing)	Site height (a.s.l.) (metres)	Antenna height (a.g.l.) (metres)
Site A	110941	256405	61	25
Site B	317898	234585	4	27.3
Site C	315528	229536	45	23.8
Site D	166899	072261	29	15.12
Site E	181202	098451	30	5.12
Site F	280046	213326	102	14
Site G	275897	102953	61	4
Site H	304324	232912	56	28
Site I	220952	120987	184	29.4
Site J	309628	232508	49	15
Site K	166345	073486	104	24
Site L	306692	238039	60	47
Site M	080984	069333	173	15
Site N	306684	238038	70	32
Site O	318341	240636	49	25
Site P	090965	072984	188	22
Site Q	319860	228710	50	26.6
Site R	324675	223471	29.23	5
Site S	171178	071191	15	9.5
Site T	155410	069462	39	18.2
Site U	318509	240946	48	18

The site locations are shown below.

Figure 5.9: Locations of fixed links operating below 25 455 MHz within an assumed 56 MHz guard band (Dublin Area)

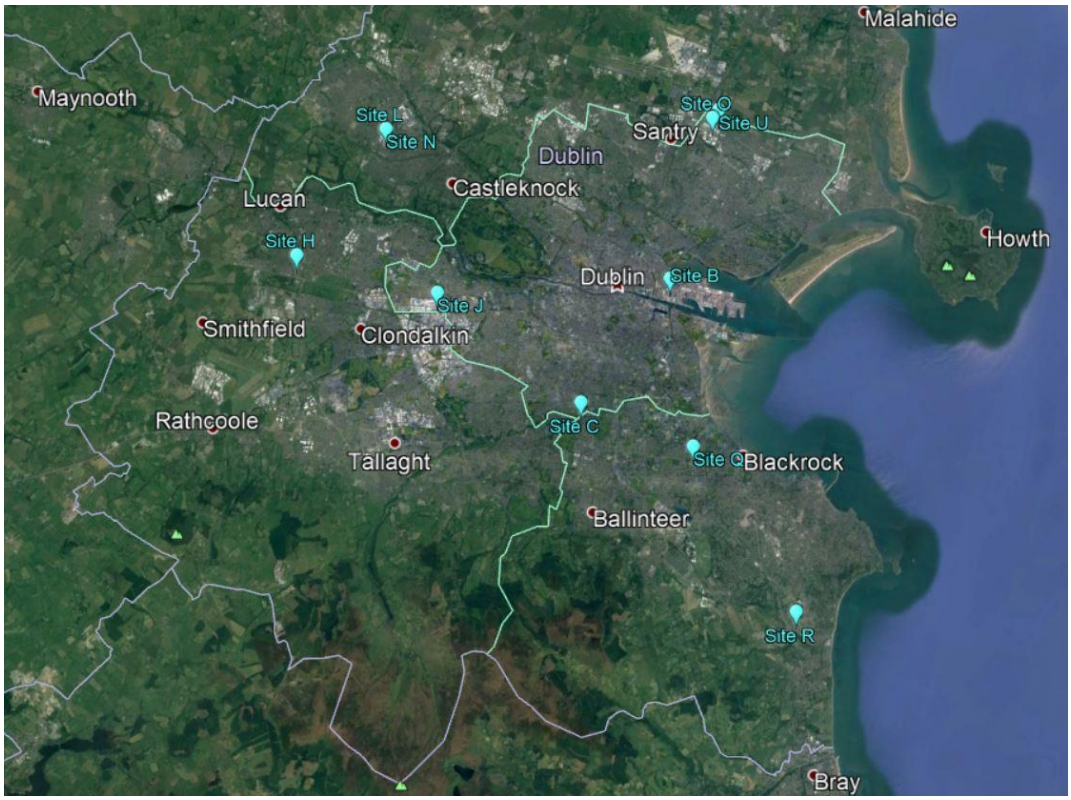
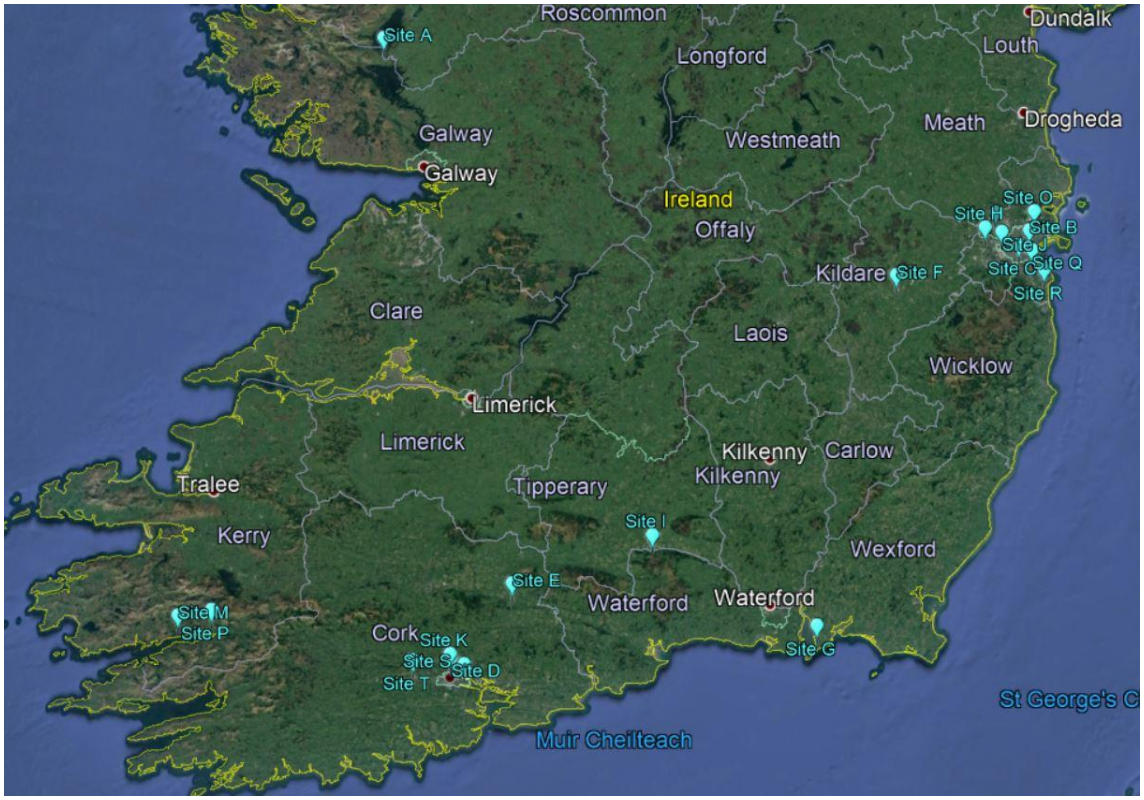


Figure 5.10: Locations of fixed links operating below 25 455 MHz within an assumed 56 MHz guard band (Ireland)



The results above show that WBB ECS deployment in 25 445 – 25 613 MHz (using 50 and 100 MHz blocks) may impact the operation of lower adjacent band fixed links in several geographic areas when the assumed guard band is 56 MHz.

If the assumed guard band is 20 MHz or 28 MHz, there will be 9 fixed links (centred at 25 431 MHz) overlapping the guard band. These are the last 9 links listed in Figure 5.8.

Figure 5.11 and Figure 5.12 show the site locations.

Figure 5.11: Locations of fixed links operating below 25 455 MHz within an assumed 20 or 28 MHz guard band (Dublin area)

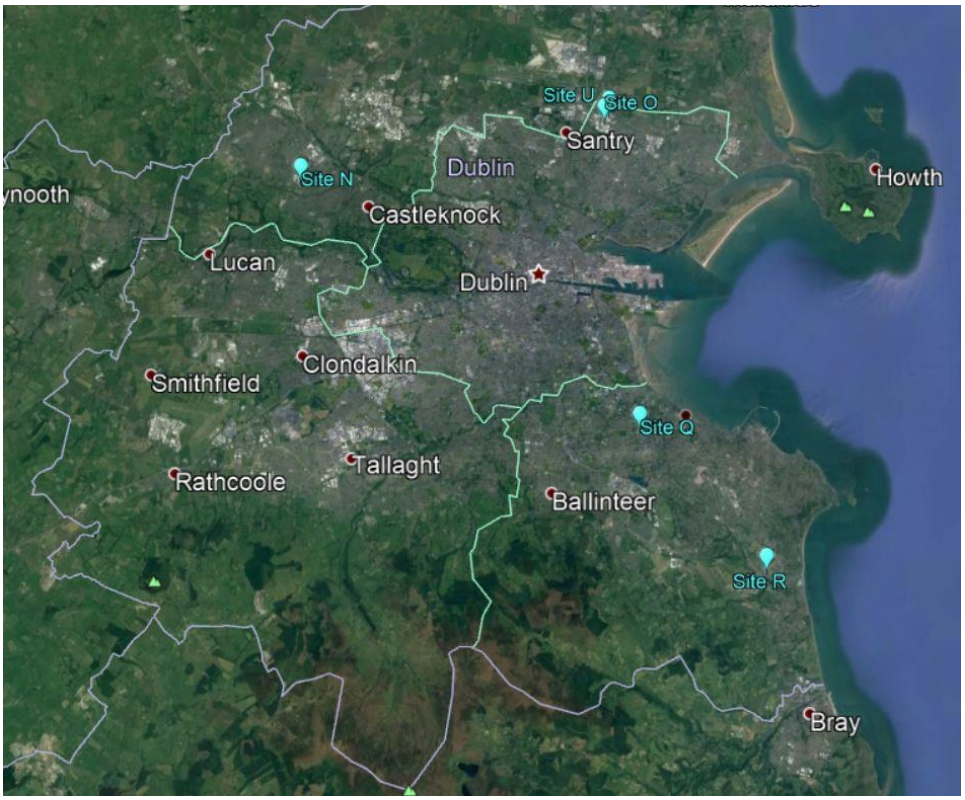
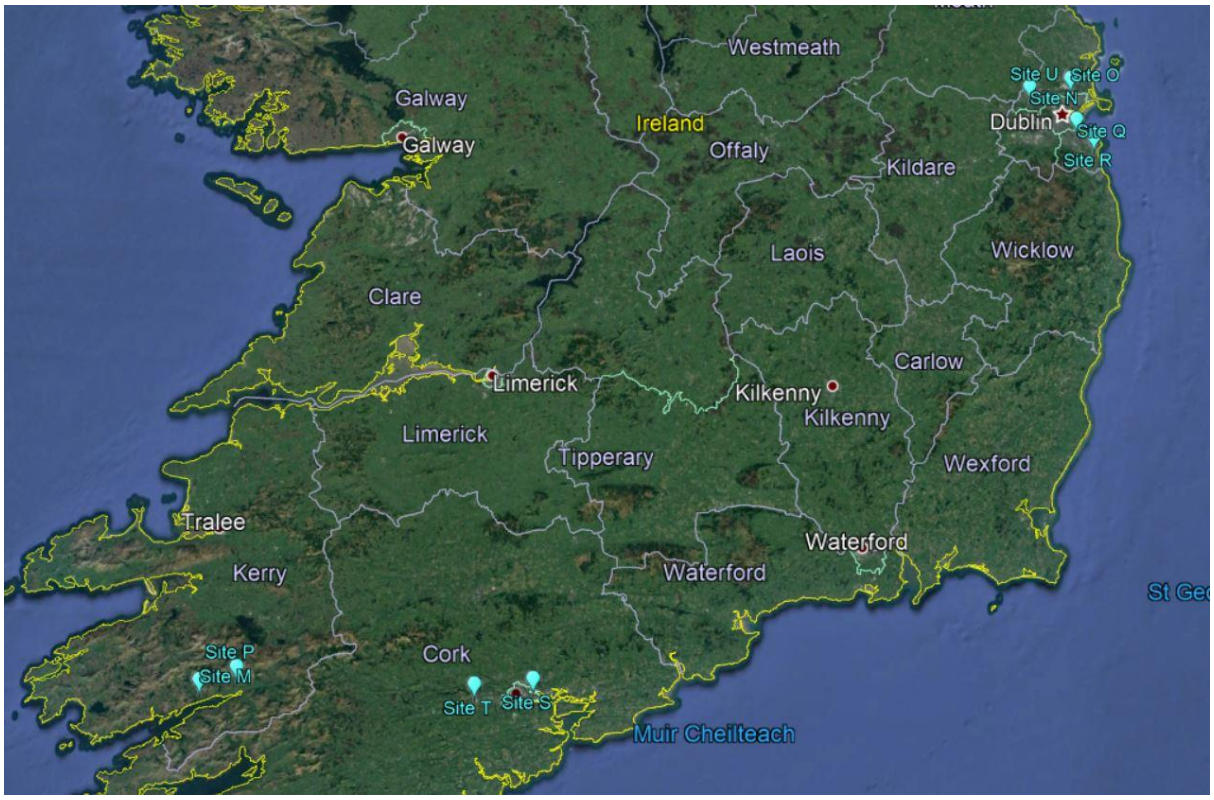


Figure 5.12: Locations of fixed links operating below 25 455 MHz within an assumed 20 or 28 MHz guard band (Ireland)

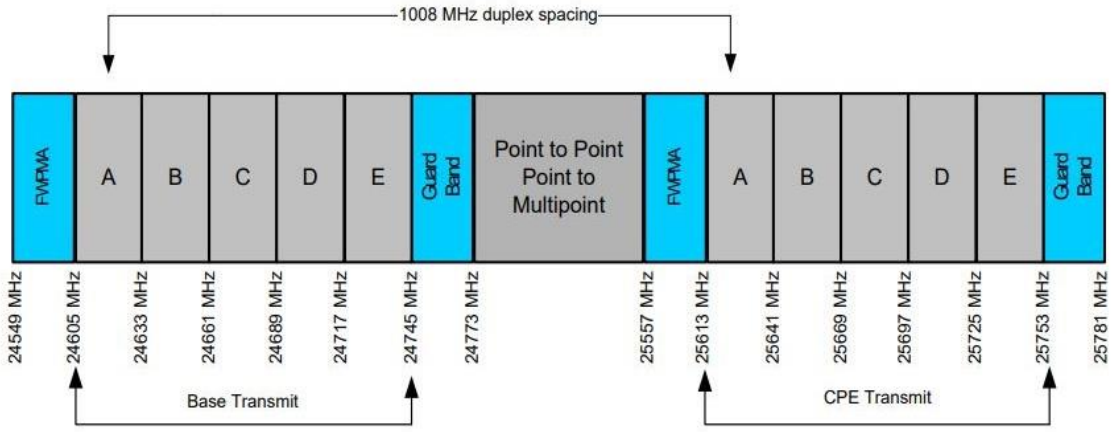


These results indicate that a coordinated deployment of WBB ECS in this band may be possible depending on precise guard band requirements to be determined from case-by-case analysis.

Adjacent band co-existence with FWALA

There is currently spectrum allocated for FWALA in the upper adjacent band. The ComReg band plan for FWALA at 26 GHz is shown below[81]. At the date of publication of this report, there are no live 26 GHz FWALA licences.

Figure 5.13: ComReg FWALA band plan



[81] https://www.comreg.ie/media/2019/05/ComReg06_17R10-guidelines-1.pdf

Note: We understand that FWPMA is no longer licensed in this band.

In terms of co-existence with a potential FWALA licensee operating in the upper adjacent band (25 613 – 25 753 MHz), the use of a guard band, ranging from 20 – 56 MHz with respect to the edge of WBB ECS block, coupled with typical separations of few hundred metres may have to be considered if WBB ECS base stations are to be deployed in proximity of FWALA base station receivers.

5.4.3 BLOCK C: Unassigned spectrum 24.25 - 24.605 GHz

In-band co-existence

There is a primary allocation to Inter Satellite Services (ISS) in the band 24.45 – 24.65 GHz. Level probing and automotive short-range radars also operate in the band on a secondary basis. The in-band co-existence conditions (related to ISS and licence exempt use) defined in Section 5.4.1 are applicable.

Adjacent band co-existence

The adjacent band co-existence conditions defined in Section 5.4.1 related to the level probing and automotive short-range radars as well as the protection of the passive band (23.6 – 24 GHz), as required in the EC Implementing Decision, are applicable.

There is also currently unassigned FWALA spectrum in the upper adjacent band (24 605 – 24 745 MHz). In terms of co-existence with a potential FWALA licensee operating in this band, the use of a guard band, ranging from 20 – 56 MHz with respect to the edge of WBB ECS block, coupled with typical separations of few hundred metres, may have to be considered if WBB ECS base stations are to be deployed in proximity of FWALA subscriber receivers.

The in-band and adjacent band co-existence considerations above indicate that it should be possible to deploy WBB ECS in 24.25 – 24.605 GHz in line with the technical conditions provided in the two EC Implementing Decisions.

5.5 Progressive release of spectrum

The issue of what processes could be used to facilitate the progressive release of spectrum is dealt with under Section 7. In this section, we consider the use of each portion of the currently assigned spectrum which may help to determine the priority in which any progressive release may take place, if at some point in the future, ComReg determines that such action(s) is appropriate.

The approach outlined in the remainder of this section is one potential option that could be considered by ComReg regarding the future use of the 26 GHz band, if required. ComReg may, at an appropriate time, wish to consider a range of potential assignment approaches separately and holistically to enable efficient use of the 26 GHz band and associated potential migration measures that may be required.

As mentioned earlier, ComReg is in the process of reviewing the Fixed Radio Links Licensing Regime adopted in Ireland and recently published two documents (20/109 and 20/109A)[82] addressing the use of a number of bands, including the 26 GHz band, by fixed links.

[82] Publications - Commission for Communications Regulation (comreg.ie)

Our starting point is the top of the 26 GHz band, that is unassigned Block A from 26 453 MHz to 27 500 MHz in which five 200 MHz blocks (B1, B2, B3, B4 & B5) are achievable.

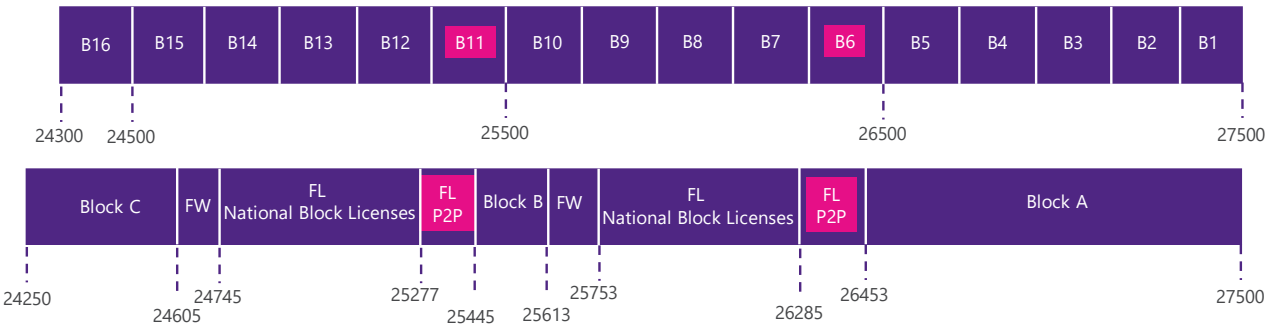
5.5.1 Progressive release of spectrum currently used by individual fixed link licences

The EC Implementing Decision (**EC Decision 2019/784)** foresees the continued operation of fixed links within the band, if WBB ECS systems can co-exist with such fixed links through managed shared spectrum use.

The individually licensed fixed links use a frequency division duplex (FDD) arrangement. If deemed necessary, migration or removal of the 178[83] links in this band would:

- release 168 MHz of spectrum from the upper duplex and facilitate one additional 200 MHz block (B6) and form a contiguous 1.2 GHz spectrum block at the top of the 26 GHz band; and
- release 168 MHz of spectrum from the lower duplex which, added to unassigned Block B, would double the unassigned spectrum in that part of the 26 GHz band to 336 MHz facilitating one isolated 200 MHz block (B11).

Figure 5.14: Release of spectrum used by P2P fixed links



This isolated 200 MHz block (B11) might be considered for use under potential approaches discussed in Section 7. The block could be reused across the country and it could under the implementation directive[84] be expanded to 300 MHz.

There are currently 178 individual fixed links licenced in this portion of the 26 GHz band (i.e. 25 277 – 25 445 MHz and 26 285 – 26 453 MHz)[85]. 166 links are licensed to MNOs (i.e. Eir/Meteor, Vodafone and Three) and the remaining 12 licences are held by 5 licensees. Figure 5.15 shows the trend over time of the number of fixed links operating in the 26 GHZ band (excluding national block licences). The trend decreases from 2013 onwards due to licensees not renewing and cancelling their licences as shown below. Anecdotal information is that part of this decline arises from licensees who hold national block licence having moved individual links into their block allocations to maximise the use of their national block licences.

[83] As of January 2021
[84] (EU) 2019/784 amended by (EU) 2020/590
[85] Publications - Commission for Communications Regulation (comreg.ie)

Figure 5.15: The variation in number of fixed links operating in the 26 GHz band (Source: ComReg)

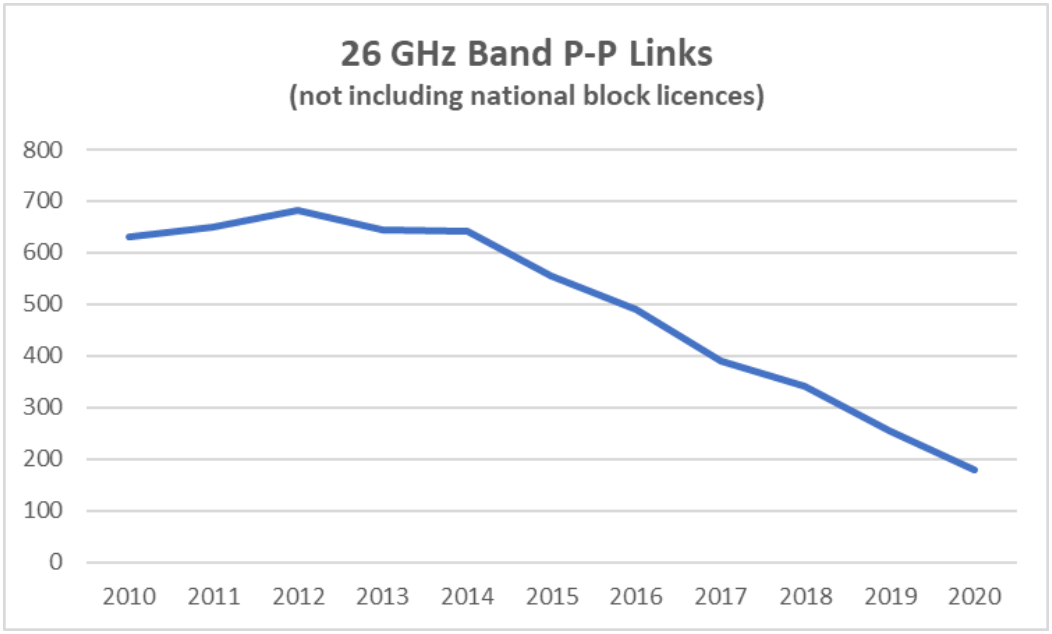
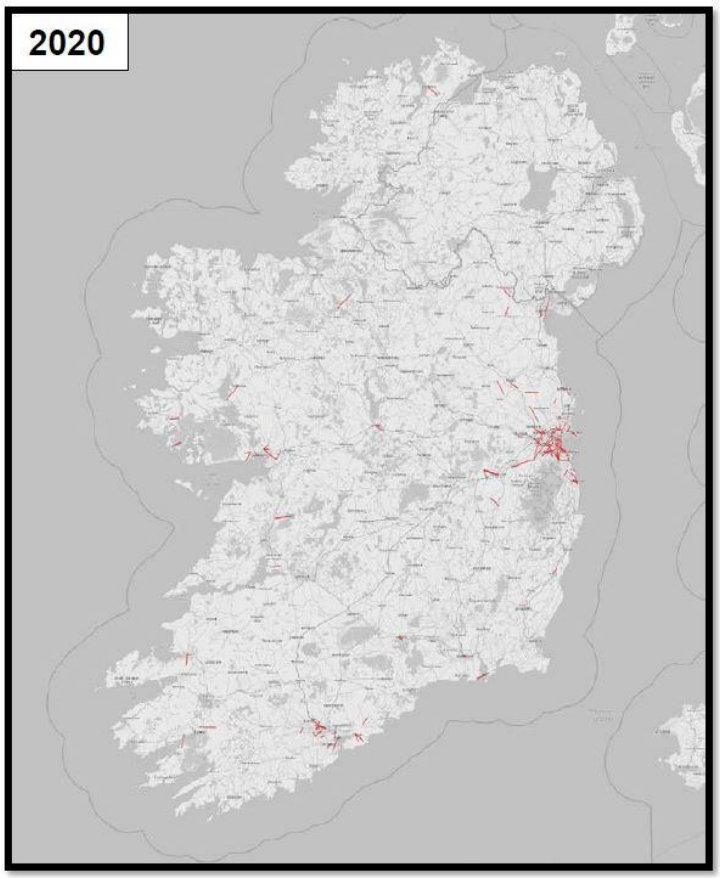


Figure 5.16 shows that these links are primarily in urban areas.

Figure 5.16: Fixed links operating in the 26 GHz band (Source: ComReg 20/109)



Even with such a small number of fixed links, the cost to incumbents, the availability of other spectrum to take these links and what constitutes a reasonable time to make the changes, would need to be determined but the scale of this task is not trivial in nature.

The spectrum allocation issue for ComReg includes balancing different demands and objectively justifying such a change. In this case, we observe that the demand for the use of a portion of the 26 GHz band for fixed links is declining, whereas the demand for 5G in the 26 GHz band is currently unclear and it is uncertain when or if sufficient demand for the use of this band for 5G will develop in the future.

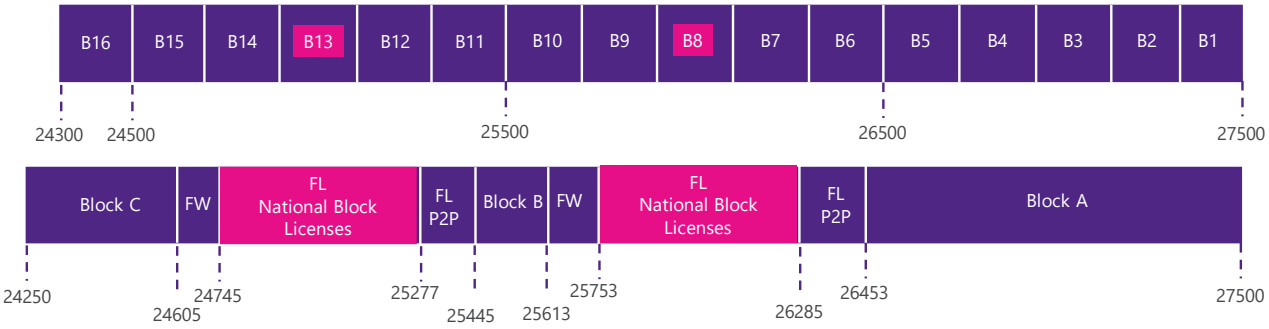
5.5.2 Potential progressive release of spectrum currently used by the national block licences

These national block licences are for the provision of fixed links. Therefore, and as noted above, the EC Implementing Decision (**EC Decision 2019/784)** foresees the continued operation of fixed links within the band, if WBB ECS systems can co-exist with such fixed links through managed shared spectrum use.

National block licensees also operate using an FDD arrangement and account for a total of 1 064 MHz of spectrum and removal of these block licences could release 532 MHz of spectrum for 5G from the upper duplex and 532 MHz of spectrum from the lower duplex. The existing national block licences expire in mid-2028.

However, due to the alignment requirements of the implementing decision[86], the release of this spectrum would only facilitate one additional 200 MHz block in each duplex (B8 & B13) as shown in the following figure, both of which could be expanded to 450 MHz[87].

Figure 5.17: Release of spectrum used by fixed links in the national block licensed spectrum



ComReg Document 18/12[88] states that "*P2P links in the 26 GHz band have increased from 1,300 National Block Links in 2011 to 2,800 National Block Links in 2017 (driven mainly by the two MNOs with National Block Licences, Vodafone and Three). Further, the potential for continued use of this portion of the 26 GHz band for fixed links in the future is supported by incumbent licensees who have all requested extensions to their existing licences for*

[86] The Implementing Decision states:
"2. The assigned block size shall be a multiple of 200 MHz. A smaller block size of 50 MHz or 100 MHz or 150 MHz, adjacent to the assigned block of another spectrum user, is also possible to ensure efficient use of the full frequency band.

3. The upper frequency limit of an assigned block shall be aligned with or spaced at a multiple of 200 MHz from the upper band edge of 27,5 GHz. If a block is smaller than 200 MHz according to paragraph 2 or needs to be offset to accommodate existing uses, this offset shall be a multiple of 10 MHz."

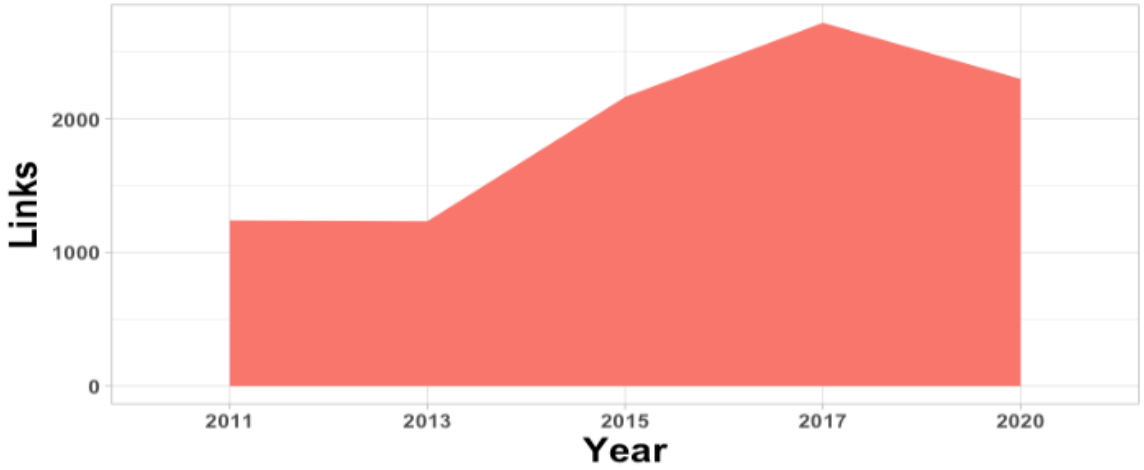
Whilst it would be possible to use smaller blocks if it ensures efficient use it means it will be necessary to review and possibly realign with 200 MHz blocks if adjacent blocks are later released for WBB.

[87] By adding 250 MHz spectrum available in blocks adjacent to B8 and B13.
[88] https://www.comreg.ie/publication/response-consultation-draft-decision-proposed-26-ghz-spectrum-award-2018/

periods between 4 – 15 years". It is further stated that "*there is an established case for fixed links in the 26 GHz band, now and for the foreseeable future*".

A recent report[89] from DotEcon published by ComReg presents a conservative estimate of the number of links deployed on block licenses as shown below.

Figure 5.18: No of fixed links deployed in block licensed bands



DotEcon notes that this is a conservative estimate of the number of links deployed on block licences and conclude that the demand for block licences is robust and that demand is not falling in the same way that individual links are declining. However, the only band available for block licensing is the 26 GHz band and moving these licensees to another band is again not a trivial task. A further complication is that the new links, often in a national network of links, would need to be up and running before the links in the 26 GHz band can be switched off.

ComReg Document 20/109 notes that the current block licences expire in 2028 and the 32 GHz band could be considered as a potential band for block licensing. The document states that:

"*The 32 GHz band (31.8-33.4 GHz) is a potentially suitable alternative to the 26 GHz Band for block licensing. For example, if some (beyond the 1 GHz available) or all of the 26 GHz band was required for 5G services the 32 GHz band could be used as alternative to provide Fixed Links (e.g. backhauls).*"

"*The 32 GHz band should be made available for block assignments where there is sufficient demand. In summary:*

- *If the 32 GHz band was identified as a replacement for block licence in the 26 GHz, this would not arise until 2028 when the 26 GHz block licences expire.*
- *However, to the extent that there may be demand for the 32 GHz band from other use cases before 2028 there is no reason for delaying access to the spectrum.*"

5.5.3 Potential progressive release of spectrum currently used by FWALA licences

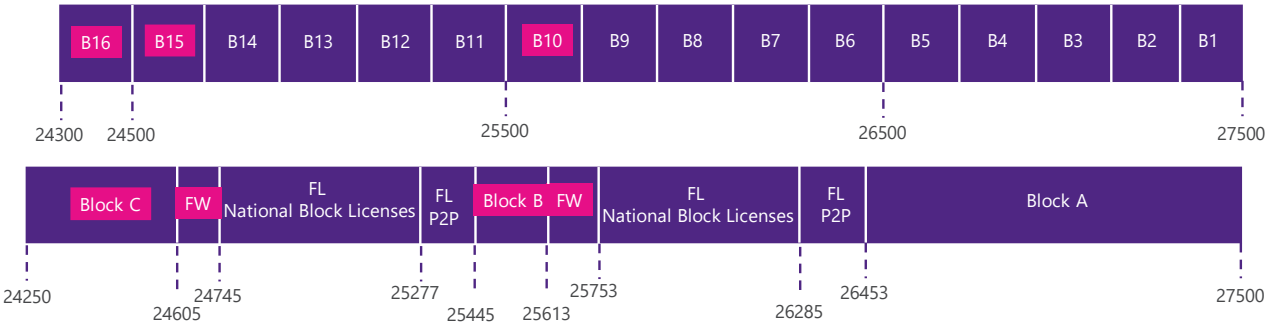
As a form of fixed service, it could be argued the provisions of the same EC Implementing Decision (**EC Decision 2019/784)** as noted in the two previous sections above apply.

[89] https://www.comreg.ie/publication/consultants-report-fixed-links-bands-review .

The FWALA spectrum is in an FDD arrangement and accounts for a total of 280 MHz and any release of this band would:

- release 140 MHz of spectrum from the upper duplex and together with unassigned spectrum Block B would facilitate one additional 200 MHz block (B10). This small amount of spectrum on its own provides only marginal gain and would not add anything unless it was vacated together with the lower duplex from the individual link licences as well as the lower duplex from the national block licences;
- release 140 MHz of spectrum from the lower duplex and together with unassigned spectrum Block C would facilitate two additional contiguous and aligned 200 MHz blocks (B15 & B16) at the bottom edge of the 26 GHz band.

Figure 5.19: Release of spectrum used by FWALA



5.6 Conclusions

In this section, having examined the current use of the 26 GHz band, we have considered the technical conditions that would need to be applied under two scenarios.

First, the scenario where the band is returned to a greenfield state with no incumbent users. This scenario is included for completeness as the likelihood of returning the entire band to a greenfield condition before licensing any form of WBB ECS is licenced does not appear particularly likely. See section 7.2 in this regard. This scenario would only require technical conditions to protect adjacent bands and to ensure the inter-operability of WBB ECS services operating in the band – as pointed out in Section 5.2.

Second, the more likely scenario is that currently unassigned spectrum will be the initial starting place for WBB ECS services. Technical conditions that would allow the use of all the unassigned spectrum and in the process make available 1200 MHz of spectrum[90] are shown in Section 5.4.1. Noting the typical time scales required to consult, put in place the necessary legislation and implement the regulatory framework, providing access to one or more of these unassigned portions of the band could be completed within 2 or 3 years of adding such a project to ComReg's action plan[91, 92]. We further note that ComReg's action plan is a consequence of the two-year strategy which is detailed in ComReg's Radio Spectrum Management Strategy Statement (RSMSS). The current RSMSS[93] is due for revision in 2021 and is expected to follow the usual consultation process.

[90] Assuming 200 MHz contiguous frequency blocks.
[91] See https://www.comreg.ie/about/strategy/action-plan/
[92] This assumes ComReg will have the resources and skills to take on this task and that the matter is not subject to litigation.
[93] https://www.comreg.ie/publication/radio-spectrum-management-strategy-statement-2019-to-2021/

In respect of the currently unassigned spectrum Blocks A, B & C, whichever option or options are selected can be facilitated by a set of technical conditions that will provide adequate protection to adjacent band services as well as between services in the 26 GHz band.

We also consider the progressive release of spectrum in the 26 GHz band in case at some point in the future, ComReg decides that this is appropriate. In the second opinion from the RSPG (see section 3.1.3) regulatory flexibility for the progressive release of the 26 GHz band was underlined in order to avoid negative impacts on the current users of the band and that in doing this progressive release, the geographical dimension of any developing market demand for 5G should be taken into account.

While removing the national block licences would release the most spectrum (1064 MHz) this spectrum is not contiguous and would only release two blocks (B13 & B8) of a maximum of 450 MHz each. According to ComReg 20/109, there is robust demand for the use of block licences and current licences do not expire before 2028.

If deemed necessary, removing the individual fixed links adds one additional 200 MHz block (B6) to the contiguous spectrum in unassigned Block A. In terms of WBB ECS this is a very marginal gain and even though the number of individual licences is in decline it may still not be the time to undertake this action. However, there is also the addition of one isolated block (B11) which together with unassigned Block B provides for a 300 MHz block which may be of some use.

There are currently no licensees using the FWALA spectrum allocation and this provides the potential to gain two contiguous and aligned 200 MHz blocks (B15 & B16) at the bottom edge of the 26 GHz band – again useful if this part of the band was considered for some initiative similar to that put in place by the UK or Australia[94]. There is precedent to closing a band for FWALA operation as was undertaken in the 3.5 GHz band[95] that ComReg could consider as an approach to release significant spectrum for example for WBB ECS or expansion of the current national block licences.

[94] Spectrum sharing for indoor use only (UK) and class licensing (Australia) – see Appendices B and C for further details
[95] See ComReg Document 10/29: Fixed Wireless Access Local Area Licensing, end date for FWALA licensing in the 3.6 GHz band.

6 26 GHz band demand in Ireland for WBB ECS

This section analyses the market demand for the 26 GHz frequency band. It presents the Irish market specific characteristics, technologies likely to compete with 5G and evaluates potential demand in Ireland for the 26 GHz band in the identified four usage scenarios.

6.1 Irish market specific characteristics

6.1.1 Reference data on the Irish telecommunications sector

This section presents the Irish telecommunications market. The table below provides details on mobile operators, subscriptions, mobile data traffic and the role of neutral hosts in the country.

Figure 6.1: Irish market data – telecommunications sector

Data	Ireland	Comments
Number of mobile operators	3	Vodafone Ireland, 3 Ireland, Eir
Mobile subscriptions	6,738,457	Q2 2020 – Source ComReg data portal
Mobile data traffic	650 GB/year from Q3 2019 to Q2 2020 Total annual mobile data traffic is forecast to increase to 1,059 million GB/year in 2022	Source ComReg data portal 2018 forecasts-Source Frontier
Role of neutral host(s)	DenseAir has a licence in the 3.6 GHz band	25 MHz in rural regions and 60 MHz in the five main Irish cities

Source: IDATE & PLUM

Subscription distribution for each technology on fixed and mobile networks is presented in the table below:

Figure 6.2: Residential and business subscriptions

Residential & Business Subscriptions x Platform	2019 Q1	2019 Q2	2019 Q3	2019 Q4	2020 Q1	2020 Q2	2020 Q3
Cable Broadband Residential Subscriptions	358 241	355 300	356 727	354 628	356 076	357 432	357 326
Cable Broadband Business Subscriptions	15 851	16 301	16 635	16 859	16 923	16 894	16 899
DSL Broadband Residential Subscriptions	226 041	214 643	202 053	192 216	180 449	171 065	159 666
DSL Broadband Business Subscriptions	55 292	53 101	50 889	48 114	47 043	44 242	42 443
VDSL Broadband Residential Subscriptions	548 182	550 546	552 364	553 906	560 209	564 560	567 710
VDSL Broadband Business Subscriptions	76 655	77 784	78 165	79 257	78 944	79 405	77 415
FTTP Broadband Residential Subscriptions	105 013	120 933	137 820	154 420	171 537	191 308	212 566
FTTP Broadband Business Subscriptions	4 936	5 752	6 791	7 941	9 006	9 825	11 188

Residential & Business Subscriptions x Platform	2019 Q1	2019 Q2	2019 Q3	2019 Q4	2020 Q1	2020 Q2	2020 Q3
Satellite Broadband Residential Subscriptions	4 058	3 658	3 659	3 234	2 988	2 800	2 603
Satellite Broadband Business Subscriptions	347	376	295	306	278	287	305
FWA Broadband Residential Subscriptions	38 868	39 817	41 695	43 617	47 218	50 486	53 343
FWA Broadband Business Subscriptions	7 089	7 224	7 832	8 051	6 038	5 913	5 368
Mobile Broadband Residential Subscriptions	157 304	155 828	155 448	150 202	153 436	153 289	158 616
Mobile Broadband Business Subscriptions	145 069	148 008	151 185	152 293	167 127	164 686	164 914
Total Residential Broadband Subscriptions	**1 437 708**	**1 440 726**	**1 449 766**	**1 452 223**	**1 471 913**	**1 490 940**	**1 511 830**
Total Business Broadband Subscriptions	**305 238**	**308 545**	**311 792**	**312 821**	**325 359**	**321 252**	**318 532**

Source: ComReg

Cable and fixed (DSL) access subscriptions represent the largest part of total broadband subscriptions in Ireland. Fibre is still at a low penetration level, but we expect to see an increase in fibre as the National Broadband Plan is rolled out, in which 90% of premises in the State will have access to high speed broadband within the next four years[96]. Satellite and fixed wireless access represent a very limited share of the subscriptions. Mobile broadband represents an alternative or a complement for almost 18% of the market.

The total of homes passed in 2020 is evaluated as follows[97]: 977,000 FTTH/B Total Sockets deployed, 1,450,000 VDSL Homes Passed and 945,000 FTTx/DOCSIS 3.0 Homes Passed.

Figure 6.3: Distribution of broadband subscriptions by technology

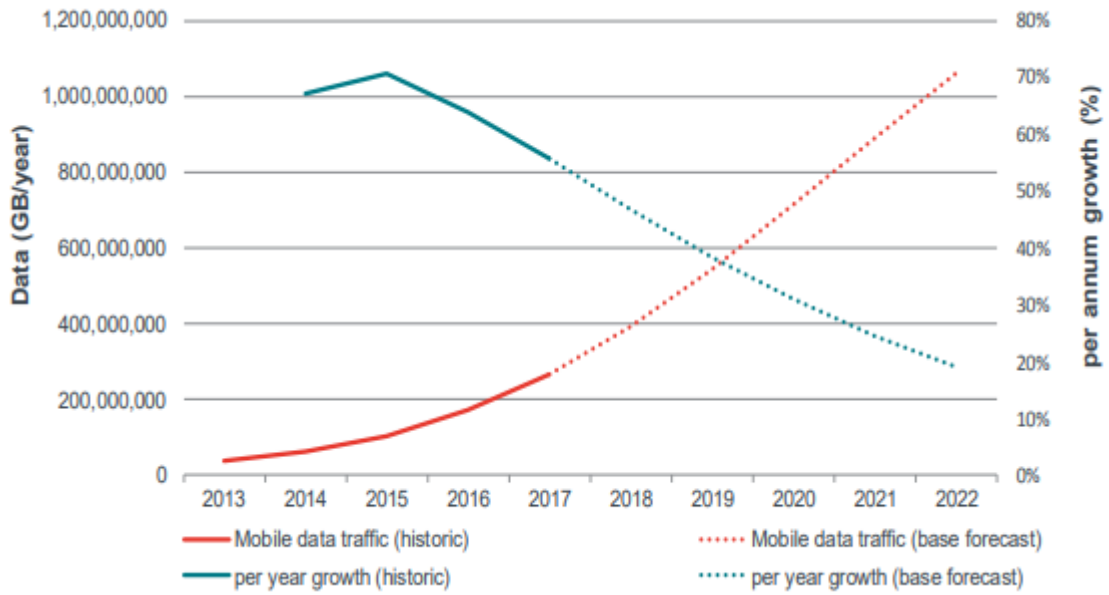
Broadband subscriptions	2020 Q3 Irish market
Cable share of total broadband subscriptions	20.4%
DSL & VDSL share of total broadband subscriptions	46.3%
FTTP share of total broadband subscriptions	12.2%
Satellite share of total broadband subscriptions	0.2%
FWA share of total broadband subscriptions	3.2%
Mobile Broadband share of total broadband subscriptions	17.7%

Source: ComReg

Mobile traffic is expected to continue to grow in the coming year according to a forecast published by ComReg.

[96] See https://www.gov.ie/en/press-release/e15062-high-speed-broadband-for-11m-people-in-homes-schools-businesses-acro/
[97] https://en.idate.org/categorie-produit/fttx-gigabit-en/

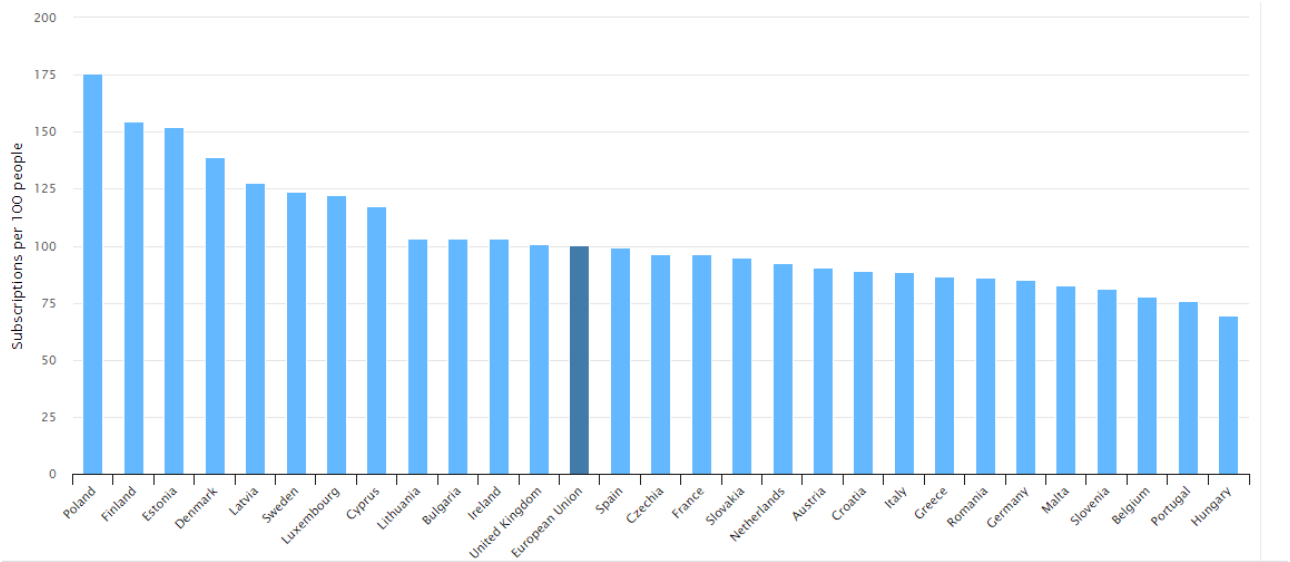
Figure 6.4: Base forecast of mobile data traffic



Source: ComReg 18/35

In June 2019 Ireland had the eleventh-highest mobile broadband penetration in the EU down from seventh in June 2017. As shown during the Covid-19 pandemic[98], mobile broadband is heavily used by people working from home. With higher data rates and falling cost per bit, 5G will certainly become an even more important means to provide broadband at home and for small businesses and enterprises in the coming years.

Figure 6.5: Take-up of mobile broadband subscriptions (subscriptions/100 people) – June 2019



Source: European Union – Digital Scoreboard (DESI 2020)

[98] Impact of Covid-19 on Home Broadband use in Ireland - April 2020 - ComReg Doc 20/35

6.1.2 The Irish population, economy and the enterprise market in Ireland

Ireland has one of the most widely distributed and rural populations in Europe. Ireland's population density of 70.9 people per km^2 is considerably lower than the EU28 average of 118 people per km^2 (Eurostat[99]). 72% of the Irish population live in NUTS 3[100] areas that are defined as predominantly rural areas whereas this figure is only 22% of the population in the European Union. In Irish rural areas, the density of population is only 27 people per km^2.

It should also be noted that 37% of the population live in rural areas and 70% of the population live in 3% of the total land area (this is based on an analysis of the small areas). These characteristics create specific challenges to provide broadband services in Ireland.

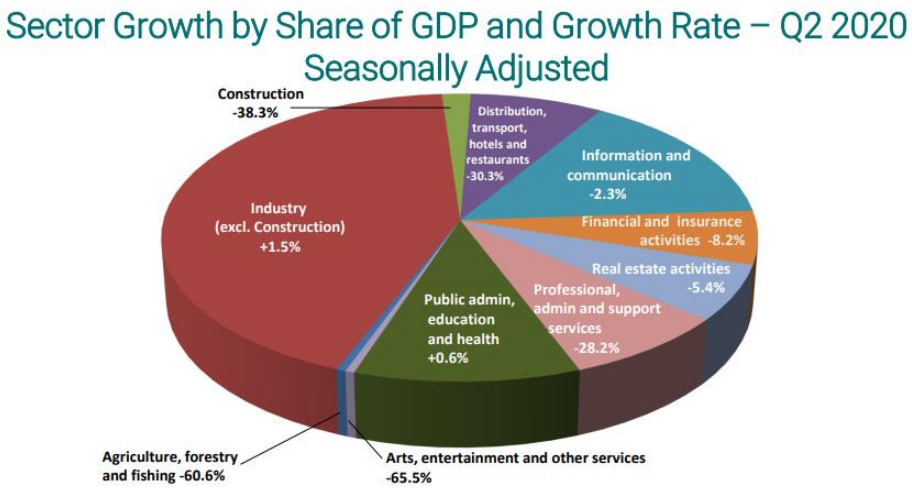
Figure 6.6: Irish market data – population

Data	Ireland	Comments
Total population	4 963 839	2020 (estimate) - Source CSO.IE
Population density	70.9 per km^2	In 2018
Dwellings number	1,697,665 - 2.75 persons per household in 2016	2016-Source CSO.IE
Distribution of the population	72% of the Irish population live in NUTS 3 areas that are defined as predominantly rural areas	

Source: IDATE & PLUM

The economy of Ireland is described as a knowledge economy (application of knowledge to generate tangible and intangible value) which mainly focuses on financial services, high tech, and life science[101]. Major sectors are industry, information and communication, public administration, education and health, distribution, transport.

Figure 6.7: Sector growth in Ireland



Source: CSO.IE

[99] https://ec.europa.eu/eurostat/databrowser/view/tps00003/default/table?lang=en
[100] There are three levels of Nomenclature of Territorial Units for Statistics (NUTS) defined. This category refers to regions belonging to the third level (NUTS 3, also known as NUTS III), which is largely used by Eurostat and other European Union bodies.
[101] https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-ireland.html

The Irish economy does not have many vertical sectors that are likely to become 5G early adopters like industry 4.0 or automotive, so we can expect a delayed development of 5G services in vertical sectors when compared to other more manufacturing-intensive countries in Europe.

6.2 Competing technologies

In this section, we discuss other service delivery options and how they compete with mobile technologies in Ireland. We analyse fixed technologies, use of cellular technologies like LTE/4G, the evolution of WiFi and other fixed wireless access technologies.

6.2.1 Fixed technologies

Fixed networks, including fibre, xDSL and cable networks, have the potential to compete with some 5G services in the coming years. Our market forecasts (homes passed) for fibre suggest a significant increase for the years to come.

FTTx/D3.0 covers several architectures, depending on cablecos' network topology. It corresponds to coaxial based networks where the optical fibre is typically deployed to a point outside the building, and/or the Docsis 3.0 standard has been implemented in the central node of the cable operators' networks to enable faster connections.

Figure 6.8: FTTx forecasts - Ireland[102]

Homes passed	2020	2021	2022	2023	2024
FTTH/B Total Sockets deployed	977 000	1 260 000	1 480 000	1 620 000	1 710 000
FTTx/DOCSIS 3.0 Homes Passed	945 000	947 000	928 000	895 000	850 000

Source: IDATE DigiWorld

As presented previously in Figure 6.2, fixed technologies provided 80% of broadband connections in Ireland in Q1 2020. According to IDATE's data for Ireland, cable networks have been surpassed by fibre networks from 2020 on in terms of homes.

As far as the 26 GHz potential is concerned, it is likely that the development of fixed broadband will reduce the potential for 5G fixed wireless services in areas where fibre is available in the coming years.

6.2.2 WiFi6

WiFI6 offers up to 9.6 Gbps data rates compared to 3.5 Gbps in WIFi5 and 75% lower latency. 14 channels of 80 MHz or 7 channels of 160 MHz will be available. Where authorised, it will use the 6 GHz band with 1200 MHz of unlicensed spectrum as well as the existing 2.4 and 5 GHz bands. WiFi6 will also provide better reliability and will be able to support IoT and Industrial IoT applications and there is considerable interest from equipment suppliers in providing consumer equipment that uses the 6 GHz band.

It is expected that WiFi will still dominate in the home environment but 5G is likely to grow in the office environment with the deployment of cheap 5G base stations in the coming years. 5G will be well adapted for

[102] https://fr.idate.org/produit/world-fttx-markets-database-report-2/

applications with stringent quality of service and performance requirements. What is not clear is in what band/s these base stations will be developed.

6.2.3 Other Fixed Wireless Access technologies

Many frequency bands can be used for providing fixed wireless access services: unlicensed bands, such as the 5.8 GHz and the 60 GHz bands, and licensed bands (3.6 GHz, 10.5 GHz and 26 GHz). Dedicated technologies are used in these frequency bands, whereas 5G will be used in the 26 GHz band in the coming years for both mobile and fixed services.

- FWA in the 5.8 GHz band

  According to ComReg, the 5.8 GHz register mentions 29 operators and 127 Base Station registrations, but some may have been decommissioned. As the follow-up of the base stations database is based on self-declaration from operators, only indicative information is available. As these figures are quite low, provision of fixed wireless access service in this band has therefore no significant impact on the Irish market.

- FWA based on 4G

  Many mobile operators in Europe currently provide fixed wireless access services with their 4G networks but the economics will be much better with 5G as it will provide a lower bit per hertz cost and will be able to provide Gbps services. The 4G bands could later be used by 5G with higher throughputs and a better business model.

- FWA in the 10.5 and 26 GHz bands

  Fixed wireless services are offered using FDD (Frequency Division Duplex) with channels of 28 MHz. They are not compatible with the TDD scheme selected for 5G in mmWave bands and will not be able to provide Gbps speeds to the customers. These "first generation" FWA systems are likely to be replaced by 5G FWA in the long term.

- FWA in the 60 and 70/80 GHz bands

  The mmWave V-band (60 GHz) and E-band (70 / 80 GHz) frequencies are today used by hundreds of operators around the world to provide wireless connections to millions of residential and business subscribers with Gigabit-speed services. This solution is often preferred where it is less expensive than trenching fibre. The main drawback of using such high bands is the limited range, a few km, which make them well suited for use in dense urban areas only. In the longer term, the 60 and 70/80 GHz will also be used by 5G applications identified for the 26 GHz band.

6.3 Potential demand in Ireland

In order to evaluate demand for the 26 GHz band, we consider the outcome of previous tasks of the study and analyse relevant information from ComReg's consultations. We also take into account inputs from advanced markets and detail the expected demand scenarios for the 26 GHz band in Ireland.

6.3.1 Relevant information from ComReg's consultations

The value of the 26 GHz band for 5G services in the future

In response to ComReg's consultation on the proposed 26 GHz Spectrum Award 2018 - Submissions to Consultation 17/85 (ComReg: 18/12b), Ericsson "*invites ComReg to carefully consider harmonizing its proposal on the 26 GHz band with other countries in Europe*" and notes:

"Whilst the need for additional Mobile Broadband capacity in Ireland may not demand the availability of 26GHz (mmWave) spectrum for 5G in the short term, it should be understood the unique nature of this spectrum and its role in the much discussed transformation of vertical industries using 5G. The 26 GHz with its ability to support very large cell edge peak rates and its ability to service Ultra Low Latency services (and high reliability) makes it very interesting for Industrial uses as well as Fixed Wireless Access (in some cases combined with the recent C Band awards)".

GSA indicates that *"at 26 GHz (24.5 – 27.5 GHz), blocks of 400 - 800 MHz of contiguous spectrum would, with the use of higher order modulation techniques, give consumers bitrate in the order of tens of Gbps"*.

Qualcomm notes that *"at 26 GHz, blocks of 400 MHz of contiguous spectrum will give well in excess of 12 GBps peak data rates. By combining these exciting new capabilities with the under-laid Gigabit LTE coverage in the Non-Stand Alone (NSA) 5G architecture, the end user will soon experience truly uniform fibre-like performance."*

Imagine comments on the FWA market: *"Imagine believes there will be significant demand for PMTP as well as PTP. As mentioned above, this will be particularly relevant to the wireless drop use case for FTTH (last 100m). This will enable short distance high bandwidth service direct to the customer's home from close by aggregation points."*

Cambridge Broadband provides insights on the FWA market:

- *" …consumer demands for bandwidth have risen, and are rising, seemingly inexorably. It is CBNL's view that five paired blocks of 28MHz is insufficient to meet this demand in a way that allows for local competition in a particular market"*

- *"Typical PMP FWA products deployed by CBNL today in 26GHz networks use paired 56MHz channels. Thus, if an operator is to have multiple channels, it is clear that the operator will need access to at least 112MHz of spectrum in total. The current sizing of the FWALA allocation therefore does not provide for more than one operator to deploy a high capacity FWA network in any given location, with the obvious competitive implications. The corollary to this is that, if there is to be competition, the competing networks will each be using smaller channel sizes than the state of the art permits, thereby limiting the throughput offered to end users".*

In ComReg's response to its consultation on proposed 26 GHz Spectrum Award 2018 (ComReg: 18/12b), a 2015 report for ComReg by Frontier Economics conservatively estimated that there will be a 33-fold increase in user demand for mobile data between 2015 and 2035[103].

Document ComReg 18/60 (Proposed Multi Band Spectrum Award - Preliminary consultation on which spectrum bands to award – published 29/06/2018) notes that:

"*In relation to the potential users of the 26 GHz Band, ComReg notes the following observations from DotEcon and Axon in their report for BEREC:*

[103] ComReg document 15/62a 'Cost benefit analysis of the change of use of the 700 MHz radio frequency band in Ireland'

- *5G has the potential to change business models for MNOs compared to the current marketplace, where MNOs have offered largely standardised services and differentiation has been limited to pricing plans;*

- *this potentially generates new roles for intermediaries in the value chain, positioned downstream of MNOs, and there may also be opportunities for new players upstream of traditional mobile networks."*

Document ComReg 19/59R (Study on Terrestrial BB-PPDR Spectrum Options - a report from LS Telcom – published 18/06/2019) mentions the possible use of the 26 GHz band:

"While 5G will therefore require spectrum in high frequency bands, existing frequency bands will also be used. The 700 MHz band, being green-field spectrum, is expected to be at the forefront of providing the initial wide area coverage layer for 5G and will be used in combination with higher frequency bands (i.e. 3.6 GHz and 26 GHz) to deliver the mix of coverage and capacity necessary to meet 5G's service ambitions."

The DotEcon Axon report for BEREC[104] on "Implications of 5G Deployment on Future Business Models" provides many details on drivers and hurdles related to 5G:

- 5G densification with small cells is likely to favour newcomers such as neutral hosts;

- Fixed Wireless Access is seen as an important service for Ireland and the authors of the report expect convergence of PPDR-MNO-FWA provision;

- Infrastructure sharing is seen as important in order to support the network investment; and

- Vertical sectors interest for 5G is detailed and it is noted that "the Sustainable Energy Authority of Ireland has set out a roadmap to explore how a smart grid could be operational in Ireland by 2050".

There is not an immediate requirement to award spectrum for 5G in the 26 GHz band

As part of its proposed Multi Band Spectrum Award process, ComReg considered and consulted upon the potential inclusion of 26 GHz band in that award process. In June 2018, ComReg set out its preliminary view that "the 26 GHz Band should not be considered for inclusion in this award process, and instead be assigned under a separate, subsequent award process, the timing and other particulars of which would be determined via separate consultation and in light of relevant developments."[105] All respondents to that public consultation who provided comments on this matter agreed with ComReg's proposal to exclude the 26 GHz band from the proposed award.

On 20 December 2019, ComReg issued Document 19/124, a response to consultation and Draft Decision on a Proposed Multi Band Spectrum Award for the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz Bands. This document contained some industry views that included noting that the network and device ecosystem for the 26 GHz band is less advanced than in other bands and that there are issues to be considered in order to optimise the 26 GHz Band before an award, and reconfiguration might be necessary.

6.3.2 Inputs from countries which have deployed 5G in 26 GHz

There is currently limited information available as there are few countries where 5G has been deployed in the mmWave bands. Appendix B and Appendix C provide details on 5G country specific developments.

[104] https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models

[105] See ComReg Document 18/60 – Published June 2018.

In the USA, the fixed wireless access service deployed by Verizon Wireless gives some interesting information regarding the performance of such a service. With an inter-site distance of 400-600 metres observed in the 2018 deployment, the subscribers of the fixed wireless access service observed downlink data rates of 400-800 Mbps. When this service was launched, Verizon Wireless guaranteed a minimum of 400 Mbps downlink given the customer premises equipment was installed by an operator's technician. To put into perspective, these data rates are orders of magnitude below those promised by the GSA and Qualcomm.

In South Korea, mobile operators started to deploy the 28 GHz band in 2020 to support higher capacity and data rates. Congestion was reported in South Korea a few months after commercial launch in 2019 with the 3.5 GHz band showing very extensive usage by 5G early adopters and limited densification by the network operators in South Korea.

In Italy, operators have shown interest for fixed wireless access in the 26 GHz band. An agreement was signed between Fastweb, which obtained 26 GHz spectrum in the Italian 5G auction, and Linkem in order to share investment in a FWA network.

FWA tests carried out by European operators such as Orange in Romania[106] show that the 26 GHz band can provide a sustainable business case for the provision of 5G services in areas where fibre has not been deployed or will not be deployed for economic reasons.

6.3.3 26 GHz usage scenarios in Ireland

In order to evaluate potential demand for 26 GHz band spectrum in Ireland, we analyse the demand for each of the identified four usage scenarios:

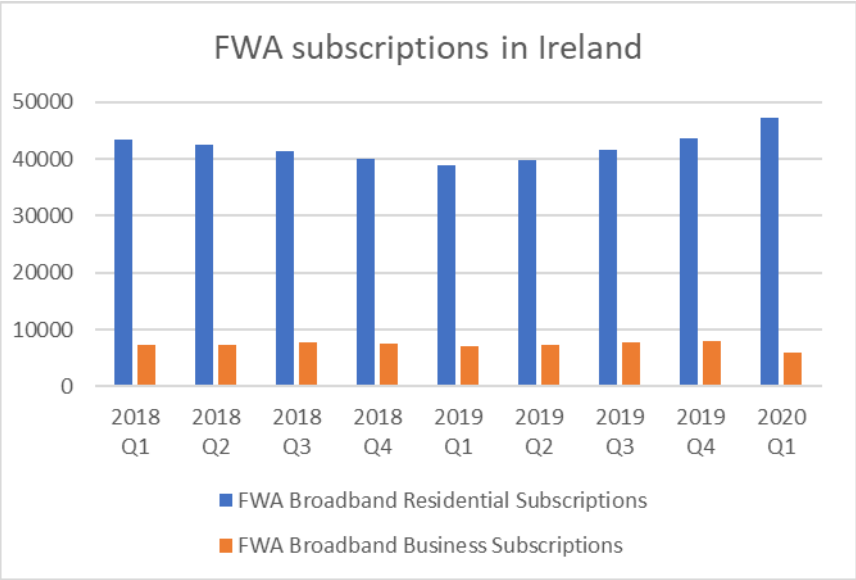
- Fixed Wireless Access;
- Mobile services (eMBB services for city centres and "hotspots" such as airports, railway stations and malls);
- Verticals such as industry, ports and airports; and
- In-band backhauling.

Fixed Wireless Access

Fixed wireless access market in Ireland has been quite flat during the past five years with a total market of about 50,000 FWA subscribers combining the residential and business subscriptions. However, in relation to the 3.6 GHz band, during the COVID-19 pandemic, ComReg has observed a significant increase in data usage of FWA services.

[106] https://www.samsung.com/global/business/networks/insights/case-studies/5g-for-fixed-wireless-access-orange-romania-case-study/

Figure 6.9: Fixed wireless access services in Ireland



Source: ComReg

As earlier outlined, 72% of the Irish population live in NUTS 3 areas that are defined as predominantly rural areas. Ireland's low population density of 70 people per km^2 falls to 27 people per km^2 in the rural areas. These factors must be considered in light of the rollout of FTTH in many of the commercially viable areas in Ireland[107] and the National Broadband Plan in all other areas by 2022.

In the coming years, FWA services in Ireland will be composed of existing FWA customers moving to 5G FWA offers and of new residential and business customers attracted by the high speeds offered by 5G FWA services where these services cannot be cost effectively covered by fibre rollouts.

Given the above context, the 26 GHz band could be used to provide FWA services as an alternative to fibre networks where they are not yet deployed or as an alternative where users do not require a fixed phone. It is likely that the 3.6 GHz band will be widely used in sub-urban and rural areas and optimistically there may be some potential for the use of the 26 GHz band for the provision of FWA services as well. At the same time, the potential for the 26 GHz to be used in rural areas is unlikely because of the economic challenges of deploying 26 GHz in low density areas. Potential for business subscriptions in urban areas will mainly be in areas where fibre is not available or for backup purposes.

Figure 6.10: 5G Fixed Wireless Access in mmWave bands characteristics

	Comments
Drivers	Increasing demand for high data rate connections, for coverage in high population density areas and for areas where fibre is not available, or users do not require a fixed phone Growing interest for the use of mmWave bands for advanced FWA around the world.
Hurdles	No areas in Ireland with an adequate population density to make any service economically viable currently. Adequate spectrum for the limited take up of FWA in the 3.6 GHz, 2.6 GHz and 2.3 GHz bands.
Opportunities	Strong support for 5G deployment from public and private actors Strong potential for use by verticals

[107] See for example https://siro.ie/

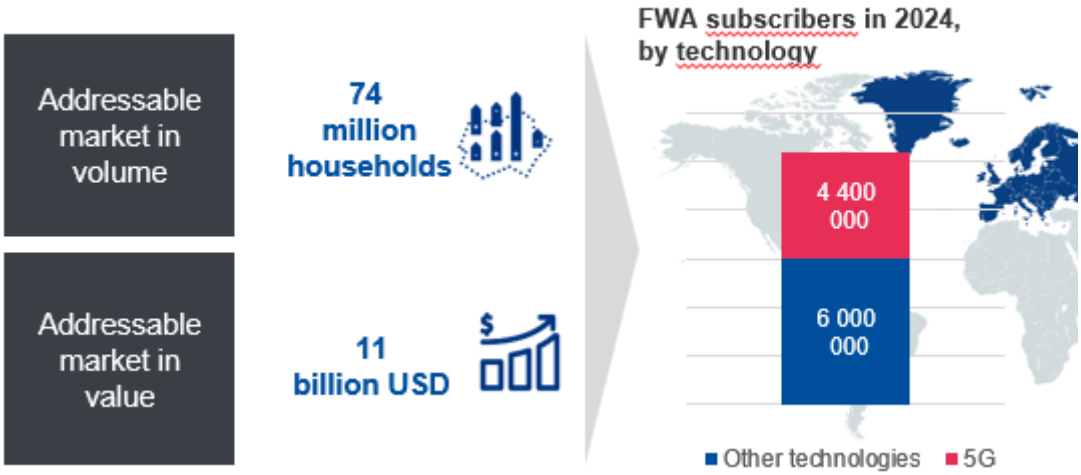
	Comments
Challenges	MIMO still poses technical and cost challenges Very limited range in the mmWave bands compared to bands such as 3.6 GHz and 2.6 GHz.

Source; IDATE

FWA forecasts

Competition in European markets is shaped by the large number of convergent fixed-mobile operators, and by any coverage obligations imposed by national regulators or governments. 5G FWA thus enables operators to deliver superfast access services rapidly to those areas that are harder to cover with FTTH, while awaiting wireline network rollouts. FWA services will also help amortise the cost of building 5G base stations before 5G mobile services launch. As a result, 5G FWA holds a clear strategic appeal for European operators, but only in a transitory and relatively short-term fashion.

Figure 6.11: FWA potential in 2024 - Europe



Source: IDATE DigiWorld, The potential of 5G fixed wireless access, July 2019

Considering this forecast, based on an average penetration ratio of 5% (FWA subscribers per household), a simple extrapolation for Ireland which has 1,697,665 households would lead to 100,900 5G FWA subscribers in 2024 in applicable bands.

However, the situation in Ireland may mitigate against such a simple extrapolation as the future distribution of any FWA 5G subscribers between the 26 GHz band and the other bands used by mobile operators, mainly the 3.6 GHz band, is difficult to predict. What should also be considered is the multi-band spectrum award which will release the 2.6 GHz, 2.3 GHz, 2.1 GHz and 700 MHz bands – making available a considerable amount of spectrum, much of it suitable for the delivery of FWA services, in the next few years.

As the 2.6 GHz and 2.3 GHz bands are currently unassigned and, taking into account the point made above regarding the short-term nature of 5G FWA, a strong argument can be made that these bands would be initially preferred to the 26 GHz band.

In addition, while the 26 GHz band is currently available for providing FWA services (although only in FDD) under the FWALA scheme, the number of FWALA licensees in this band has fallen to zero, possibly indicating the lack of a suitable business case.

5G mobile services

In the "Future Mobile Connectivity in Ireland" a report from Oxera Consulting LLP, with Real Wireless Ltd."[108], it is indicated that *"From a longlist of possible use cases, MBB will continue to be a core service and the primary beneficiary of extending mobile capacity and coverage. In our view, operators will deploy infrastructure initially for MBB and then layer additional services onto that network in order to increase revenue. "*

An expectation seems to have developed that the 26 GHz band will be used by mobile operators once they have exhausted capacity provided by existing 4G bands[109] and new 5G bands[110] and, further, that this exhaustion is imminent. In reality in the most advanced countries in Europe (Europe and the United Kingdom), it is expected that the 26 GHz band will be only be required in 2023-2024 for densification needs[111]. Furthermore, noting the number of regulators who have delayed releasing the 26 GHz band due to a lack of demand, this appears to be a drastically over optimistic view. Given the population density in Ireland, the amount of spectrum available in the 3.6 GHz band, and the release of the vacant 2.6 GHz, 2.3 GHz and 700 MHz bands it is unlikely that the 26 GHz band will be required for capacity purposes in Ireland in anywhere near the same time periods.

Noting the limitations on the widespread use of the 26 GHz to provide 5G mobile services, it is likely that mobile operators will only focus on utilising the 26 GHz band in specific environments where there is a financially viable business case, such as perhaps railway stations, airports, malls and industrial environments[112]. However, again it is not clear if there is sufficient population density at any of these locations in Ireland to justify or warrant even a limited use of the 26 GHz band. For example, the busiest rail station in Ireland, Connolly, has less than 20 500 boarding or alightings across the whole of the busiest day of the year[113] and only three rail stations (all in Dublin) exceed 10 000 boarding or alighting. Granted, there may however, be scope at Dublin airport, at the larger stadiums in Ireland (e.g. Croke Park, Aviva etc.) and in some limited industrial environments for such services to be viable.

5G verticals

ComReg has observed that, in the case of previous bands under demand, it is normal to experience some interest in testing equipment and even trialling services. However, it is noted that currently there has been no take up of ComReg's test and trial regime to conduct either tests or trials in the 26 GHz band even though ComReg has highlighted its availability.

As reported in the 5G Observatory trials database[114], the situation in other parts of Europe is different and there have been many 5G private network trials in Europe involving industries, operators and vendors. Some countries allocated dedicated spectrum to industrials for example, in Germany[115] (in the 3.7-3.8 GHz band) where players including BMW, Bosch and Siemens and have obtained local licences to deploy 5G in their facilities. Japan also reserved part of the 28 GHz band for private 5G networks. The main reasons for vertical players to deploy their private 5G network are to leverage URLLC (Ultra-Reliable Low-Latency Communication) in their facilities and to manage their own quality of service.

[108] Reference: ComReg 18/103c
[109] Such as 800 MHz and 1800 MHz, 2100 MHZ and 2600 MHz
[110] The 700 MHz, 3.6 GHz, 2.3 GHz and 2.1 GHz – not to mention the developing 1.4 GHz band.
[111] Based on discussions with European mobile operators
[112] The Test & Trial service (www.testandtrial.ie) highlights the fact that Ireland is an ideal location to test equipment or trial a service with spectrum quickly available
[113] See https://www.nationaltransport.ie/publication/nta-heavy-rail-census-report-2019/
[114] http://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/
[115] In a public consultation opened last year, BNetzA proposed separating the 26 GHz range into upper (26.5-27.5 GHz) and lower (24.25-26.5 GHz) sub-bands. Industry verticals and local use-cases would have regular access in the lower sub-band, and priority access in the upper sub-band. Mobile network operators (MNOs) have vigorously objected to the proposed division of the band, alleging it would squander most of its value. https://techpolis.com/germany-to-unlock-5g-mmwave/

According to the 5G Observatory, the most trialled verticals in Europe are media and entertainment followed by transport and automotive. Other vertical sectors with many trials reported are Industry 4.0, eHealth, virtual reality, smart cities and public safety[116].

In December 2019, the Irish Government published the Industry 4.0 strategy for Ireland. This document states that Ireland has a strong manufacturing base employing 227,000 people in key sectors such as Pharmaceuticals and Chemicals, Food and Drink, Medical Devices, Computers and Electronics, and Engineering in 2018. The main goals of Ireland's Industry 4.0 Strategy are to stimulate firms to adopt and build capabilities in Industry 4.0 technologies and to establish a world-class business environment for Industry 4.0. Adoption of 5G by verticals in Ireland is expected to be slower than in countries with a more developed industry sector but any demand that does arise can be facilitated on a local area basis.

Furthermore, the availability of 26 GHz spectrum is an argument of international competitiveness, especially for industry 4.0. Again, it is not clear if the scale of operations in Ireland will warrant the use of the 26 GHz band or if Irish verticals would instead prefer to utilise mid-band spectrum.

In-band backhauling

One key challenge to broadly expand 5G NR mmWave network coverage is the cost of deploying additional mmWave base stations, which usually requires new fibre optic backhaul installations. To make mmWave densification more cost efficient, 3GPP Release 16 introduces integrated access and backhaul (IAB) that allows a base station to provide both wireless access for devices and wireless backhaul connectivity, thereby eliminating the need for a wired backhaul. IAB can open doors to a more flexible densification strategy, allowing operators to quickly add new base stations dynamically, before having to install additional fibres to increase backhaul capacity.

Demand for in-band backhauling will not generate additional needs for 5G base stations in the 26 GHz band but will raise MNOs' interest for using this band as it will facilitate installation of small cells and remove the need to have access to a fibre optic network.

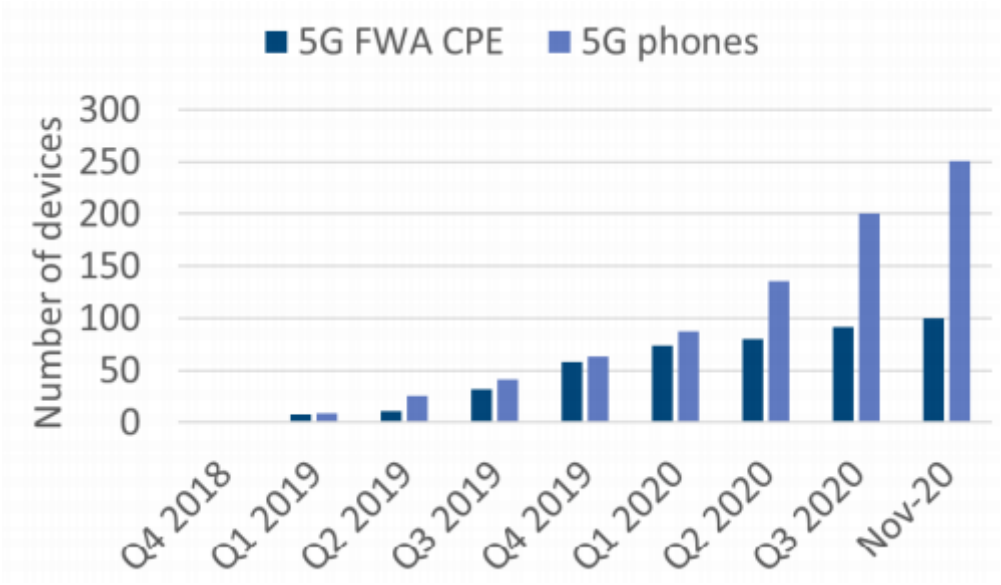
In-band backhauling is expected to be mainly useful in cities where no fibre is quickly available. This new technology will probably be mature after 2023-2024 and will have a very limited impact on demand for the 26 GHz band in Ireland by 2025 - 2028.

6.3.4 Device ecosystem

Figure 6.12 shows the split between 5G FWA CPE and phones and indicates the rate of growth seen since the end of 2018. However, there are currently far fewer 5G devices than 4G (519 compared to over 18,800[117]).

[116] http://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/
[117] LTE user devices have seen an average growth rate of more than 3,000 devices per year for the last4 years according to the GSA.

Figure 6.12: Growth In 5G FWA CPE and phone devices



Source: GSA

The majority of 5G devices are consumer and retail devices, and 48.4% of all devices are phones.[118] While there is demand for the industrial application of 4G and 5G mobile devices, the vast majority of vendors are focusing on the more versatile, non-specific modules rather than a specific form factor. At present, the mid-band frequencies between 3.3 GHz and 3.8 GHz are the primary focus for 5G device development, with some development also taking place in the 26/28 GHz bands. According to the GSA[119], in December 2020 over 100 5G devices supporting mmWave bands had been announced showing that support for these high bands is growing but of these there are currently only five phones using n257 and none using n258.

The timely availability of a broad and low-cost device ecosystem for the 26 GHz band will affect market demand.

6.3.5 Demand scenarios for the 26 GHz band

Three potential demand scenarios (optimistic, baseline, pessimistic) are detailed in the table below considering 5G adoption speed in Ireland, availability and cost of 26 GHz devices, integration of 26 GHz band in smartphones and tablets and adoption and deployment of 26 GHz band in Europe and Asia.

Figure 6.13: 26 GHz band demand in Ireland

Scenarios	Pessimistic	Baseline	Optimistic
5G adoption in Ireland	Late 5G commercial launch	On-track 5G commercial launch	Rapid 5G commercial launch
Assignment date of 26 GHz band in Ireland	After 2027	2024-2027	2022-2024

[118]Plum considers other 5G consumer devices to include indoor CPE, outdoor CPE, notebook, MiFi/hotspot, USB modem, modem, 5G phone adapter, tablet PC, router and television.
[119] https://gsacom.com/reports/

Scenarios	Pessimistic	Baseline	Optimistic
Assignment of 26 GHz band in Europe and in Asia-Pacific	Limited assignment in Europe and delayed assignment in Asian countries including China	The Chinese market quickly adopts the 26 GHz band and more European countries assign the 26 GHz band	Rapid assignment in Europe early 2021
Deployment of 26 GHz in Europe and in Asia-Pacific	Delayed deployments in Europe (2025). Slow deployments in Asia (China, Hong Kong, Singapore, Australia)	Early deployments in 2021 (China, Hong Kong). European deployments start in 2022-2023	Early deployments in 2021 (China, Hong Kong). European deployments start in 2021-2022
Availability and cost of 26 GHz CPEs	Limited availability. Cost remains high	26 GHz FWA CPEs available from 10+ suppliers early 2021	Cheap CPE quickly available for FWA, mid-tier chipsets and antenna modules cover the 26 GHz band
Integration of 26 GHz band in smartphones and tablets	26 GHz band integrated into a limited number of smartphones and tablets	26 GHz band integrated into many new smartphones and tablets	26 GHz band integrated into all new smartphones and tablets

Source: IDATE/PLUM

6.3.6 26 GHz demand evaluation

The expected demand for each of the four usage scenarios is summarised in the table below:

Figure 6.14: Irish market' characteristics affecting 26 GHz demand

26 GHz usage scenarios	Likely adoption of 26 GHz band
Fixed Wireless Access 5G	An optimistic forecast of 50,000 5G FWA subscribers in 2027 (in the 3.6 GHz and 26 GHz bands).
5G mobile services	The need for the 26 GHz small cells in large cities is expected to come later than in larger countries due to the availability of spectrum in other 5G bands
5G verticals	Adoption of 5G by verticals in Ireland is likely to be slow given the absence of 5G drivers like industry 4.0 or automotive players in the country
In-band backhauling	In-band backhauling expected to be mainly useful in cities where no fibre is quickly available. This new technology will probably be mature after 2023-2024. Limited impact on demand in Ireland

Source: IDATE

In the short to medium term (2023-2027), we expect that the only demand for the 26 GHz band may come from FWA but noting the quantum of mid-band spectrum being made available shortly, via the Multi Band Spectrum Award, this seems optimistic. The other usage scenarios are likely to increase after 2027 if an adequate business case can be developed by MNOs and / or the eco-system for self-provided 26 GHz base stations and devices develops to enable an adoption by verticals.

It should however be noted, in terms of international competitiveness and for Industry 4.0, that access to the 26 GHz spectrum in Ireland could be an argued if there is adequate scale of operations that can justify a viable business case.

Figure 6.15: 26 GHz usage scenarios relative impact in Ireland

26 GHz usage scenarios	Importance	2023-2027	2027-2030
Fixed Wireless Access (5G)	In urban and sub-urban areas	+	++
5G mobile services	For hotspots & city centres	-	++
5G verticals	For specific verticals	-	++
In-band backhauling	Likely after 2025	-	+

Legend: "-": no impact, "+": limited impact", "++": moderate impact", "+++": very important impact

Source: IDATE

Our estimates for the 26 GHz band "market" combines subscriptions for FWA and base stations for the usage scenarios:

Figure 6.16: 26 GHz usage scenarios - Irish market

26 GHz usage scenarios (2027)	Pessimistic	Baseline	Optimistic
FWA (5G)	No 5G FWA subscriptions	25,000 5G FWA subscriptions	50,000 5G FWA subscriptions
5G mobile services	No use of the 26 GHz band for mobile services	26 GHz small cells unlikely to be deployed in Ireland before 2025	26 GHz small cells deployments in Dublin and some hotspots such as Dublin airport and a small number of stadiums.
5G verticals	No use of the 26 GHz band for verticals	A few hundred small cells	A thousand to a few thousand small cells
In-band backhauling (IAB)	No usage	No usage	A few hundred base stations using IAB
Total	No use of 26 GHz base station before 2025	A few hundred 26 GHz small cells deployed each year after 2023	A few thousand small cells deployed each year after 2023

Source: IDATE

In the baseline scenario (2023-2027), 26 GHz band Irish demand would represent 25,000 5G FWA subscriptions and a few hundred 26 GHz small cells deployed each year after 2023 in limited areas.

Clearly, the limited demand under the optimistic scenario will easily be facilitated in the contiguous 1 GHz of 26 GHz spectrum available in Ireland during the coming decade. Stronger demand expected in the longer term and higher throughputs will probably require larger bandwidth per operator and potentially more spectrum availability in the 26 GHz band, although this needs to be balanced against the availability of other mmWave bands that are expected to be harmonised over the next five years in Europe.

7 Potential licensing approaches for Ireland

7.1 Introduction

It is difficult to predict how 5G will develop in Europe and whether or not at some point in the future we will see similar take-up for services as seen in South Korea. Taking into account Ireland's population and demographics (section 6.1.2) it seems very unlikely that this demand trend will arise in Ireland.

There may be some limited demand for FWA services due to increased home working and the lack of fibre and cable broadband services across the full geography of Ireland but limited in extent by the competition from FTTH and the NBP. In addition, a lot of potential demand for FWA could be soaked up in rural and semi-rural areas via FWA services in the 3.6 GHz band, the roll out of which, has not yet been the focus of Irish MNOs.

In Ireland we expect demand for 5G from verticals to be slow given the absence of 5G drivers like industry 4.0 or automotive players in the country and demand could be met through 4G and 5G in mid-band spectrum. The smart docklands / Dublin city is an example of such an initiative[120].

It is anticipated that demand in all four usage scenarios (section 6.3.3) will be slow and then only at a very limited number of locations when demand does occur. However, history has shown us that in 5 or more years the situation could change considerably and it would be imprudent to make any decision(s) based on unrealistic (e.g. over-optimistic) assumptions, crystal ball gazing or the views of vested interests.

In Ireland, there are currently five licensees (eir, Three, Vodafone, DenseAir and Imagine) who can use the 3.6 GHz band to provide both fixed and mobile 4G / 5G services[121] under their spectrum rights of use[122]. It is likely that they could all be interested in access to the 26 GHz band in the medium to long term to augment their current 3.6 GHz offerings if capacity constraints ever occurred and deployment of small cells becomes an economic option. However, at the time of the Multi Band (MBSA2) consultation[123] none of these licensees proposed the 26 GHz band should be included in the award. The issue is when (if ever) and how much spectrum will be required. The dilemma for market players (both incumbents and new entrants) is that spectrum is not a freely available commodity. As a result, when it does become available, i.e. new licence regime or award is made, they need to acquire spectrum for both immediate expected and future projected use. This future projected use under the EECC now spans up to 20 years. Getting these projections wrong can lead to either inadequate spectrum to expand into or spectrum hoarding and the inefficient use of the radio spectrum resource.

There may also be further organisations such as utilities, industries and other verticals, perhaps stadium owners and airport operators, that would be interested in access to the 26 GHz band for very local area and small cell deployment. These market players do not operate like an MNO and typically need access to the spectrum when a definite need has arisen and do not acquire spectrum for a longer term possible future requirement. Such organisations are being addressed through spectrum sharing in the UK and local licensing in Germany as described in section 4.1.

Of great importance as part of this consideration is the multiband award in 2021 for the 700 MHz, 2.1, 2.3 and 2.6 GHz bands which is making available 470 MHz of spectrum. The availability of a considerable amount of

[120] https://telecominfraproject.com/tip-launches-solution-groups-to-define-and-validate-end-to-end-open-network-solutions/
[121] DenseAir and Imagine offer different services to the three 3 MNOs. They have different amounts of spectrum – see https://www.comreg.ie/media/dlm_uploads/2017/05/ComReg-1738.pdf,
[122] For example, Three is offering 5G FWA – see https://www.three.ie/shop/broadband/broadband-devices/huawei-5g-win-fwa.html
[123] Proposed Multi Band Spectrum Award – Preliminary consultation on which spectrum bands to award – Commission for Communications Regulation (comreg.ie)

spectrum in the very near future[124] will serve to meet coverage and capacity requirements required by the current market players as well as for any potential new entrants (big or small). This will further reduce any short to medium term requirement for the capacity options provided for by the 26 GHz band.

The most common bandwidths awarded per licensee, to date, are 400 MHz and 800 MHz[125] (400 MHz in Hong Kong, Japan and Thailand and 800 MHz in Finland, Singapore and South Korea). Although it is important to note the vast difference in population density and split between urban and rural between most of these countries and Ireland. In Italy five licensees were each awarded 200 MHz, but the club model is intended to provide higher bandwidths when / where required. Plum understands that the implementation of this model is still in development at this time.

To clear the entire band either in one move or progressively to release more than 1 GHz of contiguous spectrum currently available would require the relocation of 178 individually licensed fixed links, and three fixed link block licensees[126]. The three fixed link block licensees have rights of use until 2028 and would need time to identify and migrate to alternative spectrum for all the fixed links they have established in these block licences. As well as forfeiting licence duration if this spectrum was to be vacated before their current licences expire they will incur the cost of planning and deploying to a new band(s).

Without clarity as to what the band will be used for by 5G services, the expected scale of use, the expected coverage of population and geographic area, band clearance would be an almost impossible policy for any regulator to commit to. The conundrum for ComReg in following such a policy is that it is guessing that having moved licensees from the band that the spectrum will in the first instance be taken up by new licensees and that the services offered by these new licensees would provide greater utility and value than the services being moved out of the band. However, there is a dearth of evidence to support such a view.

Overall, at this early stage in the deployment of 5G in mmWave bands, where it is difficult to predict evolution, it will be important that any licensing approaches retain flexibility so that it is possible to respond in a reasonable time if circumstances materially change.

7.2 Recommendations 1 – 6.

Based on our evaluation we offer six initial recommendations which frame our further consideration of appropriate licensing approaches. In section 7.3

Consideration 1:

Our analysis in this report supports the view expressed in CEPT Report 68 that the 26 GHz frequency band does not present the characteristics to support either national coverage or wide coverage areas.

Recommendation 1:

While ComReg's approach in all harmonised ECS bands to date has been towards national or large regional awards, there is not a strong basis for such an approach on this occasion or at least at this time.

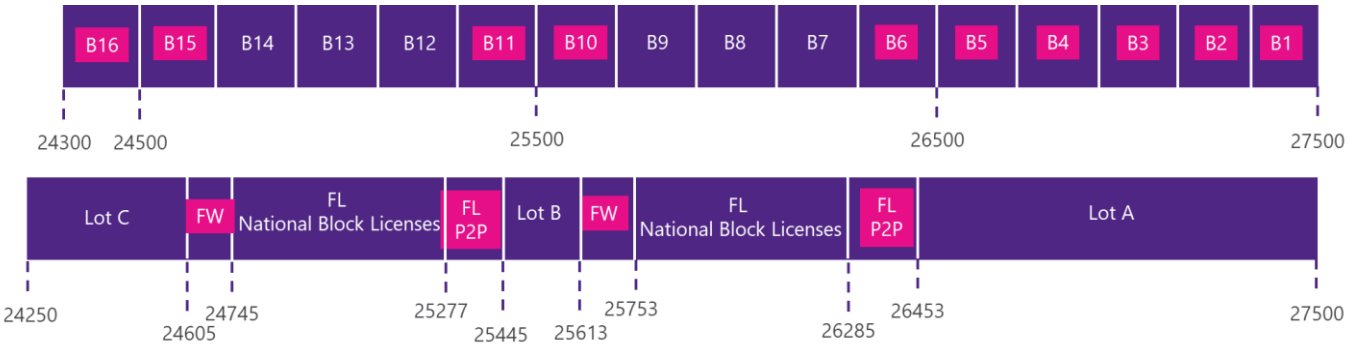
[124] https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/proposed-multi-band-spectrum-award/.
[125] ITU-R IMT 2020 vision identifies at least 800 MHz of contiguous spectrum per operator.
[126] There are no FWALA licensees or applications currently pending.

Consideration 2:

There is no demand or use of the portion of the 26 GHz band for the provision of FWALA and demand for the portion for the provision of individually licensed fixed links is decreasing.

Recommendation 2:

If additional unencumbered spectrum is required in the future, then the spectrum identified for FWALA (not currently licensed) and for individual fixed links licensing would logically be the first to be considered. The individual fixed links could perhaps be relocated to other spectrum bands in time. This would provide an additional four 200 MHz blocks, giving a total of ten 200 MHz blocks, when combined with the unallocated lots, as shown below.



Consideration 3:

There is robust demand for use of the currently assigned national block licences which will expire in 2028. Given the preceding discussion, there does not appear to be any strong basis to warrant any change to this use for the foreseeable future

Recommendation 3:

Currently, there is no foreseeable case to consider taking any interventionist steps in relation to the national block licences. Any decision should be made closer to licence expiry in 2028. Facilitating the establishment of a block licence regime in other band(s) as well as allowing migration to these other band(s) could form part of ComReg's considerations.

Consideration 4:

Previous measures such as spectrum refarming (e.g. preparing the 700 MHz band for ECS), relocating incumbents from a band (e.g. removal of all fixed links below 1 GHz) or switching off incumbent services on licence expiry (e.g. MMDS in the 2.6 GHz band) can, depending on circumstances, prove to be blunt regulatory options. There is always a risk that removing one user with the expectation that they will be replaced by another user with a more efficient use may not materialise.

Regulators are understandably averse to taking these actions where there is no certainty that once the spectrum has been cleared it will be used for new services and there is a risk of bands laying fallow for years. ComReg has also been understandably resistant to implement such measures until there is a sufficiently clear basis for such actions. ComReg has experience with and successfully used policies that are based on market forces (e.g. prices paid to access spectrum and quanta of spectrum holdings).

Rather than attempt to predict the future and to make assumptions based on inadequate and imperfect information, ComReg should consider whether there is scope for the further use of market mechanisms, such as

trading and leasing to be extended to the 26 GHz band. This would align with the EECC which expresses the view[127] that "*Trading and leasing of radio spectrum should ensure the effective use by the original holder of the right*".

Recommendation 4:

The use of market mechanisms such as spectrum trading and spectrum leasing should be considered as one possible method to determine how and when incumbents could move out of the band. Amongst other advantages this would allow the market to determine the future use of portions of this spectrum band and allow incumbents to determine when and at what cost they are willing to move. This would require the 26 GHz band to be encompassed by a trading regime.

Consideration 5:

Our analysis of potential demand for the 26 GHz band in Ireland indicates that demand for small cells in the band is not likely until at least after 2023 and will likely be few in number, see Figure 6.16. Small cells could be deployed to address any FWA demand that may develop after that time and other usage scenarios that may develop after 2025[128] at the earliest.

Recommendation 5:

Consider consulting on making available some or all the currently unassigned spectrum within the next Radio Spectrum Management Strategy Statement period to cater for any demand for niche 5G services in this band.

Consideration 6:

Irrespective of the initial demand for FWA or by verticals or any of the four usage scenarios identified in section 6.3.3, the view is that as a consequence of the physical properties of this mmWave spectrum and its direct impact on the economics of using this band, that the deployment of WBB ECS in any form will be using cells with a small range. As noted, the technical conditions in the implementing directive were devised assuming the use of an individual authorisation but are intentionally suitable for licensing on a small geographic basis as well as on a nationwide basis. This is endorsed in the second RSPG opinion (see section 3.1.3) which noted that these geographical areas could include national, regional, city or hyper-local (e.g. use in a factory).

Recommendation 6:

Licence regimes, including licence-exemption, that cater for small cells either on an individual or local area basis should only be considered in the currently unassigned spectrum – see also Recommendation 1.

7.3 Licensing approaches in Ireland and further recommendations

Based on recommendations 1 - 6 we provide our views on which unassigned portions of the band are useful and what licensing approach(es) should be considered.

In the case of the unassigned Block B, 25.445 – 25.613 GHz there is no overlapping 200 MHz block, see Figure 5.2, and at this stage would have limited use without the addition of the adjacent spectrum identified for FWALA.

[127] See preamble no. 122 and Article 51 of the EECC.
[128] This is the baseline case

There are two sufficiently large tranches of unassigned spectrum in the 26 GHz band; 355 MHz between 24.25 and 24.605 GHz and 1047 MHz between 26.453 and 27.5 GHz. We consider these two bands further below:

24.25 – 24.605 GHz

There is currently a single 200 MHz block of unassigned spectrum between 24.3 – 24.5 GHz which could be expanded by a further 50 MHz down to 24.25 GHz for WBB ECS. Further if the current FWALA spectrum is included this can provide an additional 200 MHz block (i.e. a total of 450 MHz).

There are examples where the lower part of the band has been proposed for indoor use. For example, in the UK the 24.5 – 26.5 GHz band is available[129] and Ofcom notes that enabling access to the lower 26 GHz band *"increases the options for deployment of new 5G deployments with little or no impact on existing services and without prejudicing any future use of the band outdoors"*. Licences are for shared access and allow licensees to deploy the required number of indoor base stations in a circular area with a 50-metre radius. The licence fee is £320 payable annually for 50 MHz, 100 MHz or 200 MHz channels. Ofcom can request changes to frequencies if necessary and the licensee must use their spectrum within 6 months of the licence being issued.

In Australia, the 24.25 – 25.1 GHz band was identified for class licensing[130] with 24.25 – 24.7 GHz for indoor use only to protect passive EESS operating in 23.6 – 24.0 GHz.

It is not clear whether use of this band should be for indoors only or indoors and outdoors. Protection of the EESS operating in the 23.6 – 24.0 GHz band, where all emissions are prohibited, has been a contentious issue worldwide. The potential for unwanted emissions from ECS is greater the closer they are to the lower 26 GHz band edge of 24.25 GHz. In Europe two different out of band emission levels have been agreed for 5G deployments – less stringent level for before 1 January 2024 and more stringent after that date when equipment should be available from vendors that can meet these levels. Restricting use of this lower band initially to indoor only would provide greater protection to EESS.

In Ireland, it may be beneficial to make the 24.25 – 24.5 GHz band available for indoor use to support the first phase of indoor applications, including industrial. Indoor use and no co-channel applications should make co-existence with adjacent channel uses tenable and allow either licence-exempt or a light licensing approach[131] to be adopted.

We consider the licensing approaches in more detail below.

[129] https://www.ofcom.org.uk/__data/assets/pdf_file/0033/157884/enabling-wireless-innovation-through-local-licensing.pdf

[130] A class licence allows a user to operate common radio equipment in shared frequencies. There is no requirement to apply for a class licence or pay any fee. The class licence defines what equipment can be used, the frequency range and the rules for using it.

[131] In the case of light licensing the licensee will require a licence to use the frequency band according to specified technical conditions and must notify the regulator of individual deployments (e.g. location, coverage, frequencies, date of taking into service). The regulator does not undertake any technical analysis to determine frequency assignments and in the case of interference the most recent user will be required to retune to new frequencies.

Figure 7.1: Licensing options for lower 26 GHz band

Option	Advantages	Disadvantages
Light licensing of 24.25 – 24.5 GHz for indoor use	• Light licensing allows ComReg to monitor take-up of the band to inform future decisions on release of further 26 GHz spectrum. • Fast, easy and low-cost access to frequencies. • Limiting to indoor use only, decreases potential for interference to EESS, due to the additional building penetration losses. • Co-existence considerations limited to adjacent band as spectrum currently unassigned. • Provides flexibility to change licensing approach as necessary data on licensees and locations available.	• Limited amount of spectrum available (250 MHz) so bandwidth per licensee may have to be limited (e.g. 50, 100 or 200 MHz). • Services may be limited with respect to ultra-high bandwidth applications. • Does not support outdoor deployments. • Need for ComReg to maintain licence database mainly to record transmitter locations.
Licence-exempt use of 24.25 – 24.5 GHz for indoor use	• Fast and easy access to frequencies for higher number of users including small users. • Ideal for undertaking tests and trials. • Limiting to indoor use only, decreases potential for interference. • Co-existence considerations limited to adjacent band as spectrum currently unassigned.	• Difficult to establish visibility for ComReg on actual utilisation. • Need to establish appropriate spectrum access methods for fair use. • More difficult to identify and address interference. • Nascent nature of 5G means may be too early to adopt such an approach as very difficult to modify when have no information on usage. • Limited amount of spectrum available (250 MHz) so bandwidth allowed per user may be limited with respect to ultra-high bandwidth applications. • Does not support outdoor deployments
Increase spectrum beyond 24.5 to 24.7 GHz to provide greater bandwidth (requires removal of FWALA allocation)	• Could allow applications requiring higher bandwidths to be deployed.	• Have to ensure no co-existence issues with incumbents, e.g. national block licences (easier to manage with light licensing)

Recommendation 7:

Consider releasing the 24.25 – 24.5 GHz band for indoor use using a light licensing regime to provide the flexibility later to allow outdoor use and / or a different licensing approach based on initial experience.

26.5 – 27.5 GHz

This segment of the 26 GHz band has been identified for use in a significant number of European countries (for example Czech Republic, Denmark, Finland[132], Greece, Italy and Slovenia). It has the benefit of overlapping the 28 GHz band being adopted elsewhere in the world so has the potential for a significant device ecosystem.[133]

There is no single licensing approach adopted based on the benchmarking in terms of national, regional or local licences or the method of award.

We consider below possible licensing options best suited to Ireland for this band.

Licensing option	Advantages	Disadvantages
Local area licence	• Potential to support a wide range of licensees. • Potential to obtain higher bandwidths of 400 MHz and above. • Licences will be specific to geographic areas, for example urban hotspots, where there is requirement for additional capacity, and this may help to facilitate co-existence with incumbents such as fixed links located outside urban areas. • Could attract neutral hosts in hotspots. • Could be aggregated into city licences or wider regions.	• Need to be able to clearly define geographic area of the licence • Need to determine application and any selection procedure if demand exceeds supply in any geographic area (see Australia and Germany) • Need to define how interference will be minimised between users (e.g. mutual agreements between users in adjacent or the same geographic areas) • Need to include appropriate licence conditions (e.g. "use-it-it-lose-it", fees, etc.) to ensure spectrum is utilised
Individual cells	• Potential to support a wide range of licensees. • Potential to obtain higher bandwidths of 400 MHz and above. • Meets the needs for FWA which is identified as important service • Can support cell aggregation over a wider geographic area (see Australia AWL licensing)	• Potential for significant licensing effort required from ComReg • Interference management between 5G users may be more complex if at individual cell level • Aggregation to serve larger areas not as easy as for local area licences • Need to include appropriate licence conditions (e.g. "use-it-it-lose-it, fees, etc.) to ensure spectrum is utilised

Recommendation 8:

Consider releasing the 26.5 – 27.5 GHz band for local area licensing and appropriate licensing approach(es) should be adopted. This can be either once use cases emerge and demand crystallises or earlier to stimulate the market as sufficient numbers of devices become available.

Recommendation 9;

At this stage there is insufficient WBB ECS demand to consider reconfiguring the 26 GHz band and migrating fixed links and national block licences from the band to release further spectrum especially considering the robust demand for national block links. Should this situation change it is noted that migration of existing users to other bands (for example 31.8 – 33.4 GHz) or switching off users may take, based for example on responses

[132] In Finland the award of 2.4 GHz of the spectrum included the 26.5 – 27.5 GHz band
[133] Band n257 26.5-29.5 GHz.

to ComReg Document 17/85 regarding the 26 GHz band award[134], from 2 years to "a very long transition time"[135].

7.4 Conclusions

At this early stage in the deployment of 5G in mmWave bands it is difficult to predict its evolution. In Ireland in particular it is potentially more challenging when considering the local context (low population density, low industry, near term availability of considerable amount of additional spectrum, slow ramp up of 5G over time, etc), and the current licensing regimes and density of use. It will be important that identification of spectrum and licensing approaches retain flexibility to respond to evolution.

International perspectives

It is noted that international experience does not show any trend towards a harmonised approach currently as summarised in section 2 and section 4 . There have been more awards to date in the USA and Asia Pacific region using a mix of approaches including a direct award in Hong Kong with no fees payable, Japan via a beauty contest, awarded with 3.5 GHz using a beauty contest in Singapore and using auctions in South Korea and Thailand. Australia is proposing a mix of unlicensed spectrum as well as apparatus and spectrum licences (to be auctioned) with some apparatus licences recently awarded. There are also proposals for localised spectrum awards; in Hong Kong 27.95 – 28.35 for localised shared use and in Japan 100 MHz for private 5G and potentially 800 MHz for local private 5G services.

In Europe there have only been three awards in Finland, Greece and Italy, in all cases via auctions. Local licensing has been planned or implemented; in Finland 24.25 – 25.1 GHz is reserved for local / regional vertical players and research and development and educational use, in Germany 24.25 – 27.5 GHz is for verticals and local use and the UK has added the 24.25 – 26 GHz band to their spectrum sharing frequency bands for localised use. Most countries that have plans or have awarded the 26 GHz band have identified the 26.5 – 27.5 GHz band; Czech Republic, Greece, Italy and Slovenia. It is noted that in Europe 26.5 – 27.5 GHz is not allocated to fixed links[136] which is mentioned by several countries to be the main incumbent user in the 26 GHz band.

There is, however, agreement within Europe on the necessary technical conditions for the award of the 26 GHz band taking into account the co-existence considerations (adjacent and co-channel). The key technical conditions are (as defined in European Commission Implementing Decision (EU) 2019/784, amended by European Commission Implementing Decision (EU) 2020/590):

- block edge masks for ensuring mutual co-existence between WBB ECS;
- out-of-band emission limits applicable for the protection of the passive band 23.6 – 24 GHz; and
- restriction of an outdoor base station antenna beam below the horizon for the protection of satellite receivers.

EC Decision 2019/784 also states that '*additional measures may be required at a national level to ensure coexistence with other services and applications, such as radio astronomy services*'. CEPT Report 68 suggests that exclusion areas around Radio Astronomy sites could be introduced in addition to the out-of-band emission

[134] Three's response indicated "would need a transition period of a minimum of 2 years from the time it is known exactly what spectrum will be used to replace the current channels in the band. Vodafone noted "moving these links to another band ..... would be a very significant task" and would require a very long transition time. See Doc. 18/12b.

[135] See also ComReg consultation document (20/109) Review of the Fixed Radio Links Licensing Regime – Commission for Communications Regulation (comreg.ie)

[136] As defined in T/R 13-02 Recommendation on preferred channel arrangements for foxed services on frequency range 22.0 – 29.5 GHz

limits. In terms of the protection of other services such as fixed link receivers and FSS, EESS and SRS earth stations, case-by-case interference analysis may have to be implemented.

Irish situation

Ireland has one of the most widely distributed and rural populations in Europe with 72% of the Irish population living in predominantly rural areas. These characteristics, see section 6.1.2, create specific challenges to provide broadband services in Ireland.

Based on three different demand scenarios (optimistic, baseline, pessimistic) the likely demand in Ireland has been evaluated. The scenarios consider 5G adoption speed in Ireland, availability and cost of 26 GHz devices, integration of 26 GHz band in smartphones and tablets and adoption and deployment of 26 GHz band in Europe and Asia (see Figure 6.13). The expected demand in Ireland considers four sub-market scenarios: fixed wireless access, small cells for mobile, verticals and in-band backhauling. Considering the current trends and the demographics of Ireland it is concluded that in the short to medium term (2021-2027), we expect that demand for the 26 GHz band will mainly come from fixed wireless access services. The other sub-markets are likely to develop after 2027 once the 5G network deployment has been made in Ireland and the price of 26 GHz base stations and devices is low enough to enable a wide adoption. Our estimates for the 26 GHz band market combine subscriptions for the fixed wireless access market and base stations for the other sub-markets are:

Figure 7.2: 26 GHz demand scenarios (2027)- Irish demand

26 GHz demand scenarios 2027	Pessimistic	Baseline	Optimistic
Fixed Wireless Access 5G	No 5G FWA subscriptions	25,000 5G FWA subscriptions	50,000 5G FWA subscriptions
5G mobile	No use of the 26 GHz band for the mobile market	26 GHz small cells unlikely to be deployed in Ireland before 2025	26 GHz small cells deployments in Dublin and some hotspots in the country
5G verticals	No use of the 26 GHz band for verticals	A few hundred small cells	A few thousand small cells
In-band backhauling (IAB)	No demand	No demand	A few hundred base stations using IAB
Total market	No use of 26 GHz base station before 2025	A few hundred 26 GHz small cells deployed each year after 2023	A few thousand small cells deployed each year after 2023

Source: IDATE

In the baseline scenario (2021-2027), there would be 25,000 5G FWA subscriptions and a few hundred 26 GHz small cells deployed each year after 2023. This limited demand could readily be met by the 1 GHz of 26 GHz spectrum available in Ireland during the coming years. Stronger demand expected in the longer term and higher throughputs will probably require larger bandwidth for each user and more spectrum in the 26 GHz band.

Our recommendations

The international experience does not currently show any trend towards a harmonised approach for the 26 GHz band and the potential market demand in Ireland does not indicate a significant or urgent requirement to award this spectrum (and certainly not on a long-term, national basis). We would recommend that any approach adopted should provide ComReg with the necessary flexibility to respond to market developments and, as such,

consider that the use of localised approaches seems to fit better with the context of Ireland and the view that the 26 GHz band will not support national and wide area coverage.

Specifically, we conclude:

Spectrum

- Only the two larger tranches of spectrum currently unassigned (355 MHz between 24.25 and 24.605 GHz and 1047 MHz between 26.453 and 27.5 GHz[137]) should be currently considered for WBB-ECS.
- The key band for award is the 26.5 – 27.5 GHz due to the expected equipment availability including devices and its adoption across Europe and overlap with 28 GHz band frequencies used outside of Europe.
- 24.25 – 24.5 GHz could be made available for indoor use to support the first phase of the indoor applications, including industrial. Indoor use only will limit potential out of band emissions to EESS until tighter 5G equipment limits are introduced.
- Currently there are no indications that further spectrum should be considered for award.

Method of award

- On the basis that the use of the 26 GHz band will be localised, the 26.5 – 27.5 GHz portion should be awarded on a local licensing basis either on a frequency / area basis or using an individual small cell approach (see Recommendation 1).
- 24.25 – 24.5 GHz should be made available using either a licence-exempt or light licensing approach.
  - On balance initially a light licensing approach, rather than licence exemption, may be beneficial to allow ComReg to monitor nature and extent of actual use of the band.

Licensing

- Technical licensing conditions should be those defined in European Commission Implementing Decision (EU) 2019/784, amended by European Commission Implementing Decision (EU) 2020/590.
  - No additional conditions are necessary based on co-existence with other services in the 26 GHz band.
  - If Radioastronomy is planned in the future appropriate exclusions or co-ordination zones may be necessary.
- Appropriate licence conditions (e.g. Use-it-or-lose, as proposed in Germany and Australia, fees, etc.) to ensure spectrum is utilised.

[137] In practice there will be slightly less spectrum available as the 26 GHz band is divided for WBB ECS into 200 MHz blocks starting at 27.5 GHz.

Timescales

- Demand for the upper 1 GHz of the 26 GHz band could emerge from 2023-2027 and depending on the type of award (local, regional or national) that is most suitable, the upper 1 GHz of the 26 GHz band could be made available by 2028[138].
- Assignment of the lower 250 MHz of the 26 GHz band could be within 2022 – 2023 subject to demand.
- There is no strong basis currently to limit the use of existing licensing regimes for point to point or national block allocations or announce migration plans.
  - As there is no current use of the FWALA bands it might be useful to consider their future use and establish a roadmap to avoid any downstream migration or co-existence issues.
- The development of WBB-ECS in Ireland should be reviewed at an appropriate date (to be determined by ComReg) and subject to demand, to assess whether there is a need for further spectrum and / or a different long-term licensing approach beyond 2027.

[138] Demand and device availability can change significantly over these timescales depending on developments in other countries and the specific need of the 26 GHz band to meet the uses that develop

Appendix A Further information on 5G

In addition to the information provided in section 1.2 we provide further detail on equipment availability and private networks.

A.1 Equipment availability

Network equipment availability in the 26 GHz Band has been a hurdle in the past years in Europe as mobile operators were only offered 28 GHz base stations. Overlap with the 28 GHz band enables base stations to operate in the 26 GHz band with a wide tuning range. Devices availability for the 26 GHz band has also been an obstacle to test and trials in Europe until recently as devices were only available for the 28 GHz band.

Figure A.1: 5G/NR bands - operating in frequency range 24.25 – 43.5 GHz

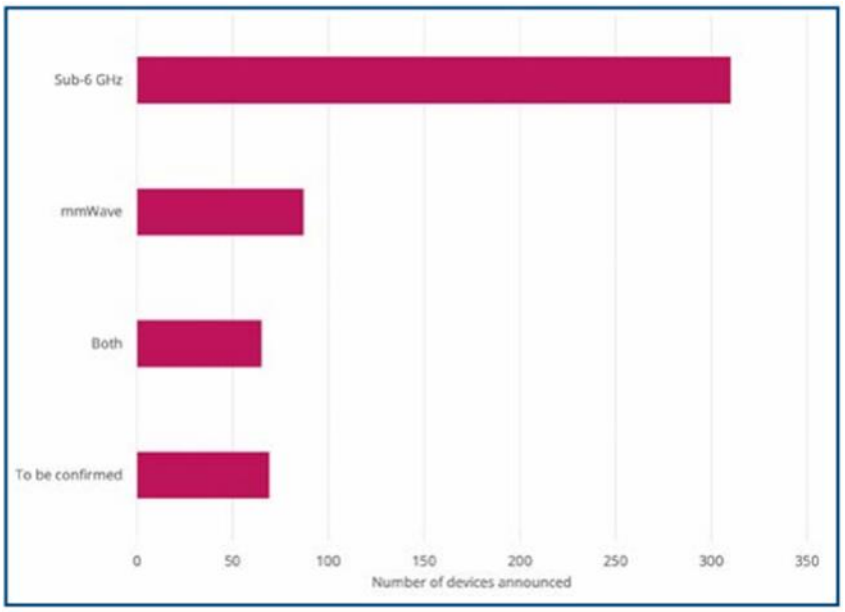
Band	Frequencies (GHz)	Bandwidth (MHz)	Duplex mode
n257	26.5-29.5	50-400	TDD
n258	24.25-27.5	50-400	TDD
n259	39.5-43.5	50-400	TDD
n260	37.0-40.0	50-400	TDD
n261	27.5-28.35	50-400	TDD

Source: 3GPP

Chipsets supporting band n258 (24.25-27.5 GHz) are becoming available. Qualcomm Technologies scheduled to ship samples of Snapdragon X60 and QTM535 in the first quarter of 2020, with commercial premium smartphones using the new Modem-RF System expected in early 2021. Qualcomm mm-wave antenna modules support 3GPP bands n.260, n261 and n257 (26.5 – 29.5 GHz) and n258 (24.25 –27.5 GHz).

According to GSA, in July 2020, "only 31 of the commercially available devices (23% of them) are understood to support services operating in mmWave spectrum".

Figure A.2: Announced devices with known spectrum support, by broad category – September 2020



Source: GSA

During the first half of 2020, much of the mm-wave device ecosystem was driven by the need to support US 5G networks but this was expected to gradually change from Q2 2020 as use of other mm-wave bands occurs in countries such as Korea and Japan. While no devices had been announced for the n258 (26 GHz) band in December 2019, (the mm-wave frequency of choice in Europe and China for latter deployments), devices are now becoming available.

Figure A.3: Distribution of announced 5G devices by range of frequency band*

Frequency band range	Number of devices announced	Average progress in the category March 20 / Dec 19
39 GHz (mainly US)	22	37,5%
28 GHz (mainly US)	41	51,9%
n257 (JP, SK and US)	13	62,5%
n258 (Australia, China, Europe)	5	66,7%
n261 (Verizon)	23	43,8%
between 3.5 and 5 GHz (Global)	190	5,4%
between 1.8 and 2.6 GHz (Global)	351	56,6%
< 1.8 GHz (Global)	148	43,7%

Source: gsacom, halberdbastion and IDATE * Note that one same device might be listed several times in different category when supporting several bands at the same time

According to Huawei, high–end smartphones incorporating mm-wave bands, will cost 500$ and mid-end smartphones 300$ in 2021.

Network equipment is also becoming available from the main network equipment manufacturers (Huawei, Ericsson, Nokia, Samsung and ZTE). Samsung provided 26 GHz base stations and customer premises equipment

(CPE) to Orange Romania in 2018/2019 in order to perform tests of fixed wireless services. The operator used 500 MHz of spectrum between 26.65 GHz and 27.5 GHz.

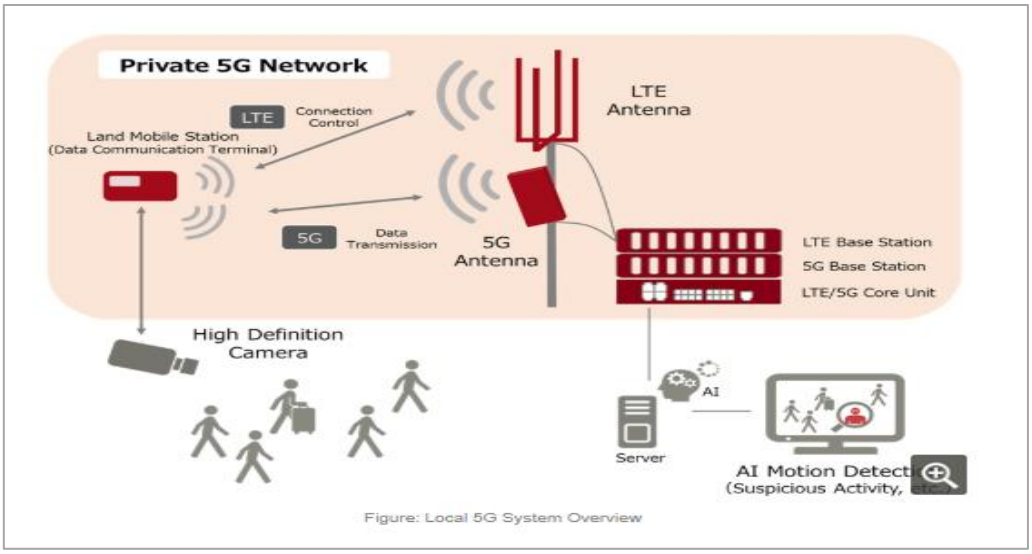
A.2 Private networks

The following are two examples of private networks.

In September 2020, Mercedes Benz announced that its latest factory with private 5G network was provided by Ericsson and Telefonica Germany.

In Japan, Fujitsu was the first industrial players to obtain a private 5G radio station provisional licence in the 28 GHz band. Fujitsu installed a 5G network at its offices in Kawasaki City to cover approximately 28,000 square metres and is expected to obtain another licence for private 5G at its Oyama plant in Tochigi Prefecture, which serves as a manufacturing base for network equipment. The functionalities supported by the 5G network are various use cases for private 5G, to deliver business innovation and to help resolve regional issues through the Fujitsu Collaboration Lab, the provision of high-definition images collected by multi-point cameras and the use of motion analysis for an AI-powered security system.

Figure A.4: Fujitsu 5G private network system overview



Source: Fujitsu

Appendix B 26 GHz award in USA and Asia Pacific

In the following sections we provide further information on the awards and associated services in the USA and Asia Pacific (Australia, China, Hong Kong, Japan, Singapore, South Korea and Thailand).

B.1 USA

B.1.1 Award of mmWave spectrum and regulatory backdrop

- July 2016: 10.85 GHz made available in the 28 GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz) and 39 GHz (38.6-40 GHz) bands. FCC also enabled use of spectrum between 64 GHz and 71 GHz by unlicensed devices (subject to restrictions).
- In November 2017 additional 1700 MHz of high band spectrum for flexible terrestrial wireless use in the 24 GHz (24.25-24.45/24.74-25.25 GHz) and 47 GHz (47.2-48.2 GHz) bands made available
- In June 2018, the FCC voted to proceed with making the upper 26 GHz (25.25–27.5 GHz) and 42 GHz (42–42.5 GHz) bands available for 5G services, while examining further aspects of the bands already in the 5G pipeline.
- In July 2018, the FCC considered options for up to 500 MHz of spectrum in the 3.7-4.2 GHz frequencies. It is usually satellite companies that use these frequencies.
- On 28 September 2018, the FCC and the White House hosted a session on how to foster private investment on 5G. The FCC announced its 5G Fast Plan. Described in a one-page document, the strategy includes three key topics: releasing more spectrum, infrastructure policy updates and modernising outdated regulations. For each topic, the 5G Fast Plan mentions recent FCC actions and documents.
- The FCC's auction of residual 28 GHz (27.5-28.35 GHz) frequencies began in November 2018. The auction closed in January 2019. Bids reached 703 million USD.
- FCC's 24GHz auction ended in May 2019, generating total bids of 2.02 billion USD (1.77 billion EUR). Twenty-nine bidders won 2904 licences.
  - AT&T was the big winner, paying USD982 million (862.1 million EUR) for 831 of the 2,909 available licences.
  - T-Mobile US paid USD803 million (705 million EUR) for 1,346 licences.
- In December 2019, the Federal Communications Commission unveiled plans to establish a new "5G Fund" of up to 9 billion USD (8 billion EUR) in Universal Service Fund to support mobile operators to contribute with the deployment of 5G services across rural America.
- Auction 103, which comprised spectrum in the upper 37 GHz, 39 GHz and 47 GHz bands, started in December 2019 and concluded in March 2020.
  The auction generated gross proceeds of USD7.57 billion.
  - Verizon offered 3.417 billion USD for a total of 4,940 licences.

- AT&T offered 2.379 billion USD for 3,267 concessions.
- T-Mobile US committed to pay 931.609 million USD for 2,384 spectrum permits.

B.1.2 Obligations attached to the licences

Document 47 CFR Parts 2, 25 and 30 of the FCC[139] describes use of spectrum bands above 24 GHz for Mobile Radio Services.

Population coverage are set at "at least 40 percent of the population within the service area of the licensee".

Coverage obligations are the following: « ...demonstrating mobile or point-to-multipoint coverage of at least 25% of their license's geographic area, or by showing the presence of equipment transmitting or receiving on the licensed spectrum in at least 25% of census tracts within the license area."

24 GHz FSS (Fixed Satellite Sharing) Sharing is also mandatory for 5G users of this frequency band.

B.1.3 5G services

In the USA 5G has been launched and provides useful information on the services that may be provided.

Figure B.1: 5G services in the USA

Operator	Service	Launch date	Coverage and comments
Verizon	5G Mobile service	April 2019	35 cities as of July 2020. Expects to offer it in more than 60 markets by the end of 2020.
	5G Fixed service	October 2018	Parts of Houston, Indianapolis, Los Angeles, Sacramento, Chicago. Expects to offer it in 10 cities by the end of 2020. - Expected speeds ranging from 300 Mbps to up to around 1 Gbps, depending on location.
AT&T	5G Mobile service	December 2018	5G network in the 850 MHz band in over 355 markets, covering about 180 million people as of June 2020. AT&T's faster mm-wave network was launched for consumer access in March 2020, now offers 5G coverage in parts of 35 cities. A much slower version "5G E" was launched in December 2018.
T-Mobile	5G Mobile service	July 2019	In July 2019, T-Mobile USA pre-launched its 5G services in selected parts of six US cities (Atlanta, Cleveland, New York City, Los Angeles, Dallas, and Las Vegas) using the 28 and 39 GHz frequencies. On December 2, 2019 T-Mobile switched on its 5G network using the 600 MHz frequency band, covering more than 200 million people and more than 5 000 cities and towns across the country. However, data rates available with the 600 MHz spectrum alone are not much faster than the data rates provided by LTE services.

[139] https://www.govinfo.gov/content/pkg/FR-2018-07-20/pdf/2018-14806.pdf

Operator	Service	Launch date	Coverage and comments
Sprint	5G Mobile service	May 2019	Atlanta, Dallas-Fort Worth, Houston, and Kansas City and in Chicago, Los Angeles, New York City, Phoenix and Washington, DC in September 2019. As of April 2020, T-Mobile started to open nationwide 5G access for Sprint customers network in the 600 MHz and mm-wave bands and as of June 2020 the operator started to deactivated Sprint's 5G service using 2.5 GHz spectrum, switching Sprint customers to its own 5G network. - 5G Non-Standalone network is using 2.5 GHz spectrum and massive 128-antenna MIMO equipment to be able to operate 4G at the same time.

Source: IDATE DigiWorld, 5G markets in North America, July 2020

Fixed Wireless Access services

Verizon 5G Home service was launched on 1 October 2018 in limited parts of four US cities using the 28 GHz band. The 5G fixed wireless access service delivers average speeds of 300 Mbps and peak speeds up to 1 Gbps with unlimited data usage, no data cap, and no annual contract. The 5G home plan is a data-only plan, which is subscribed separately from other Verizon plans. The service is free of charge for the first three months. After the promotion time, it will cost 50 USD per month for current Verizon subscribers and 70 USD per month for non-Verizon subscribers.

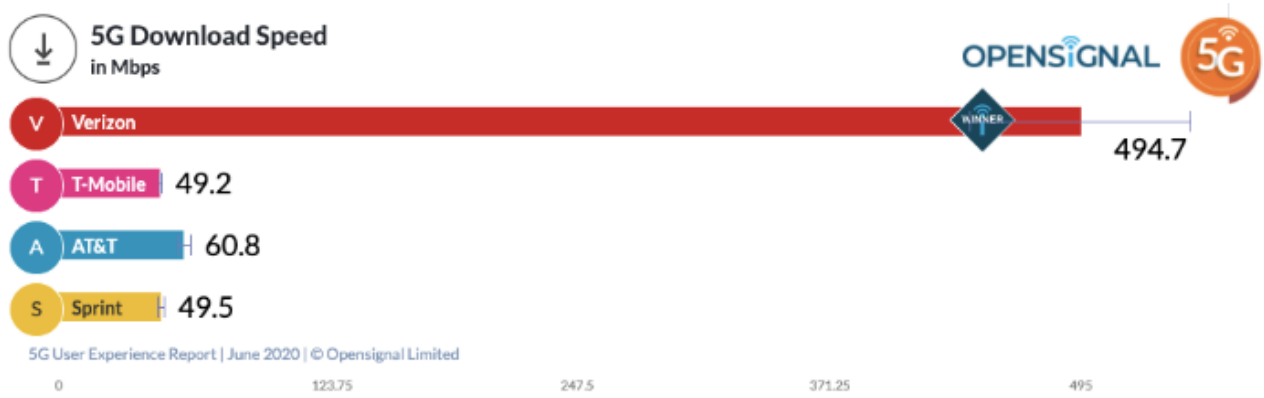
Mobile services

AT&T pre-launched 5G services with mm-wave network in December 2018. AT&T's faster mm-wave network was launched for consumer access in March 2020, now offers 5G coverage in parts of 35 cities.

In July 2019, T-Mobile USA pre-launched its 5G services in selected parts of six US cities (Atlanta, Cleveland, New York City, Los Angeles, Dallas, and Las Vegas) using the 28 & 39 GHz frequencies.

In April 2019, Verizon also launched 5G services using the 28 & 39 GHz mm-wave spectrum bands. The table below shows that Verizon is offering much higher throughputs than its rivals, close to 500 Mbps.

Figure B.2: **5G download speed in the USA**



Source: OpenSignal

B.2 Australia

Australia planned to assign the 26 GHz band to their mobile operators in March 2021. Following analysis from the Australian Competition and Consumer Commission, the Australian Communications and Media Authority

(ACMA) was requested to set the allocation limit in each designated area at 1 GHz, or about 42 per cent of the total 26 GHz spectrum available. For the 26 GHz band, the Australian government has proposed:

- Class licence access to 24.25–25.1 GHz
- area defined spectrum & apparatus licenses in 25.1–27.5 GHz
- national apparatus licenses in 24.7–25.1 GHz

Figure B.3: Status of the 26 GHz band in Australia

Australia	Characteristics	Comments
Frequency bands	26 GHz	
Assignment date	April 2021	
Quantum of spectrum assigned	2.4 GHz (in 2021)	Allocation limits of 1 GHz for this spectrum auction per operator
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	ACMA has developed apparatus and class licensing frameworks across the 26 GHz and 28 GHz millimetre wave bands. Auction for spectrum licenses. The spectrum will be divided into 29 geographic blocks.	Spectrum licences in the 26 GHz band will have a 15-year term and will be sold via an auction. ACMA will charge AWL holders in annual licence tax. It is proposing a fee of A$0.0003/MHz/pop. AWLs (Area Wide Apparatus Licences) will have a five-year term
Licensees assigned the spectrum	Spectrum not yet assigned	
Services being provided, its take-up and planned for the coming years	Mobile services and fixed wireless access services should be provided in 2021.	mm-wave technology will enable higher speed and reduced latency for its customers, especially in highly dense areas with large demand (Optus)
Use cases being served	Services in the 26 GHz band not yet available	Expected use cases: robotics, automated vehicles, advanced manufacturing and the remote operation of heavy vehicles and equipment in resources and construction. It will also support the use of sensor technology which has many important applications, such as networks of soil moisture monitors on farms to allow improved yields while using less water
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	Tests by Optus in Sydney	

Source: IDATE/PLUM

The ACMA proposes to allocate apparatus licences adjacent to the spectrum licences in the 26 GHz band. The Minister asked the ACCC to provide advice on any competition issues associated with the apparatus licences and whether restrictions on allocation of apparatus licences should be applied. The Minister also asked for the ACCC to consider whether apparatus licensed spectrum holdings in the 26 and 28 GHz bands should be taken

into account for any allocation limits on the 26 GHz spectrum licences. ACMA will also award conventional 5G spectrum licences in the bands.

Figure B.4: Summary of licensing arrangements and available bandwidth

Geographic area		Frequency range (GHz)		Bandwidth (MHz)	Licence Type
Australia-wide		24.7	25.1	400	Apparatus
Australia wide	**Defined areas**	**25.1**	**27.5**	**2400**	**Spectrum**
	Outside defined areas	25.1	27.5	2400	Apparatus
Australia wide	Defined areas	27.5	28.1	600	Apparatus
	Outside defined areas	27.5	28.1	600	Apparatus
Australia-wide		28.1	29.5	1400	Apparatus

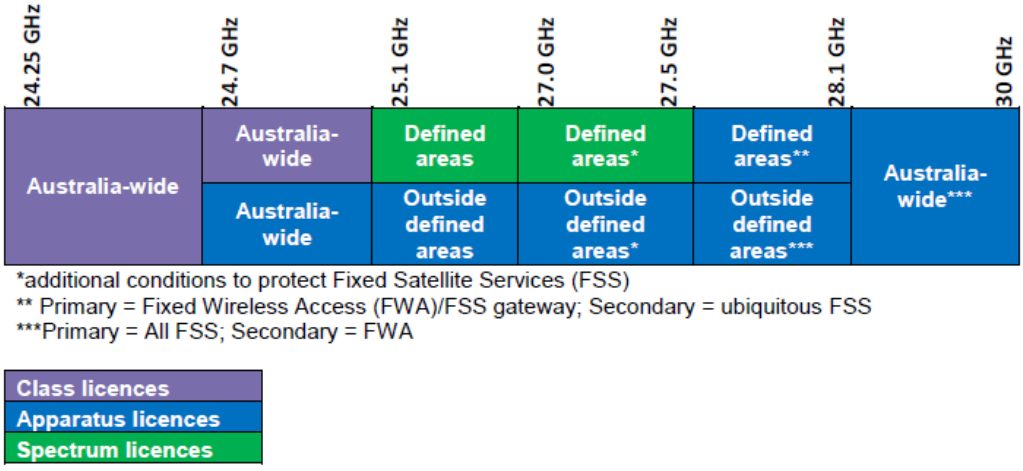
Source: ACMA

Main characteristics of apparatus licences

Apparatus licences, or AWLs will represent a new arrangement to accommodate localised, possibly industry-specific 5G applications as well as FWA (fixed wireless access) and FSS (fixed service satellite) applications. An apparatus licence enables a user to operate the transmitters or receivers associated to a licence. It is only possible to use them at the place or in the area specified on the licence. AWLs will only have a five-year term; they give a much higher level of flexibility than traditional apparatus licences.

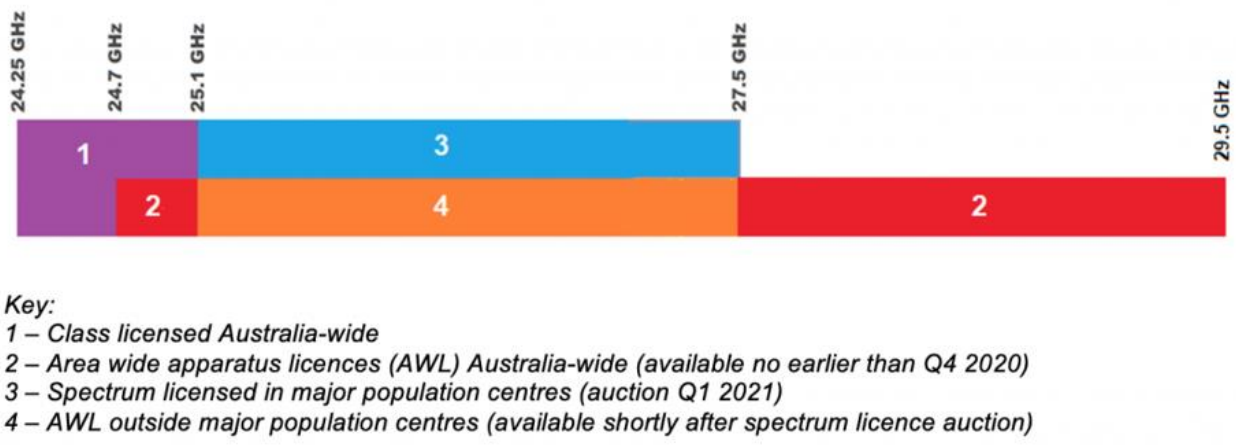
An apparatus licence may be an assigned licence or a non-assigned licence.

Figure B.5: Licensing arrangements for the 26 GHz and 28 GHz bands



Source: ACMA

Figure B.6: Licensing arrangements to be implemented in the 26-28 GHz band



Source: ACMA

The ACMA has now detailed the process for award of AWL licences[140]. Licences allow users to aggregate frequencies area blocks in a single licence. Areas are based on pre-defined HCIS cells. There are two planned rounds for licence applications:

- Round 1: 24.7 – 25.1 GHz, Australia wide between 4 and 17 November 2021 with restrictions on number of base stations to manage interference by preventing wide and dense deployments, and
- Round 2: 25.1 – 27.5 GHz in all areas other than those designated for spectrum licensing in first half of 2021.
- After these two rounds will use FCFS.

In the case that there are competing applicants for the same spectrum in rounds 1 and 2 then, these applications will move to the second stage of the decision-making process: resolving competing spectral demand. First when 2 or more applicants have applied for spectrum in the same HCIS cell and frequency band, but there is sufficient spectrum across the bands to meet all demand then the ACMA will assist the applicants to negotiate an outcome, where one or more of the competing applicants may be offered other spectrum in the same segment or in another segment of the bands.

In the case there is insufficient spectrum for all applicants in the bands and the geographic location then applications will be considered in accordance with the following principles:

- "the allocation (both in quantum of spectrum and in geography) will be consistent with the proposed use-cases of the applications received
- the allocation will promote the efficient use of spectrum in a manner consistent with the technical arrangements supporting planned uses
- the allocation outcome will facilitate a diversity of licensees offering a variety of innovative technology use-cases
- the allocation will consider, for each applicant, the extent to which a denial of the spectrum in question would affect the ability of the applicant to deploy services."

[140] https://www.acma.gov.au/area-wide-apparatus-licensing-26-and-28-ghz-bands

With a complex patchwork of licence types, ACMA's objective is to enable a range of different services and providers to coexist in the 26 and 28 GHz band.

The ACMA announced in December 2020 that a total of 15 companies have secured new spectrum in the 26GHz and 28GHz bands[141]. The ACMA noted that a number of the successful applicants intend to provide wireless broadband services across all states and territories and across urban, regional and rural areas, while highlighting the fact that there had been 'considerable uptake from fixed satellite service providers across Australia, including from existing providers and new entrants to the Australian satellite market'.

Business case

At mid-2020, Australian operators are using the 3.6 GHz band for 5G commercial services. Telstra launched 5G late in May 2019 and announces its 5G network will cover 75% of the country's population by June 2021.

Optus pre-launched in 2018 with Fixed Wireless Access services in the 3.6 GHz band. Mm-wave spectrum will enable higher speed and reduced latency, especially in highly dense areas with large demand. Optus obtained approval from the Australian Communications and Media Authority (ACMA) to test 5G technology in the 26 GHz band at four locations in Sydney. Optus had announced in 2019 the availability of its 5G Home fixed wireless service across the 138,000-home footprint covered by its 5G network.

TPG (previously Vodafone Hutchison Australia) is still in the process of deploying its 5G network.

In June 2020, Qualcomm Technologies, Casa Systems and Ericsson performed a 5G data call using mm-wave spectrum over a distance 3.8 kilometre's. According to the three companies, it is the "farthest-ever connection" ever realised and it proves that millimetre-wave bands are suitable for fixed wireless access services in rural areas.

B.3 China

mm-wave bands status

China has announced that they will assign the 26 GHz band to their mobile operators. The 24.75-27.5 GHz and 37-42.5 GHz frequency bands have been approved for 5G trials in China. There is not yet a timeline for the allocation of mm-wave spectrum to the operators.

Figure B.7: Status of the 26 GHz band in China

China	Characteristics	Comments
Frequency bands	24.75–27.5 GHz 37–43.5 GHz	
Assignment date	n.a.	
Quantum of spectrum assigned	n.a.	

[141] ACMA offers 15 applicants 26GHz/28GHz spectrum (commsupdate.com)

China	Characteristics	Comments
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	n.a.	
Licensees assigned the spectrum	Spectrum not yet assigned	
Services being provided its take-up and planned for the coming years	Mobile services	
Use cases being served	Services in the 26 GHz band not yet available.	Expected use cases: Automotive & Transport, Industry 4.0, Media & Entertainment, Energy/utilities monitoring, Security, Finance
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	Tests by China Mobile, China Unicom, and China Telecom.	

Source: IDATE/PLUM

Chinese officials have allocated mostly mid-band spectrum (2.6 GHz, 3.5 GHz, and 4.8 GHz) to the country's four 5G wireless providers at no cost.

The Ministry of Industry and Information Technology (MIIT) announced that it is expected that the country will also use the 24.75–27.5 GHz band and the 37–43.5 GHz band and initiated a stakeholder consultation on these bands with no set timeline yet for allocation to operators.

In the meantime, China Mobile, China Unicom, and China Telecom are performing trials and building pilot networks using the 26 GHz band in preparation for a large-scale demonstration of mm-wave 5G at the Beijing Winter Olympics in February 2022.

Figure B.8: 5G commercial launches, coverage, and subscriptions in China

Operator	Launch date	Coverage	5G subscriptions	Comments
China Mobile	November 2019	As of July 2020, China Mobile provides 5G coverage in 50 cities. Carried out 5G network construction in more than 300 cities across the country. 140 000 5G base stations as of May 2020. The company target to construct 300,000 base stations by the end of 2020.	70 million 5G subscriptions as of April 2020. 100 million self-brand and third-party 5G smartphones sells in 2020.	The Ministry of Industry and Information Technology announced 250,000 5G base stations across the country as of May 2020. China expects to build
China Telecom	November 2019	Agreed with China Unicom in September 2019 to share the construction of base stations in 24 cities. The company expects to complete the construction of 300,000 base stations by the end of Q3 2020, covering all municipals levels of the country.	38 million subscriptions as of July 2020.	

China Unicom	November 2019	Agreed with China Telecom in September 2019 to share the construction of base stations in 24 cities. China Unicom and China Telecom had co-construct 115,000 base stations. China Unicom target to co-build and share 250,000 5G base stations by Q3 2020, covering all municipals levels of the country.	1.76 million customers in early October 2019. Has not issue 5G statistics in 2020.	more than 600,000 5G base stations by the end of 2020.

Source: IDATE DigiWorld, 5G markets in Asia-Pacific, July 2020

On November 1st, 2019, China Mobile, China Telecom and China Unicom jointly launched 5G services nationwide in 50 cities using mid-band spectrum. China is by far the world leader with over 80 million 5G connections as at end May 2020 according to public announcements.

The Ministry of Industry and Information Technology announced that up to date, telecommunications companies have built more than 250,000 5G base stations across the country. China expects to build more than 600,000 5G base stations by the end of the year, covering cities above the prefecture level in the country.

B.4 Hong Kong

On 15 July 2019, the Office of the Communications Authority (OFCA) invited applications for assignment of spectrum in the 26 GHz band (24.25 – 27.5 GHz) and 28 GHz band (27.5 – 28.35 GHz) on a geographically sharing basis (Shared Spectrum), for the provision of 5G or other advanced mobile technologies. 400 MHz of the total 4,100 MHz available in the two bands is being set aside on a shared basis for localised wireless services, for instance a specific application or industry.

The 26.55 – 27.75 GHz band was awarded with three operators each receiving 400 MHz of spectrum for the provision of large scale public mobile services without any charge.

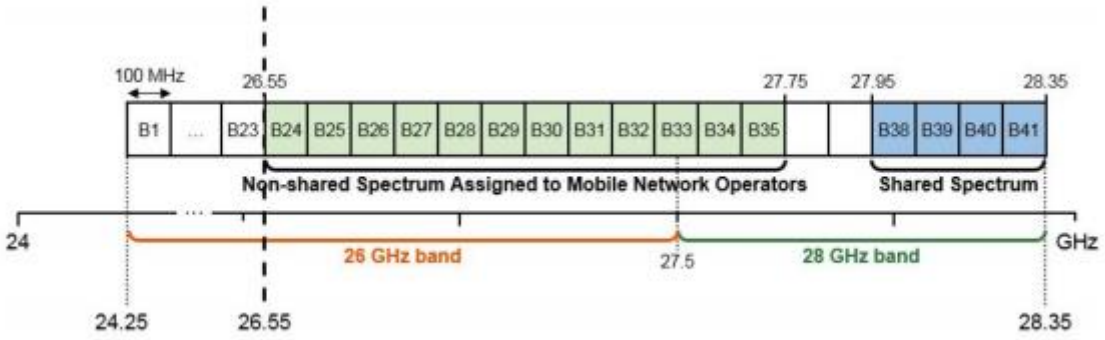
Figure B.9: 26 GHz assignments in Hong Kong

Successful applicant	Frequency range	Amount (MHz)
SmarTone Mobile Communications Limited	26.55 – 26.95	400
China Mobile Hong Kong Company Limited	26.95 – 27.35	400
Hong Kong Telecommunications (HKT) Limited	27.35 – 27.75	400

Source: OFCA

The band plan for the 26 and 28 GHz bands in Hong Kong is presented in the figure below:

Figure B.10: Band Plan for the 26/28 GHz Bands



Source: Office of the communications authority – Hong Kong

The detailed status of the 26 GHz band in Hong Kong is provided below:

Figure B.11: Status of the 26 GHz band in Hong Kong

China	Characteristics	Comments
Frequency bands	26 GHz (26.55-27.75 GHz)	
Assignment date	March 2019	
Quantum of spectrum assigned	1200 MHz	
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	Competitive award process No charge for the spectrum assigned in 2019 400 MHz of shared spectrum (27.95-28.35 GHz) reserved in different specified locations for the provision of localised and innovative wireless broadband services. Newly created Localised Wireless Broadband Service (LWBS) Licence with less stringent requirements as compared with conventional public mobile services licensed under the Unified Carrier Licence. Total network coverage of each assignee shall not exceed 50 square kilometres.	OFCA imposes licence holders to install and put into use a minimum number of units within five years.
Licensees assigned the spectrum	HKT, SmarTone, China Mobile HK (CMHK)	
Services being provided its take-up and planned for the coming years	Fixed Wireless Access (SmarTone)	Mobile services
Use cases being served	N/A	
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	N/A	

Source: IDATE/PLUM

Business case

In September 2020 SmarTone has announced a fixed wireless service that will effectively target incumbent HKT. The operator will target "20-25% of the market" for customers that currently have either slow or an expensive home broadband service using legacy ADSL. The fixed wireless service will be priced at HK$148 ($19.10) – half the standard HK$298 ($38.45) price charged by incumbent HKT.

Hutchison 3, the territory's fourth mobile operator did not take part in the award process, indicating that there will be sufficient spectrum available for its 5G services in the 3.3GHz, 3.5GHz and 4.9GHz bands.

B.5 Japan

mm-wave bands status

Japan is progressively seeing use of the 28 GHz band (27.0-29.5 GHz) for 5G. MIC has awarded in March 2019 four blocks of 400 MHz at 28 GHz. The 28.2-28.3 GHz band is reserved for private 5G networks and applications were opened in December 2019. MIC has stated it would consider allocation of spectrum from 28.3–29.1 GHz for local private services, in the future, which might not be allocated to national mobile operators.

Figure B.12: Status of the 26 GHz band in Japan

Japan	Characteristics	Comments
Frequency bands	27.0-28.2 GHz 29.1-29.5 GHz	
Assignment date	April 2019	
Quantum of spectrum assigned	400 MHz for each of the four mobile operators	
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	Beauty contest. All four telcos must launch 5G services using the new spectrum in every Japanese prefecture within two years (including spectrum in the 3.6-4.2 GHz & 4.4-4.9 GHz). Japan was sub-divided into 4,500 blocks. All four spectrum holders must set up base transceiver stations (BTS) in at least half of the blocks within five years. Coverage of the population 5 years after issuance of the licence: between 56% and 90% of the population. MNOs also committed to a minimum investment in their 5G networks. 28.3-29.1 GHz reserved for local licences.	
Licensees assigned the spectrum	NTT Docomo, KDDI, Softbank, Rakuten	
Services being provided its take-up and planned for the coming years	Mobile services	

Japan	Characteristics	Comments
Use cases being served	Services in the 26 GHz band not yet available.	Expected use cases: Media & Entertainment, Automotive & Transport, Industry 4.0, Autonomous services, logistics.
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	Services in the 26 GHz band not yet available.	

Source: IDATE/PLUM

Sub-6 GHz and 26-28 GHz auction, April 2019

No fees applied in this spectrum allocation process. However, 5G spectrum allocation implies several commitments for operators. All four operators must launch 5G services using the new spectrum in every Japanese prefecture within two years (including spectrum in the 3.6-4.2 GHz & 4.4-4.9 GHz). Japan was sub-divided into 4,500 blocks. All four spectrum holders must set up base transceiver stations (BTS) in at least half of the blocks within five years.

Figure B.13: Sub-6GHz and 26-28 GHz auction results, allocation by operator (April 2019)

	Sub 6 GHz	24 GHz	26-28 GHZ	39 GHz
NTT DoCoMo	3.6 - 3.7 GHz4.5 - 4.6 GHz	—	27.4 - 27.8 GHz	—
KDDI	3.7 - 3.8 GHz4.0 - 4.1 GHz	—	27.8 - 28.2 GHz	—
Softbank	3.9 - 4.0 GHz	—	29.1 - 29.5 GHz	—
Rakuten	3.8 - 3.9 GHz	—	27.0 - 27.4 GHz	—

Source: IDATE DigiWorld, 5G markets in Asia-Pacific, September 2019

The mobile operators committed to the following coverage of the population 5 years after issuance of the licence:

- NTT Docomo: >90%
- KDDI: >90%
- Softbank: 64%
- Rakuten: 56%

The mobile operators also committed to the following investments in their 5G networks:

- NTT Docomo: 7 billion USD
- KDDI: 4.1 billion USD
- Softbank: 1.8 billion USD
- Rakuten: 1.7 billion USD

Figure B.14: 5G commercial launches and coverage in Japan

Operator	Launch date	Coverage
NTT DoCoMo	March 2020	The network went live in 150 areas in Japan (500 base stations) covering 29 of the nation's 47 prefectures. Plans to go live in 500 cities by YE2020. 90% of the country covered by 2025. Expects 2.5 million 5G subscribers as at YE 2020 and 20 million in 2023. 10,000 base stations in June 2021 and 20,000 in March 2022.
KDDI	March 2020	15 of Japan's 47 prefectures. 90% of the country covered by 2025. 10,000 base transceiver stations by 31 March 2021 and 50,000 BTS by the end of March 2022.
Softbank	March 2020	7 prefectures across Japan. 10,000 5G base stations by end of March 2023 64% of the country covered by its 5G network by 2025.

Source: IDATE DigiWorld, 5G markets in Asia-Pacific, July 2020

Business case

Fujitsu Launches Japan's First Commercial Private 5G Network using the 28.2 GHz to 28.3 frequency band:

Fujitsu was granted in March 2020 Japan's first commercial Private 5G radio station license from the Kanto Bureau of Telecommunications in the 28.2 GHz to 28.3 frequency band for its Shin-Kawasaki Technology Square office (about 28,000 square meters).

Fujitsu will strengthen crime prevention measures in the building by leveraging its Private 5G technology for data transmission of high-definition images collected by multi-point cameras, creating an AI-powered security system that quickly detects suspicious behaviour through motion analysis.

Fujitsu will also offer customers and partners the chance to workshop various use cases for private 5G to deliver business innovation and help resolve regional issues.

Furthermore, the company aims to obtain an additional licence for private 5G to create a smart factory at its Oyama plant in Tochigi Prefecture, which serves as a manufacturing base for network equipment. Fujitsu will verify the utility and possible applications for its private 5G technologies.

Mitsubishi conducts test of local 5G network using the 28.2 GHz to 28.3 frequency band:

The Ministry of Internal Affairs and Communications licenced local 5G network to the Japanese company for use in a limited area and operating the 28.2GHz-28.3GHz band.

In May 2020, Mitsubishi Electric announced the completion of a test designed to verify wireless transmission between local 5G base stations and Mitsubishi Electric's factory automation products.

Mitsubishi Electric expects to deploy local 5G systems to deliver new services and businesses incorporating a wide range of Factory Automation and other products.

The test will also help to confirm various possible uses of envisioned local 5G systems, such as remote operation and maintenance support, usage of augmented and virtual reality for enhanced work efficiency, said Mitsubishi Electric.

B.6 Singapore

In June 2020, the IMDA awarded the two mobile-network operators' national spectrum packages, comprising 100 MHz of 3.5 GHz frequency, each paired with one lot of 800 MHz of millimetre wave (26GHz and 28GHz), to Singapore Telecommunications Limited and joint-bidders StarHub and M1 - based on their network security designs, network rollout and financial standing[142].

B.7 South Korea

mm-wave bands status

The 3.5 GHz and 28 GHz auction was completed in June 2018- Total bids reached 3.6 trillion KRW (2.8 BEUR) of which 82% was for 3.5GHz spectrum. Spectrum authorisations were issued between September and December 2018. Use of spectrum was possible from December 1st, 2018.

The government arranged the simultaneous 5G launch by all players in April 2019. Commercial launches in 2019 used the 3.5 GHz band. The 28 GHz band is going to be used at a second stage by South Korean mobile operators to provide capacity and higher data rates.

Figure B.15: Status of the 26 GHz band in South Korea

South Korea	Characteristics	Comments
Frequency bands	28 GHz (26.5-28.9 GHz)	
Assignment date	June 2018	
Quantum of spectrum assigned	2400 MHz	
Key aspects of the licensing framework for assigning this spectrum (e.g. competitive award process, national/local area licences, indoor only, etc.)	Base price of 621.60 billion KRW (440 million EUR). Licences valid from December 2018 for five years. 800 MHz assigned to each operator (Maximum amount of frequencies to be assign to one operator: 1000 MHz)	
Licensees assigned the spectrum	LG Uplus, SK Telecom, KT	
Services being provided its take-up and planned for the coming years	Mobile services should be provided in 2021. Services for industry by 2021.	
Use cases being served in Q3 2020	Services in the 26 GHz band not yet available.	Expected use cases: Industry, Media (Immersive media, AR/VR, UHD, 360° VR live broadcast), Immersive services, Autonomous services, Intelligent services, PPDR services, Smart city.
Actual use of the band (noting if this usage is in demographic areas comparable to Ireland)	Services in the 26 GHz band not yet available.	

Source: IDATE/PLUM

[142] https://www.fitchratings.com/research/corporate-finance/singapore-presses-ahead-with-5g-driving-telecoms-capex-29-04-2020

28 GHz spectrum auction, June 2018

Starting prices were confirmed in April 2018, with the minimum cost of blocks in the 3.5GHz band set at 2.65 trillion KRW (1.88 billion EUR), and a base price of 621.60 billion KRW (440 million EUR) decided on for blocks in the 28GHz band. 2400 MHz of 28 GHz spectrum was allocated, under licences valid from December 2018 for five (28GHz), ten (3.5GHz) years.

Figure B.16: 5G spectrum auctions in South Korea

28 GHz auction, June 2018						
Operator	Quantity of spectrum (MHz)	Frequency band uplink	Frequency band downlink	Total price (LC)	Total price (EUR)	Price (EUR cent) / MHz / pop. (for 10 years)
LG Uplus	800	27.3	28.1	207 200 000 000	159 196 029	
SK Telecom	800	28.1	28.9	207 300 000 000	159 272 861	
KT	800	26.5	27.3	207 800 000 000	159 657 021	
Total	2400	26.5	28.9	622 300 000 000	488 294 314	0.80 €

Source: IDATE DigiWorld, 5G markets in Asia-Pacific, July 2019

The MSIT also set a limit on the maximum amount of frequencies that could be assigned to one mobile carrier: no more than 100MHz in the 3.5GHz band and 1,000MHz in the 28GHz band.

Business case

The figure below provides information on commercial launches.

Figure B.17: 5G commercial launches and coverage in South Korea

Operator	Launch date	Coverage	5G subscriptions	Comments
LG Uplus	April 2019: 5G service nationwide	Cities of Seoul, Incheon, Daejeon, Bucheon, Goyang, Gwangmyeong, Hanam and other cities in Gyeonggi Province. 18,000 5G sites (April 2019). Planned 50,000 end 2019.	As of May 2020, with 1.68 million 5G subscribers	The Korean government said in Q2 2020 that local operators had already deployed over 115,000 5G base stations across the country. South Korea ended May 2020 with almost 6.9 million 5G subscribers, 10% of the 69.43 million mobile service lines in the country.
SK Telecom	April 2019: 5G service nationwide	Main areas of 85 cities nationwide, university districts, sports stadiums, expressways, subway lines and beaches. Also expanding indoor coverage in 120 department stores, shopping malls and airports throughout the country.	As of May 2020, with 3.11 million 5G subscribers. Expects to reach between 6 and 7 million 5G subscribers by the end of 2020.	
KT	April 2019: 5G service nationwide	7 cities covered, 24 additional cities to be covered soon, 85 cities as at end of 2019. They are seeking to provide 5G coverage in subways, public office buildings, hospitals, and colleges.	Ended April 2020 with 1.8 million 5G subscribers.	

Source: IDATE DigiWorld, 5G markets in Asia-Pacific, July 2020

South Korean operators targeted to launch 5G, over mm-wave frequencies, to industry by the end of 2020. The mm-wave 5G service will be initially available for the B2B segment. Stations for the mm-wave 5G network will be installed in areas that handle high loads of data traffic.

Operators have not yet finalised investment plans for the B2C sector, as the cost of building additional infrastructure represents a major issue. An SK Telecom official said; The launch of the mmWave 5G network for personal smart devices is likely to start in 2021 or in 2022", reported The Korea Herald.

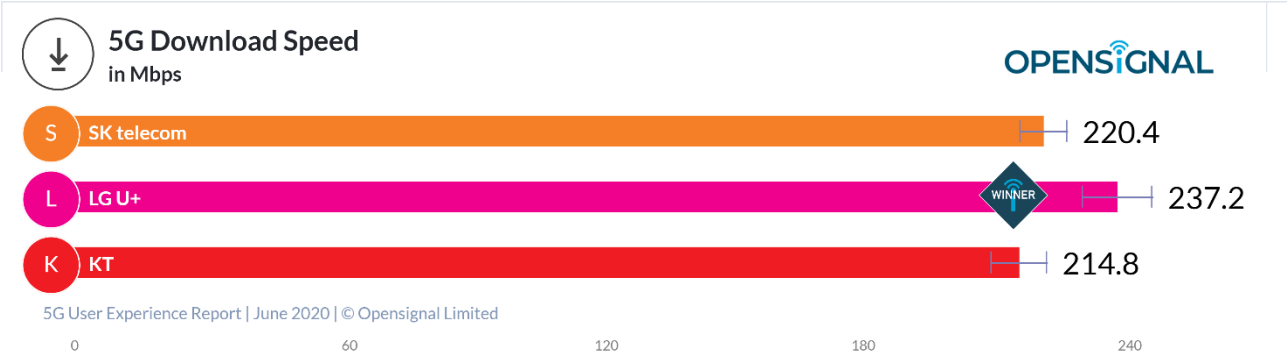
SK Telecom and Microsoft have announced they will launch the Xbox cloud gaming streaming service in South Korea in September 2020, using mid-band frequencies. Formerly known as Project xCloud, the service will be added to the Xbox Game Pass Ultimate. This means users can play Xbox console games on Android mobile phones and tablets, from cloud servers streaming over 5G.

By paying around 14 USD a month for a subscription, users will have access to a library of around 100 Xbox games, each of which is available to play on mobile using the cloud infrastructure, without requiring a download.

SK Telecom has increased customers' 5G experience and acceptance by creating around 70 5G Clusters in key commercial districts and densely populated areas throughout the nation. To date, around 1 million customers visited 5G Clusters to experience differentiated 5G services including 'Jump AR Zoo' and '5G LoL Park' (esports).

In 2020, SK Telecom will bring the total number of its 5G Clusters to 240 and expand 5G coverage to neighbourhoods of 85 cities nationwide by working closely with telecommunications equipment manufacturers.

Figure B.18: **5G download speed in South Korea**



Source: OpenSignal

B.8 Thailand

In February 2020 Thailand awarded 26 out of 27 national 26 GHz licences each with 100 MHz bandwidth[143].

Market leader AIS was limited from bidding for more than 100 MHz in the 2.6 GHz band and 1200 MHz in the 26 GHz band by spectrum caps. AIS spent THB42.1 billion for the remaining 5 MHz block in the 700 MHz band, 100 MHz of 2.6 GHz and 1200 MHz in the 26 GHz band.

TOT obtained 400MHz of 26 GHz spectrum for THB1.8 billion, while DTAC acquired 200 MHz in the band for THB910 million.

[143] https://www.nationthailand.com/business/30382237

Appendix C 26 GHz award in EU countries and the UK

In the following sections we provide further information on completed 26 GHz awards and consultations in the following countries:

- Czech Republic
- Denmark
- France
- Finland
- Germany
- Greece
- Italy
- Luxembourg
- Poland
- Slovenia
- UK

C.1 Czech Republic

In the Czech Republic, the Czech Telecommunication Office published a consultation in August 2020 on proposals to amend the radio spectrum use plan for the frequency band 24.25 – 27.5 GHz[144]. The changes proposed are related to the use of IMT in the band. The closing date for comments was 11 September 2020.

It notes that the main use of the band is for fixed services (24.25 – 25.25 GHz for civil applications, 25.25 – 26.5 for civil and non-civil and 26.5 – 27.5 GHz for non-civil). Future fixed service developments are for larger bandwidths and future use of 26.5 – 27.5 GHz by fixed services will depend on mutual co-existence with mobile services.

The 24.25 – 26.65 GHz band is temporarily used by short range automotive radars. There is also mention of SAP / SAB[145] presumably on a secondary basis and industrial radars for level probing in 24.05 – 27 GHz[146].

The spectrum use plan refers to base stations using frequencies in accordance with the Annex in the Commission Decision, EU 2019/784:

[144] https://www.ctu.cz/vyzva-k-uplatneni-pripominek-k-navrhu-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spekt-103
[145] CEPT ERC/REC 25-10 details frequencies for temporary audio and video links
[146] Reference ECC/DEC/(11)02, Commission Implementing Decision 2019/1345 of 2 August 2019 amending Decision 2006/771/EC on radio spectrum harmonisation for short range devices.

- 5 adjacent blocks of 200 MHz. Upper frequency 27.5 GHz.
- TDD operation.
- Total radiated power (TRP) of base station antenna maximum of 25dBm/200 MHz,
- Base stations with maximum TRP exceeding 5 dBm used outside must have the possibility of introducing timing synchronisation of transmit and receive mode time frames. The Office may recommend or establish a synchronisation obligation.
- Indoor base stations must be installed to ensure radiation to outside the building is limited. External base stations must have a s/n ratio of at least 30 dB.
- Outdoor base stations using the maximum allowable TRP and the same channel and unsynchronised must be separated by 3 kms where there is line of sight and by 1.6 km where the antenna height is 6 metres above ground level and there is an obstructed path (e.g. in urban deployments). In the case of the adjacent channel the separation distances are 1.5 km ad 0.9 km respectively.
- Base stations with active antennas must point the main radiated beam below the level of the horizon.

It also notes that nothing is defined for the 24.25 – 26.6 band and no individual authorisations are available for IMT. Conditions will be determined according to the development of demand from spectrum users, harmonisation, experience with the operation and planning of IMT/5G networks and conditions of shared use of frequencies.

The spectrum use plan also mentions that there is no use of Inter-satellite Service of Satellite service and that the Earth Exploration Satellite service and Space Research Services are not used and there is no restraint on use and development of the band based on these services (Radio Regulations footnotes 5.536, 5.536B and 5.536C).

The conditions for industrial radars (level probing radars in the 24.05 – 27 GHz band refer to ECC/DEC/(11)02 and Commission Implementing Decision 2019/1365 of 2 August 2019 amending Decision 2006/771/EC on radio spectrum harmonisation for short range devices.

Amendment of measures for 24.25 – 27.5 GHz band

In October 2020 it was announced that part of the "Measure of General Nature" relating to the 24.25 – 27.5 GHz band would be updated[147]. The Measure sets out basic technical parameters and how to authorise the first mmWave bands for 5G networks. Based on the responses to the public consultation and evidence gathered during meetings with stakeholders the CTU proposes to make 1 GHz of the band available for individual authorisation for experimental use. CTU also noted that supply of 5G equipment is just merging and that there is no demand for new services in this band. The Measure took effect on 15 November 2020[148].

CTU will monitor and assess the development of given areas at the end of the first half of 2021. Based on the evidence of experimental band use, optimisation of planning mechanisms and results of negotiations on European technical-regulatory draft measures for ensuring mutual network coexistence, CTU will specify the conditions for commercial use.

[147] https://www.ctu.cz/tiskova-zprava-prvni-krok-k-vyuziti-milimetrovych-vln-pro-site-5g
[148] https://www.ctu.cz/sdeleni-o-vydani-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spektra-c-pv-p2102020-10-pro

C.2 Denmark

The Danish Energy Agency (DEA) published a 5G action plan[149] where it indicated the following timescales:

- 700 MHz band to be auctioned end of February 2019 with spectrum becoming available April 2020,
- 3.5 GHz band available from 2020, and
- 26 GHz band at some time later but by the end of 2020.

It was noted that the European Commission was expected, during the first half of 2019, to adopt technical conditions for the 26 GHz bands in accordance with CEPT's conclusions.

A number of action points were noted in the document to facilitate the network rollout and delivery of 5G:

- Examine the opportunities and challenges of network sharing,
- Define, with the assistance of the telecommunications industry, what is meant by small cells in Europe,
- Prepare guidelines on standard case administration for public authorities, and
- Prepare new guidelines on mast rental.

In December 2018 DEA consulted on interest in private 5G networks in the 3.5 GHz bands[150]. One respondent mentioned demand for mmWave (26 GHz) as well. The mobile companies recommended that 26 GHz should be suitable for locally limited use, amongst other things due to range and small risk of mutual interference between uncoordinated users. There has been no decision posted on spectrum for private 5G networks.

In February 2020 DEA requested information on interest in the 26 GHz band. In the consultation document the DEA noted that the "new Telecommunications Directive stipulates that Member States at the latest by the end of 2020 must provide at least 1 GHz in the 26 GHz frequency band …". It also mentions the uncertainty over the technical conditions that should apply, and that clarification was not expected before Summer 2020 and the impact on equipment availability. The DEA concluded that in practice it was only the upper part of the 26 GHz frequency band that can actually be used for mobile communication, i.e. 1 GHz out of a total of 3.25 GHz.

In Denmark there are two licences for fixed links totalling 2 x 364 MHz which expire on 31 December 2025 and 31 December 2026, respectively. The DEA proposed to investigate the possibilities for coexistence between existing licenses and mobile communications (5G).

On the basis of the above information the DEA asked a number of specific questions. Responses were required by the end of February. To date no further information has been provided by the DEA on the responses as a number were confidential but we understand that the conclusion was there is more demand than supply of frequencies and the band would be included in the forthcoming auction.

On the 6 November the DEA published a draft Information Memorandum[151] for comment by 4 December 2020. The Information Memorandum covers the award of the 1500 MHz, 2100 MHz, 2300 MHz and 3.5 GHz bands as well as the 26 GHz band, In the 26 GHz band 2850 MHz of spectrum will be awarded between 24.65 – 27.5 GHz on a national, service and technology neutral basis, as follows:

[149] https://ens.dk/sites/ens.dk/files/Tele/5g_action_plan_for_denmark.pdf
[150] The DEA has a separate portal for consultations and requires users to sign in.
[151] https://hoeringsportalen.dk/Hearing/Details/64536

- The frequencies are proposed to be offered in generic frequency blocks of 400 – 450 MHz with a maximum of 1650 MHz per bidder.
- There are no proposed coverage obligations, but licensees have to install, no later than 4 years after licence issue, antennas and transceivers, connected to the networks, for at least 100 mast positions and providing service for at least one electronic communication.
- Technical conditions are as provided in the Commissions Implementing Decision ((EU) 2020/590 and (EU) 2019/784).
- Incumbents in the band include EESS, FSS, Fixed, SRDs, SRS.
- New earth stations will only be licensed if they are located at least 8kms from the nearest town with greater than 1000 inhabitants.
- Until 1 December 2021 Telia and Telenor can continue to use existing fixed links[152] and must be provided protection from interference. Users of the band must inform Telia and Telenor of expected use who can agree to deployments. After this date if the fixed links cause interference into the new licensees the fixed links must be removed.
- Coexistence between licensees in adjacent blocks can be mutually agreed including synchronisation arrangements.
- Mast Act covers sharing of masts. Passive infrastructure sharing and network sharing is possible.

24.25 – 24.65 GHz will be available for private networks.

C.3 France

The 26 GHz band in France, is currently used by fixed services (24.25-27.5 GHz) and satellites services and for military purposes (24.5-25.249 / 25.5-26.257 / 26.5-27.5). In June 2018, the French regulator has launched a public consultation regarding the introduction of 5G in the 26 GHz band. 13 contributors including the four local MNO's, Airbus, Eutelsat and Qualcomm[153] have submitted their views on the 26 GHz band, commenting on the following questions:

- Question 1: What is your analysis regarding the use of the 26 GHz band for the introduction of 5G?
- Question 2: How can we articulate the provision of the band for 5G and the current use of the band by the Fixed point to point links? Under what conditions can the two uses can coexist?
- Question 3: What are your views regarding the proposed authorization regime? Do you have other propositions considering the specific context of the 26 GHz band?
- Question 4: Do you have plans to install earth stations in the 26 GHz band and what would be the frequency and geographic requirements?

[152] Fixed links use 24.969 - 25.333 GHz and 25.777 – 26.341 GHz. Telia's licence is to 2025 and Telenor's to end of 2026
[153] The full list of contributions is available here: https://www.arcep.fr/actualites/les-consultations-publiques/p/gp/detail/perspectives-pour-lintroduction-de-la-5g-dans-la-bande-26-ghz-22-mai-2018.html

- Question 5: What would be, in your opinion, the necessary conditions to ensure the coexistence existing and future earth stations with 5G? Under what conditions the constraints imposed by these stations to 5G would be acceptable?

Figure C.1: Current spectrum use in France

Amongst the numerous contributions to the consultation we can note the following:

On the question "What is your analysis regarding the use of the 26 GHz band for the introduction of 5G:

- Several contributors consider that 5G at 26 GHz will allow data rates of several gigabits for localized needs of very high-speed mobile networks in areas with high density, but also to offer new 5G services dedicated to industry.

- Several contributors consider that the first 5G deployments in the 26 GHz band will be limited to the last gigahertz of the band (26.5-27.5 GHz) due to the availability of equipment operating in the 26.5-29.5 GHz band (known as the 28 GHz band) more suitable for American and Asian markets. However, some contributors (AFNUM, Bouygues Telecom, Iliad, Orange) believe that the priority is the provision of frequency bands below 6 GHz, especially in the 3.5GHz band.

- Several players advocate for an individual licensing regime for the 26 GHz band. Orange for instance is in favour of such a regime, although it considers that it is still premature to choose between an individual authorization regime at the national level or at a smaller geographic scale.

The French regulator was also seeking view on its authorization regime for fixed point to point links, and on the duration of these authorizations. Question 3 of the consultation was to collect views on whether authorizations should be issued for a specific duration, thus expiring at the end of 2023. Views on this question include the following:

- Bouygues Telecom believes that the proposal to award all the new authorizations for a maximum duration until a specific date, for example December 31, 2023, will gradually reduce the number of point to point fixed links, give more visibility on the use of the bad beyond 2023 and should encourage actors to favour other frequency bands. Bouygues Telecom also proposes that for a request to increase the capacity of fixed links, the end date of the new authorization should be taken as the earliest between the expiration date of the initial authorization and December 31, 2023.

- SFR on the other hand, is not in favour of this proposal and considers that coexistence between fixed point to point links and 5G is possible with location and spectrum sharing. The operator thus proposes to maintain the current framework setting the duration of authorizations at 5 years.

- Huawei and Orange are also not in favour of the proposal and suggest that any new request for spectrum to use in fixed services in this band should be authorized in another frequency band.

On the question "Do you have any plans to install earth stations in the 26 GHz band and what would be the frequency and geographic requirements?", Arcep received the following responses:

- Bouygues Telecom, Iliad, Orange and SFR have indicated that they have not planned to install earth stations in the 26 GHz band.

Arcep has also requested views from contributors on the necessary conditions to guaranty coexistence between existing and future earth stations and 5G. Most respondents have indicated that coordination and / or exclusion zones are necessary to ensure, where appropriate, the coexistence of these earth stations with 5G.

More recently, the head of French regulator has suggested in an interview with policy tracker[154], that the country may opt for a sharing regime in the 26 GHz band, allowing verticals to gain access to spectrum. The regulator has already started experimenting with new licensing options in the 26 GHz band, offering temporary licences (3 years duration) to companies willing to create "open-access" trials available for third parties.

C.4 Finland

The 26 GHz auction took place on June 2018. Each of the three current MNOs were assigned 800 MHz of spectrum at the starting price of 7 million EUR. Elisa won the 25.1-25.9 GHz frequencies, Telia the 25.9-26.7 GHz and DNA got the 26.7-27.5 GHz frequencies. 850 MHz of the band (24-25-25.1 GHz) has been reserved for local/regional vertical players and R&D or educational usage.

Technical licence conditions for the 25.1-27.5 band are publicly available[155], and include the following provisions:

- The 25 100 - 27 500 MHz frequency band uses Time-Division Duplex (TDD), both base station transmitters and terminal station radio transmitters use the band.
- Radio networks operating in this frequency band must be synchronised unless there is no harmful interference caused to each other.
- Details of base station transmitters in the 25 100 - 27 500 MHz frequency band operating within a maximum distance of 90 kilometres from the border of a neighbouring country must be provided to the Finnish Transport and Communications Agency for coordination valuation before deployment, unless there is a separate coordination agreement on the use of the frequencies with the country in question.
- A licence holder has the right to share the use of mobile network base stations with another licence holder in frequencies for which the other licence holder has a radio licence. A licence holder must notify the Finnish Transport and Communications Agency of the use of the shared network and frequencies before deployment of the network. A licence holder must also notify the Agency if the use of the shared network ends partially or completely.
- The total radiated power (TRP) for a base station transmitter outside the frequency block assigned for a licence holder is as follows:

Frequency band	Maximum TRP	Measurement bandwidth
Up to 50 MHz below or above a licence holder's block	12 dBm	50 MHz

[154] France hints at spectrum sharing in the 26 GHz band. By Manuel R.Marti, Policy Tracker New Article Feb 07, 2019
[155] See: https://www.traficom.fi/sites/default/files/media/file/EN_26_GHz_tekniset_lupaehdot_Rev3.pdf

Traficom also provided a document on technical usage in the 26 GHz band[156] that comments on possible technical conditions that may be required if EESS, SRS, FSS and radio astronomy are deployed in the 26 GHz or adjacent bands. There is currently no use of these services. The technical licence conditions provided for the 26 GHz band note the possible need to take account of such services in the future[157].

C.5 Germany

The German regulator launched a public consultation in December 2016 to identify and provide suitable spectrum for the introduction of 5G. Interested parties were invited to submit their views by March 2017. A summary of the 39 responses is available on the Bundesnetzagentur's website[158].

Regarding the 26 GHz band, some notable observations are :

- All the respondents welcomed the international activities for the harmonised provision of this spectrum for 5G applications with reference to the need for harmonised technical conditions of use to protect existing applications. Also, some respondents pointed out the large use of the 26 GHz band for the radio relay links of the fixed service for the connection of public mobile base stations and military users' base stations for which protection was required.

- Calls from some respondents for the provision of large contiguous frequency bands for 5G – unpaired assignments of 200 MHz or several hundred MHz per network operator.

- Some respondents called for flexible use of the entire radio relay band for radio relay or for 5G systems. Thus, all the assignments should be made in the form of fixed PMP links. However, there were also continued calls for assignments for fixed PP links, these being essential for delivering mobile services to rural areas.

It is reported[159] that BNetzA proposed, in a public consultation in 2019, "separating the 26 GHz range into upper (26.5-27.5 GHz) and lower (24.25-26.5 GHz) sub-bands. Industry verticals and local use-cases would have regular access in the lower sub-band, and priority access in the upper sub-band. Mobile network operators (MNOs) have vigorously objected to the proposed division of the band, alleging it would squander most of its value".

Based on the consultation results, the regulator has concluded that spectrum above 24 GHz is to be provided for 5G, with consideration of existing uses, at the earliest possible time and in line with demand. Given that existing uses in these bands are subject to specific protection requirements, a general assignment does not appear feasible. The Bundesnetzagentur issued a draft administrative regulation in July 2020[160] for local licensing in the 24.25 – 27.5 GHz band.

According to the draft regulations applications will be accepted based on the operator's intended frequency usage information that needs to include a description of the area (no maximum size is stipulated) and justification for the requested bandwidth. The bandwidth is initially restricted to a maximum of 800 MHz as

156 https://www.traficom.fi/sites/default/files/media/file/Taajuusalueen_26_GHz_tekniset_k%C3%A4ytt%C3%B6rajoitteet_%28lausuntokierros_muistio%29_Rev3.pdf

157 https://www.traficom.fi/sites/default/files/media/file/26_GHz_tekniset_lupaehdot_Rev3.pdf

158 Key elements for the rollout of digital infrastructures and Identification of Demand for nationwide assignments in the 2 GHz and 3.6 GHz bands. Available at : https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/201070704_KeyElementsDemandIdentification.pdf?__blob=publicationFile&v=1

159 https://techpolis.com/germany-to-unlock-5g-mmwave/

160 Frequencies for local broadband in frequency range 24.25 – 27.5 GHz, 27.07.2020

expect main demand in the 26.5 – 27.5 GHz band based on availability of devices. Operator agreements between neighbouring users are required to manage use of the local broadband frequencies (indoor and outdoor) and notes are provided on drawing up operator agreements. Synchronisation of networks is seen to be beneficial. Allocation of frequencies requires interference free co-existence with existing radio applications for other services. Licence duration is up to a maximum of 15 years and not beyond December 31, 2040. Frequencies can be partially or wholly revoked after 12 months under use-it-or-lose-it licence conditions.

On 17 December 2020 the Bundesnetzagentur published the Administrative Regulation on Frequency Allocations for Local Broadband Frequency Uses in the 24.25 - 27.5 GHz Frequency Range[161]. The Bundesnetzagentur reserve the right to modify these regulations one year after opening the application procedure on 1 January 2021. No spectrum cap or maximum bandwidth has been set based on the expectation of further spectrum becoming available in the 40.5 – 43.5 GHz band[162]. It is expected that a typical user bandwidth will be 800 MHz - the more bandwidth requested, the more detailed the justification must be for the need. Applications for specific frequency sub-ranges in the 26 GHz band must also be justified. Frequencies may be fully or partially revoked after 12 months ("use-it-or-lose-it"). Frequencies for wireless network access can only be allocated if the interference-free operation of the existing radio applications of other radio services is also ensured. Any natural or legal person is entitled to apply. Licences are awarded on a FCFS basis.

C.6 Greece

The Greek Regulator, EETT, has issued at least two consultations. The first consultation was on the award of the 700 MHz, 2.1 GHz, 3.4 – 3.8 GHz and 26 GHz bands[163] and ran from 7 February 7 to 30 April 2020. This has been followed by a consultation between 15 July and 4 August 2020 on the draft tender documents[164].

The spectrum was awarded by auction in December 2020 with the three MNOs obtaining 26 GHz spectrum along with other frequency bands. Both Cosmote and Vodafone acquired 400 MHz for €6.5 million each, while Wind paid €3.2 million for a single lot of 200 MHz at 26 GHz. The auction placed particular emphasis on 5G R&D, with the government dedicating up to 25 per cent of the auction revenues and spectrum to future research projects to improve business competitiveness and drive economic development and prosperity.

The Greek government has already drafted legislation that aims to boost 5G private networks. It plans to reserve frequencies in the low, mid and high bands for R&D[165].

Consultation on award of the 700 MHz, 2.1 GHz, 3.4 – 3.8 GHz and 26 GHz bands

The consultation on the award of the 26 GHz band addresses a number of issues, including:

- Highlight the market interest in WBECS in the different bands and consider limiting the number of rights of use that would be granted.
- Obtain views on terms of use and proposed obligations.
- Views on necessary technical conditions and restrictions for 5G networks for coexistence with:

[161] Bundesnetzagentur - Regionale Netze

[162] A mandate has been issued by the European Commission to CEPT to develop harmonised technical conditions for the band.

[163] https://www.eett.gr/opencms/opencms/admin/News_new/news_1130.html

[164] https://www.eett.gr/opencms/opencms/admin_EN/News/news_0539.html

[165] Source: Policy Tracker

  - Fixed service in 24.5 – 26.5 GHz sub-band,
  - Systems of satellite earth exploration service and space services in the 25.5 – 27 GHz sub-band.
  - Fixed satellite service stations in 24.65 – 25.25 GHz sub-band, and
  - Inter satellite service operating in 25.25 – 27.5 GHz.
- Division of 26 GHz band into 200 MHz bands.
- Possibility of continuing operation of fixed links in 24.25 – 27.5 GHz through managed spectrum sharing.
- Obligation on Member States to ensure continuity of ground stations is feasible in a way they do not disproportionately impose restrictions on MFCN 5G systems.

Services in Greece

The following summarised the current situation:

- SAP/SAB in 24.25 – 24.5 GHz not currently used.
- Satellite services – Space services. Operation of services is foreseen and co-existence with MFCN 5G networks is ensured with technical limitations of Decision 2019/784 / EU.
- Use of passive satellite systems in neighbouring countries is ensured with technical limitations of Decision 2019/784 / EU.
- Short range devices in 24.25 – 26.65 GHz – there is no current or planned use of car radars.
- Fixed services – spectrum blocks awarded to mobile operators WIND, Cosmote and Vodafone in 2017 and expire in 2032 for point to point and point to multipoint wireless access. Greek Police also have spectrum for fixed services. In the case of fixed services, it is noted that there are 3 options going forward: shared approach, phased approach and migration approach. The EETT has concluded that by adopting a guard band of 20 MHz the protection distances between fixed services and 5G are less than 1 km.

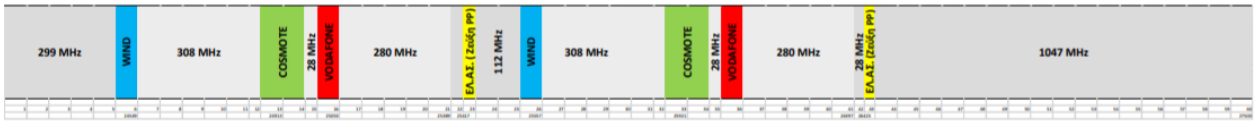
Currently available spectrum

The EETT has estimated, based on current use of the 26 GHz band by fixed wireless that 2350 MHz could be sold immediately:

- 24250 – 24500 MHz (250 MHz)
- 24650 – 24850 MHz (200 MHz)
- 25150 – 25500 MHz (350 MHz)
- 25650 – 25820 MHz (200 MHz)
- 26150 – 27500 MHz (1350 MHz)

Therefore at least 1 GHz of the 26 GHz band is available for MFCN-5G before 31 December 2020.

Figure C.2: Current use of 26 GHz band Source: EETT)



Band reorganisation

EETT notes that further spectrum could be made available through reorganisation of the band. This could include:

- Moving the Greek police links to another band.
- Moving links of existing fixed access to other bands.
- Modification of existing fixed access rights of use so each provider can coexist their own links with 5G within their licensed sub-band.
- Defining national coordination procedures between fixed wireless access and new 5G mobile[166].

In Greece the alternative bands available for migration are:

- 23 GHz. Case by case basis as large current use.
- 28 GHz. Currently regional licences, almost zero use in provinces and small use in Attica and Thessaloniki.
- 32 GHz. Licensing on a per link basis but minimum current use.

Coexistence between MFCN networks

Coexistence between MFCN networks ensured by the technical requirements in Decision ECC/DEC/(18)06 and 2019/784 EU and in particular by block edge masks (BEM) and possible synchronisation of networks. These limits are proposed to be adopted for synchronised operation and it is suggested there may be the possibility of non-synchronised operation indoors based on harmonised limits and agreement of all providers that will operate in the 24.25 – 27.5 GHz band.

Licence obligations

In addition, the following licence conditions were proposed or considered for the 26 GHz band:

- No maximum spectrum limit per provider;
- Licence duration of 15 years plus possibility of extension for a further 5 years – spectrum would be available immediately;
- Coverage obligation of providing at least 5 base stations in each municipality with greater than 50,000 inhabitants within 5 years of licence award except for Attika and Thessaloniki regions;

[166] For coexistence of fixed and mobile in adjacent bands it is considered that guard bands of the order of 30 MHz (minimum) are required

- Envisage colocation and / or sharing of facilities or property will be imposed when deemed that the overlap of multiple deployments is not economically efficient and practically impossible by any provider. The EETT notes that the new Electronic Communications Code (Directive (EU)2018/1972) states that the sharing of network infrastructure and in some cases spectrum sharing may enable more efficient and effective use of radio spectrum and ensure rapid development of networks. The EETT plan to provide for:
  - Sharing passive or active infrastructure,
  - Commercial roaming access agreements, and
  - Joint development of infrastructure.

  The EETT does note the disadvantages of such approaches in regards service offerings and incentives to invest in own infrastructure (more so with active sharing) and reduction in available networks and impact of faults on service greater.

Predictions for verticals

The EETT recognises that verticals could play a major part in 5G (for example, automotive industry, transport, industry, networks infrastructure supply chains, health sector and public sector). They note two approaches to servicing verticals:

- Exclusive spectrum allocation in vertical markets, and
- Leasing or partnership with providers awarded spectrum.

Additionally, the Greek regulator reserved 5G spectrum 733-736 MHz and 788-791 MHz, 3400-3410 MHz, as well as 200 MHz from the higher 26 GHz band for universities and start-ups to research and develop 5G-based services and applications. The spectrum is offered free of charge for 12 months, for experimentation purposes and a quarter of the proceeds from the 5G auction will be available for these projects. The funds are supposed to be awarded for digital innovation in the transport and logistics, manufacturing, defence, utilities, health, and tourism sectors.

Consultation on draft tender documents

There will be a multi-round simultaneous auction for all the frequency bands including 26 GHz. There will be 5 blocks of 200 MHz available immediately in the 26.5 – 27.5 GHz band on a national basis. The licences will be for 15 years plus possibility of extension for a further 5 years. The licences will be technology neutral.

According to the draft licence the following conditions are proposed for the 26 GHz band:

- Quality of service. At maximum traffic times the network should be designed to support:
  - Call probability < 2% calculated over the air interface;
  - Probability of interruption of calls <3% calculated over the air interface;
  - Availability of network per year should be ≥ 99.5% while for a continuous period of 48 hours cannot be < 95%.
- Must ensure support the "Cell Broadcast Service".

- Access to MVNOs must be provided on reasonable terms upon request.
- Access to business verticals – must negotiate in good faith access to its network (such as leasing capacity) or leasing frequencies and providing this on reasonable terms for the verticals own use.
- Infrastructure sharing. The holder of the Rights to Use have the right to conclude commercial agreements for infrastructure sharing:
  - Use of passive structures requires a simple notification to EETT,
  - Use of active infrastructure requires EETTT to be notified 20 days from signing the agreement and EETT may intervene.
- The licensee may transfer or lease the whole or part of their spectrum.

There are no coverage obligations.

C.7 Italy

Italy has been the first country to auction 5G mmWave spectrum. The multi band auction that included the 700 MHz and 3.5 GHz bands has ended in October 2018 with 1000 MHz in the 26 GHz band being assigned to Telecom Italia, Illiad, Fastweb, Wind and Vodafone. Licences are valid until 2037 and Licence fees are due in instalments between 2018-2022.

The Italian regulator has adopted an innovative regulatory framework based on a "Club use" model[167] and is working with the Ministry of Economic Development (MiSE) and the mmWave spectrum licensees on its practical implementation. Under this framework, we particularly note the following:

- Licensees can share spectrum on a geographical basis when frequencies are not used, and each licensee would still have priority access to its own block.
- Licensees can stipulate reasonable commercial agreements combining spectrum sharing and infrastructure sharing policies.
- Licensees could also make agreements with a trusted third party ("Neutral Host") to manage concurrent installations or develop of the physical network's infrastructures.
- Additional provisions have been put in place to define how a licensee can lease spectrum to vertical players.

Moreover, Licence obligations include:

- Spectrum usage in all the Italian provinces within 4 years
- No coverage obligations for the 26 GHz band
- Access obligations:

[167] This is a variant of the classic "club use" formula, as the club members and the access criteria are decided by the regulator, while the club "members" decide on their own rules of coexistence and management.

- Access to be provided to other players (non-Telco's) for the development of 5G services
- In closed lands with public attendance (i.e. ports, airports, stadiums, arenas, cinemas, theatres, national parks, museums, metros, etc.), where the radio sites building must be authorized by the landowner/manager, the licensee(s) implementing coverage has to offer access to the other licensees.

C.8 Luxembourg

The Luxembourg Regulatory Institute (ILR) launched a consultation, on October 28th to assess the interest and needs of all stakeholders concerned for the future use of the 26 GHz frequency band[168]. ILR notes that "*As the physical properties of the 26 GHz band do not cover a large area but offer very high communication speeds, very short latency and the simultaneous connectivity of a very large number of terminals, the 26 GHz band aims to attract not only the interest of traditional mobile operators but also the interest of industries (often called 'verticals' in 5G) and communities (common cities) in search of innovative connectivity solutions*.

In order to allow all these players simultaneous access without interference to the radio spectrum in the 26 GHz band, new models of spectrum allocation may be considered. The consultation therefore also focuses on these new technical and regulatory modalities to be implemented when allocating this new frequency band. The purpose of this consultation is therefore not to assign user fees. The effective allocation of the various parts of the spectrum and the granting of the associated user rights will take place at a later date"

Interested stakeholders have been invited to express their interest, specifying how they would use the resources and estimating the amount of spectrum they require by the 8th of December. The objective of the consultation is not to grant rights of use or licenses at this point. The actual allocation of the various parts of the spectrum as well as the granting of the rights of use will be made on a date and according to a selection procedure to be determined subsequently.

The band is currently used in the country by:

- Fixed point to point links ((24.5-25.5 GHz / 25.5-26.5 GHz)
- Fixed Satellite Services (FSS) (24.65-25.25 GHz). Allocated to FSS but is not currently used at this point.
- Short Range Devices (24.25-26.65 GHz). This should stop by the 1st of January 2022 as these applications will migrate to the 77-81 GHz band.
- Military use (26.5-27.5 GHz)

The regulator indicates a hypothetical estimation for annual fees based on international benchmark analysis of 80 EUR/ MHz

Questions included in the consultation concern 4 main areas:

- General aspects: What is your assessment of the maturity of the ecosystem for using the 26 GHz band as part of the introduction of 5G?
- Services

[168] https://gouvernement.lu/fr/actualites/toutes_actualites/communiques/2020/10-octobre/28-ilr-consultation-5g.html

- Technical aspects including specific questions on minimum and optimal bandwidth, spectrum aggregation, network and infrastructure sharing.
- Authorization aspects including questions regarding individual (national or local),"Light licensing" and "Use-it-or-share it" methods

C.9 Poland

The Polish Office of Electronic Communications, UKE, issued on 30 July a request for comments and expectations regarding the 24.25 – 27.6GHz band[169]. The consultation was open to 7 September 2020. Based on the questions posed it appears that the band 24.3 – 27.3 GHz, currently civil use, is under consideration.

Figure C.3: Questions posed in consultation (Source: UKE)

1. What is the proposed allocation date for the 26 GHz band?
2. What are the expected dates of commercial network availability, taking into account the availability of equipment and devices in this band?
3. Is provision of services in the 26 GHz band foreseen for fixed or mobile users and by what date would it be desirable to make this band available for broadband applications?
4. What services do you envisage to provide in the 26 GHz band, except services related to mobile broadband Internet access?
5. Where could the 26 GHz band be used? (e.g. high-capacity geographic areas, cities, rural areas, road and rail routes, industrial centers, businesses, indoor)
6. In the case of the deployment of 5G base stations in the 26 GHz band, is it assumed that they will be single stations, cell clusters, or multiple stations covering specific area (commune, poviat)?
7. What is the desired amount of spectral resources that should be allocated to one operator?
8. How important is it to allocate contiguous blocks to operators (please indicate minimum block width)? Would it be desirable to aggregate non-adjacent neighbors and aggregate with blocks from other frequency ranges?
9. Should small cells in the 26 GHz band be exempt from the obligation to have a radio license?
10. Should the 26 GHz band be allocated and used taking into account the shared use with the fixed service?
11. Is it justifiable to migrate users of the fixed service from the 26 GHz band? (If so, to which bands?)
12. Is it possible to share the 26 GHz band with other users (eg government users)?
13. Should the selection procedure for the 26 GHz band be combined with the allocation of other bands as well?
14. Should the entire part of the band available to civil users (in the 24.3-27.3 GHz range) be allocated at one time?
15. Which model of the allocation and use of the 26 GHz band would be appropriate (selection procedure - frequency reservations, only radio licenses)?
16. Should you consider making the band available for devices exempt from the requirement to obtain a radio license? If so, on what terms?
17. Do you show any interest in using the 28 GHz band for the needs of the fixed and / or mobile service?
18. Is the 28 GHz band the appropriate band for user migration from the 26 GHz band?
19. What are the potential application types for the 28 GHz band?
20. Do you indicate the need to start work on making other frequency bands available for the purposes of IMT 2020? If so, in what time perspective?

It is understood that the Polish telcos said "they do not see a need for 26GHz 5G frequencies arising before 2022 or 2023. Responding to a consultation run by the country's telecoms regulator , cellular operators Orange, Play, T-Mobile and Plus said that there would be no need to allocate millimetre wave (mmWave) spectrum any earlier as there would be no end-user equipment available prior to that. Telko.in reports that Orange and Play favour nationwide licensing, while T-Mobile and Netia (sister company of Plus) lean more towards licences being

[169] https://uke.gov.pl/en/newsroom/consultations-of-26-ghz-band-and-other-millimeter-bands,308.html

allocated on a local basis, to help boost network capacity in high demand areas. The Polish government is expected to launch an auction for 3.7GHz spectrum by the end of this year."[170]

C.10 Slovenia

In Slovenia AKOS (the Agency for Communication Networks and Services of the Republic of Slovenia published, on 3 August 2020, an information memorandum providing draft terms and requirements for a public tender for the allocation of radio frequencies for the provision of public communications services to end-users in 700 MHz radio spectrum bands, 1500 MHz, 2100 MHz, 2300 MHz, 3600 MHz and 26 GHz[171].

At the same time, it invited comments by the closing date of 2 September on the information memorandum. After considering the opinions received and the comments received, the Agency will prepare a decision on the opening of a call for tenders and tender documentation.

The intention is to offer all the currently available spectrum simultaneously. They will be technology neutral.

The Agency notes that the 26 GHz band will be used to deliver speeds in Gbit/s – setting up hotspots to cover smaller local areas where such services are needed (for example, airports, bus stops, stadiums or hospitals of the future).

Aims of award

The aim of the award is to:

- Ensure technically efficient allocation of spectrum,
- Maintain and promote effective competition between suppliers of terrestrial systems that can provide WBECS, and
- Enable the allocation of spectrum at market prices.

In accordance with these 3 aims and Articles 195 – 197 of the Electronic Communications Act and the European Digital Agenda further objectives of the tender are:

- Enable the introduction of the technologies by allocating sufficient spectrum in a timely manner,
- Provide a stable environment for operators and other investors,
- Ensure digital inclusion of the population in as large a percentage of the country as possible,
- Contribute to achieving the greatest possible socio-economic progress,
- To follow the most developed countries in the world in the introduction of Industry 4.0 and intelligent connectivity,

[170] https://www.commsupdate.com/articles/2020/10/15/polish-operators-foresee-no-demand-for-26ghz-spectrum-for-next-two-years/?utm_source=CommsUpdate&utm_campaign=cf273058a9-CommsUpdate+15+October+2020&utm_medium=email&utm_term=0_0688983330-cf273058a9-11672558

[171] https://www.akos-rs.si/javna-posvetovanja-in-razpisi/novica/informativni-memorandum-za-dodelitev-radijskih-frekvenc-za-javne-mobilne-storitve-v-radiofrekvencnih-pasovih-700-mhz-1500-mhz-2100-mhz-2300-mhz-3600-mhz-in-26-ghz

- Create conditions for the construction of radio systems, and
- Driving connected automated driving and other verticals.

26 GHz band award details

Spectrum in the 26.5 – 27.5 GHz band will be awarded in 5 blocks each of 200 MHz for 15 years. There is a proposed spectrum cap of 800 MHz – there are 4 MNOs[172].

Coverage obligations are set for all the frequency bands to be awarded and in the case of the 26 GHz band it proposes that within 5 years of spectrum availability must offer services to end-users in at least one major city. Provision of services means that the service is provided through base stations covering at least 75% population of an individual urban settlement.

Sharing of frequencies and active equipment is permitted in the 26 GHz band between licensees. The Agency will impose passive sharing and obligations to conclude localised roaming agreements where justified on the grounds there are insurmountable economic or physical barriers to providing network infrastructure or services. Where obligations to require passive is not sufficient to address the problems obligations to provide active sharing may be imposed.

26 GHz band technical information

The licensee must deploy terrestrial systems that can provide WBECS in accordance with European Commission Decision (EU) 2020/590 and European Commission Decision 2019/784 and in accordance with the second paragraph of Article 24 of ZEKom-1 to act in accordance with international legal acts established in the Republic of Slovenia.

The Information Memorandum also list all other relevant documents which must be complied with by the licensee:

- Decision ECC/DEC/(18)06. Harmonised technical conditions for mobile / fixed communication networks (MFCN) in the band 24.25 – 27.5 GHz.
- ECC Recommendation ECC/REC/(19)01 on technical tools to support the introduction of 5G while ensuring the proportional use of existing and planned EESS/ SRS receiving earth stations in the 26 GHz band and the possibility for future deployment of these earth stations.
- ECC Recommendation (20)01. Guidelines to support the introduction of 5G while ensuring proportional use of existing and planned FSS transmitting earth stations in the frequency band 24.65 – 25.25 GHz and possibilities for the future use of these earth stations.
- CEPT Report 68 in response to the EC mandate.
- Report ECC 303. Guidelines for coexistence between 5G and fixed connections in the 26 GHz band ("Tool")
- ECC Report 296. Tool for the most appropriate synchronisation control framework.
- ECC Report 216. Report on practical guidelines for synchronising TDD networks.

[172] 3 major players and 1 stagnating as indicated in the market report 2014- 2019 https://www.akos-rs.si/fileadmin/user_upload/Povzetek_analize_mobilnega_trga.pdf

Other regulations that must be observed are:

- Must be used in accordance with technical requirements of applicable NURF.
- International coordination in border areas must be carried out in accordance with relevant CEPT documents and international agreements available on the Agency's website.

The licensee will have to comply with the spectral masks in (EU) 2020/590 on the limits of unwanted radiation in the band 23.6 – 24.0 GHz in Chapter "ANNEX Table 4 and Table 6" and for the others in the decision of the EC 2019/784, in the chapter Annex – technical conditions relating to Articles 2 and 3.

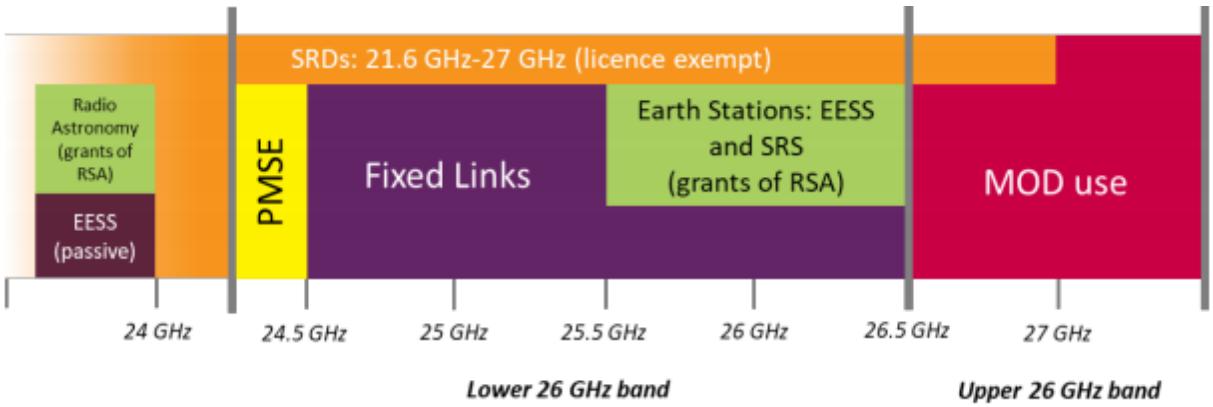
It also notes that 24.25 – 27.5 GHz should not be used to connect from base stations to terminals on drones or unmanned aerial vehicles. Further studies are still required on UAV deployments in the band.

According to EFIS[173] the band 24.25 – 27.5 GHz is used for military / defence applications, fixed links and automobile and land probing radars. ISS, EESS and SRS are also listed in the applications.

C.11 UK

In the UK, the 26GHz band which offers a total of 3.25 GHz of future bandwidth potential for 5G systems is currently used by fixed links (24.5-26.5 GHz), Satellite receiver Earth stations (25.5-26.5 GHz), Programme Making and Special Event stations (PMSE) (24.25-24.5 GHz), Short Range Devices (SRDs) (24.25-27 GHz) and for military uses by the Ministry of Defence (MoD) (26.5-27.5 GHz).

Figure C.4: 26 GHz band in the UK (Source: Ofcom)



In July 2017, Ofcom published a call for inputs (CFI) regarding 5G spectrum access at 26 GHz, seeking information from the various stakeholders. The regulator believes that a progressive approach to meet demand, when and where it arises, is likely to ensure optimal use of spectrum. Thirty contributions have been submitted by MNO's, equipment vendors, satellite operators and other players. According to Ofcom, responses to the CFI indicated that the band was likely to become important for 5G, but it was too early in 2017 to precisely determine how the band would be used, and for what purposes. Thus, Ofcom has indicated that it will continue gathering evidence from stakeholders and engaging internationally to inform its understanding of the high frequency mmWave spectrum.

[173] www.efis.dk/

Since the CFI, several discussions and workshops have been held by the regulator and numerous 5G related documents confirming support for the future potential use of the 26 GHz band, have been published[174]. More recently, Ofcom has published a statement about shared access to spectrum to support mobile technology, explaining how adopting a local access approach to some frequency bands, including the 26 GHz band would allow more people and businesses to use spectrum.

In particular, the lower 26 GHz band (24.25-26.5) has been added to Ofcom's spectrum sharing framework for indoor use from end of 2019. This enables deployment of new 5G indoor applications with little to no impact on existing services and without prejudice to future outdoors use of the band. Based on this approach, users will be allowed to apply for a 26 GHz Shared Access licence for indoor use. Once the licence is granted, they can deploy the required number of indoor base stations in a circular area with a 50-metre radius without requiring further individual base station authorisations. It is possible to apply for multiple licences to cover a larger area. The licence will also cover terminal stations and a licence fee of £320 will be applicable per licence.

[174]Enabling 5G in the UK, 9 March 2018, ii) UK preparations for the World Radiocommunication Conference 2019 (WRC19), 7 June 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0017/114524/consultation-wrc-19.pdf and iii) Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrumbands.pdf

Appendix D Harmonisation of 26 GHz band in Europe

D.1 BEREC

BEREC is the Body of European Regulators for Electronic Communications. It released many studies dealing with 5G issues.

In March 2018, BEREC released a 15-page preliminary study carried out with DotEcon Ltd and Axon Partners Group on "Implications of 5G Deployment on Future Business Models".

Amongst the key conclusions reached, the study estimated that:

- 5G was evolutionary (compared to 4G, enhancements identified were higher speeds, lower latencies, enhanced reliability, lower power consumption and greater terminal device densities) rather than revolutionary in the short to medium term and that eMBB was to be the main driver for early 5G deployment (but would not be a revenue growth opportunity).
- Network slicing was key to allow differentiated services targeting different users by prioritising certain features. Additional revenues would come from those new added-value niche services and applications. There would be no killer application for 5G.
- 5G could meet verticals'/user groups' specific requirements (QoS, jitter, latency, data throughputs, reliability…), modify the usual mobile value chain by creating opportunities for new national or trans-national intermediaries and shake traditional pricing structures. New pricing structures could lead to inefficient outcomes.
- Private networks should multiply within vertical industries, be encouraged to help solve the coverage issue and be coordinated.
- To solve coverage issues and exploit mmWave frequencies, small cells should be deployed in many avenues. Site owners may gain power due to small cells. Deployment of sites would be encouraged by Governments
- Infrastructure sharing should thus be encouraged but should avoid excessive concentration
- Edge computing might prove useful for some applications.

In June 2019, BEREC published results of the public consultation on its draft common position on mobile infrastructure sharing – BoR (19) 109 and 110

The BEREC common position on mobile infrastructure sharing provides background information on infrastructure sharing and describes key criteria to take into consideration by NRAs when evaluating sharing agreements.

BEREC built on the work performed and positions disclosed in the last 10 years on this issue. Notably, it built on outcomes of its public consultation on its draft position on infrastructure sharing organised from 12 December till 18 January 2019 BoR (19) 109.

Particularly, based on shared background information on mobile infrastructure sharing, BEREC thinks that NRAs should analyse mobile infrastructure sharing agreements case-by-case and support them while remaining subject to competition law – BoR (19) 110.

In October 2019, BEREC disclosed a draft Feasibility study on development of coverage information for 5G deployments - BoR (19) 191

Based on results from the March 2018 study, BEREC investigated further and asked NRAs for input first and verticals second. It consulted NRAs in February 2019, but the survey proved to be too early to raise 5G verticals coverage issues. Four months later in June 2019, BEREC called for inputs from verticals but received only four answers and concluded the consultation was also too early to take definitive steps. The consultation aimed at understanding verticals' connectivity and coverage needs and how those needs can be translated into KPIs.

Between 10 October and 28 November 2019, BEREC again called for further stakeholder inputs and received five contributions to its public consultation on its "draft Feasibility study on development of coverage information for 5G deployments."

In December 2019, BEREC provided a report on "the impact of 5G on regulation and the role of regulation in enabling the 5G ecosystem" – BoR (19) 245.

The BEREC Planning and Future Trends Working Group developed a report aiming at further understanding how 5G could lead to adjustments to the regulatory environment, in a view to assist NRAs based on preliminary conclusions reached in the DotEcon and Axon Partners study.

Key points include:

- Information on new business models opened up by network slicing and accompanied by the emergence of new players coming in. Ensuring access to new players is key. In that sense, wholesale aspects on 5G will be central.
- Issues around planning permission, notably on the 26 GHz, remain.
- Backhaul studies can be extended to any-haul as increasing needs are expected for front-haul and mid-haul. The key point here is to ensure non-discriminatory backhaul commercial viability and costs
- Small-cell deployment should be eased.

In March 2020, BEREC published the outcome of the public consultation on the draft Feasibility study BoR (19) 191 "on development of coverage information for 5G deployments"

In March 2020, BEREC disclosed answers and comments received from the five respondents (Cisco, EBU, GSMA/ETNO, TDF and Telefonica) in the BoR (20) 32 Report and released main conclusions in the BoR (20) 33 Report.

BEREC and respondents underlined the fact that information on coverage and QoS should be made available by operators under the BEREC umbrella. BEREC and respondents also highlighted challenges in disclosing sensitive information too widely.

In the end, BEREC considers that setting a policy objective to provide harmonised coverage and QoS information was too early again but estimated it was worth continuing investigating and facilitating discussions within the industry on the 5G QoS and coverage issues at its Stakeholders' Forum event scheduled for 1 April 2020. The Forum event was then postponed to 19 October 2020 due to Covid-19 and turned virtual.

D.2 RSPG

The RSPG published three Opinions on 5G issues between November 2016 and January 2019.

First Opinion on 5G, Opinion of spectrum related aspects for 5G (November 2016)

The first Opinion was released in November 2016. This First Opinion underlined that spectrum was needed for 5G networks.

- It was the first paper to consider three pioneer bands for 5G networks (700 MHz, 3400-3800 MHz, 26 GHz) and to mention topics to further study to harmonise the 26 GHz band for 5G (24.25-27.5 GHz as a pioneer band for implementation in Europe of 5G above 24 GHz). The CEPT reused those limitations.
- The first RSPG Opinion also identified that the 31.8-33.4, the 40.5-43.5 GHz and the 66-71 bands for 5G as respectively "promising", "viable" and "potentially important".
- The RSPG recommended 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, taking into account that 5G deployment in this frequency range is likely to remain geographically limited by 2020.
- The RSPG also mentioned that the harmonisation of the 24.25-27.5 GHz frequency band would need to take into account that:
  - The roll-out of 5G in this band is expected to be progressive, starting in major urban centres and to use only a portion of the band.
  - mobile network operators are the main users of this frequency band for fixed service. This may reduce the need for extensive clearance of fixed links from the band.
- The RSPG also addressed issues related to the number of EESS Earth stations in the 25.5-27 GHz frequency band, the number of FSS Earth stations in the 24.65-25.25 GHz frequency band and protection issues of on-board receivers of the Data Relay Satellite Systems and of the passive service in the adjacent band (23.6-24 GHz).

RSPG Second Opinion on 5G , Opinion on 5G networks (Strategic Spectrum Roadmap towards 5G in Europe) (January 2018)

In the Second Opinion, the RSPG adopted further recommendations for administrations.

- It underlined that the 3.4-3.8 GHz is expected to be the key frequency band for 5G in Europe and asked for large chunks. It also reaffirmed the potential of low-bands already harmonised (700, 800, 900, 1800, 2000, 2600 and 1500 MHz). It also called for flexible authorisations, flexible coverage requirements.
- It also reaffirmed that rural areas and wide coverage have to be taken into account and suggested that satellite could play a role.
- The RPSG also pushed for research programs led by the European Commission.

- As far as the 26 GHz is concerned, the RSPG 2nd Opinion pushed for an individual licence regime but did not exclude to award licence under the general authorisation regime if attached with sharing conditions to protect existing users of the band. Protection of existing users including FSS and EESS/SRS satellite services was reiterated several times. In this 2nd Opinion, the RSPG provided details on sharing conditions with existing users at 26 GHz. For example, it proposed to only authorise future EESS or FSS: authorisation of EESS and FSS earth stations after evaluation of their potential impacts on 5G networks.

- For the 26 GHz band, the RSPG also emphasised that the band was dedicated for local coverage and that a large portion of the band, at least 1 GHz, should be made available as from 2020 presumably implicating the 26.5-27.5 GHz portion of the band. With regards to sharing with fixed satellite services, the RSPG opens the opportunity for administrations to progressively migrate existing users and to open the band in congested areas, roads and transport paths.

- Regulatory flexibility for the progressive release of the 26 GHz band was underlined in order to avoid negative impact on the current users of the band. The geographical dimension of the market demand for 5G should be taken into account.

- The 42 and 66-71 GHz bands should be used beyond 2020 for 5G under the general authorisation regime.

- At last, the 32 GHz band that had been mentioned in the RSPG first Opinion was no more considered as a priority for studies: first results from sharing studies illustrated strong difficulties.

RSPG Third Opinion on 5G, Opinion on 5G Implementation challenges (January 2019):

- The third RSPG Opinion released early 2019 dealt with the defragmentation of the 3.4-3.8 GHz frequency band. The RSPG pushed for spectrum assignment mechanisms able to provide large contiguous spectrum blocks.

- The RSPG also looked into the provision of connectivity to verticals. Acknowledging verticals' connectivity needs are not always met by mobile operators (too business-specific, coverage issues, not economic viable needs…), the RSPG proposed to assign dedicated or shared spectrum for verticals through specific authorisation or spectrum trading/leasing.

- The RSPG recognizes that, in order to support implementation of EECC, the European Commission might consider additional recommendations on spectrum use for verticals and in this case, it should seek advice from the RSPG.

D.3 European Commission

The EU Public Private Partnership 5G PPP in 2013

The 5G Infrastructure Public Private Partnership (5G PPP) is a joint initiative launched in 2013 between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and researcher Institutions).

The 5G PPP is now in its third phase where many new projects were launched in Brussels since June 2018. The last eight projects launched (Phase 3 Part. 4) started in November 2019. They work on the longer term vision for 5G.

The 5G PPP delivers solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade. The challenge for the 5G Public Private Partnership (5G PPP) is to secure Europe's leadership in the particular areas where Europe is strong or where there is potential for creating new markets such as smart cities, e-health, intelligent transport, education or entertainment & media. The 5G PPP initiative reinforces the European industry to successfully compete on global markets and open new innovation opportunities. It "opens a platform that helps us reach our common goal to maintain and strengthen the global technological lead".

Key challenges for the 5G Infrastructure PPP are:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
- Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
- Reducing the average service creation time cycle from 90 hours to 90 minutes
- Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- Ensuring for everyone and everywhere the access to a wider panel of services and applications at lower cost

The 5G Action Plan in 2016

In September 2016, the European Commission launched a plan to boost EU efforts for the deployment of 5G networks and launch 5G commercial services by year-end 2020. The 5G Action Plan involves stakeholders, private or public, small and large in all Member States.

To achieve this goal, the European Commission proposed to:

- Align roadmaps and priorities across Member States to coordinate 5G deployment, target early 5G launch in 2018 and larger scale introduction by year-end 2020
- Identify and make provisional spectrum available for 5G before the WRC-19 and add additional spectrum as quickly as possible
- Promote early deployment in major dense urban areas and along major transport paths
- Encourage multi-stakeholders trials at European level
- Ease the implementation of an industry-led fund in support of 5G-based innovation
- Unite concerned actors in working towards the promotion of global standards

The 5G Action Plan asked all Member States to launch 5G services in at least one major city by year-end 2020 and to provide 5G services in all urban areas and along major transport paths by 2025.

5G Observatory quarterly reports and scoreboards: monitoring progress (2018-2021)

Since 2018, the European Commission regularly follows developments and initiatives in Europe and in major international markets through the 5G European Observatory. It analyses consistency and timing with the objectives set in the 'Gigabit Society Communication (GSoC)', in the 5G Action Plan and in other policy documents. An online platform (https://5gobservatory.eu/) was designed. Initiatives, developments and progress made can be accessed.

5G Observatory quarterly reports and scoreboards

The European 5G Observatory provides updates on all of the latest market developments, including actions being undertaken by the private and public sectors in 5G. It also delivers an analysis of the strategic implications of the 5G Action Plan and other policy objectives.

Appendix E Key harmonisation measures in Europe

E.1 The European Electronic Communications Code (EECC, 2018)

The EECC is an EU directive. It regulates electronic communications and services within the EU. The last one was adopted on 21 December 2018. It consolidated and modernised the EU regulation framework. It is a key legal measure of the EU's Digital Single Market Strategy. The Member States have to transpose it into national laws by December 2020.

The 2018 EU' Telecommunications code has been supporting 5G by enabling the regulatory environment for 5G. Key measures for 5G include:

- Common deadlines for licensing
- Commitments for pioneer bands for 5G
  - 700 MHz: by 30 June 2020 - 3.5 GHz by 31 December 2020 - 1 GHz in 26 GHz frequencies by 31 December 2020
  - General exceptions apply
- In line with technical conditions adopted in 2018 and 2019
- Coordinated auctions' mechanisms
- At least 20 years' licence for spectrum
- Flexibility on spectrum (Authorisation eased, spectrum sharing and trading allowed, infrastructure sharing permitted or local roaming if major bottlenecks)
- Lighter authorisation for small cells

Article 54(1)(b) of the European Electronic Communications Code (EECC) Directive (EU) 2018/1972

Article 54 of the European Electronic Communications Code addresses "Coordinated timing of assignments for specific 5G bands". It states that:

- By 31 December 2020, for terrestrial systems capable of providing wireless broadband services, Member States shall, where necessary in order to facilitate the roll-out of 5G, take all appropriate measures to:
  - reorganise and allow the use of sufficiently large blocks of the 3,4-3,8 GHz band;
  - allow the use of at least 1 GHz of the 24,25-27,5 GHz band, provided that there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance.
- Member States may, however, extend the deadline laid down in paragraph 1 of this Article, where justified, in accordance with Article 45(3) or Article 53(2), (3) or (4).

- Measures taken pursuant paragraph 1 of this Article shall comply with the harmonised conditions set by technical implementing measures in accordance with Article 4 of Decision No 676/2002/EC.

Article 57 paragraph 2 of Directive (EU) 2018/1972 of the European Parliament and the Council of 11 December 2018 establishing the European Electronic Communications Code.

Article 57 of the European Electronic Communications Code deals with "Deployment and operation of small-area wireless access points". It states that:

- Competent authorities shall not unduly restrict the deployment of small-area wireless access points. Member States shall seek to ensure that any rules governing the deployment of small-area wireless access points are nationally consistent. Such rules shall be published in advance of their application.

  In particular, competent authorities shall not subject the deployment of small-area wireless access points complying with the characteristics laid down pursuant to paragraph 2 to any individual town planning permit or other individual prior permits.

  By way of derogation from the second subparagraph of this paragraph, competent authorities may require permits for the deployment of small-area wireless access points on buildings or sites of architectural, historical or natural value protected in accordance with national law or where necessary for public safety reasons. Article 7 of Directive 2014/61/EU shall apply to the granting of those permits.

- The Commission shall, by means of implementing acts, specify the physical and technical characteristics, such as maximum size, weight, and where appropriate emission power of small-area wireless access points.

- The first such implementing act shall be adopted by 30 June 2020.

The European Commission respected this deadline and published the implementing regulation (EU) 2020/... of 30 June 2020 on small-area wireless access points (see next section for more details).

E.2 EC small-area wireless access points (implementing regulation (EU) 2020/... of 30 June 2020)

Characteristics of small-area wireless access points (implementing regulation (EU) 2020/... of 30 June 2020)

In June 2020, the European Commission has adopted the Implementing Regulation on small-area wireless access points, or small antennas.

It aims to help simplify and accelerate 5G network installations, which should be facilitated through a permit-exempt deployment regime, while ensuring that national authorities keep oversight.

The Commission Implementing Regulation defines the physical and technical characteristics of those small cells, which are exempted from any individual town planning permit or other individual prior permits.

- The new small cells (antennas) will be less visible (either fully integrated and invisible to the public or, if visible, occupy a maximum space of 30 litres).

- Small cells will produce less electromagnetic emissions. In fact, they could be compared to WiFi installations. Small cells will use lower power levels and therefore create lower exposure levels than existing 4G infrastructure. The overall exposure with the rollout of 5G networks will, therefore, be

comparable to existing levels – it will be well below the strict EU exposure limits, which, for the general public, are 50 times lower than what international scientific evidence would suggest as having any potential effect on health. Public health protection is ensured by the strict exposure limits set out in Council Recommendation 1999/519/EC, which sets exposure limits at 50 times lower than international scientific recommendations that ensure public safety.

Appendix F Technical considerations for coexistence

F.1 ITU allocations

When considering potential coexistence and associated technical conditions it is important to consider ITU allocations, for example, for the protection of international services (e.g. satellite systems). ITU Radio Regulations Region 1 allocations include the following services and relevant footnotes for the 26 GHz band (24.25 – 27.5 GHz) and adjacent bands.

Figure F.1: ITU allocations

Band	Allocation
23.55 – 23.6 GHz	Fixed Mobile
23.6 – 24 GHz	EESS (passive) Radio Astronomy Space Research (passive) Note: All emissions are prohibited. (5.340)
24 – 24.05 GHz	Amateur Amateur Satellite Note: Also designated for ISM applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. (5.150)
24.05 – 24.25 GHz	Radiolocation *Amateur (secondary allocation)* *EESS (active) (secondary allocation)* Note: Also designated for ISM applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. (5.150)
24.25 – 24.45 GHz	Fixed
24.45 – 24.65 GHz	Fixed Inter-satellite
24.65 – 24.75 GHz	Fixed Fixed Satellite (Earth to space) Inter-satellite Note: Use of the band 24.65-25.25 GHz in Region 1 and the band 24.65-24.75 GHz in Region 3 by the fixed satellite service (Earth-to-space) is limited to earth stations using a minimum antenna diameter of 4.5 m. (5.532B)

Band	Allocation
24.75 – 25.25 GHz	Fixed Fixed Satellite (Earth to space) Note: Use of the band 24.65-25.25 GHz in Region 1 and the band 24.65-24.75 GHz in Region 3 by the fixed satellite service (Earth-to-space) is limited to earth stations using a minimum antenna diameter of 4.5 m. (5.532B)
25.25 – 25.5 GHz	Fixed Inter-satellite Mobile *Standard frequency and time signal-satellite (Earth-to-space) (secondary allocation)* Note: Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space. (5.536)
25.5 – 27 GHz	EESS (space-to-Earth) Fixed Inter-satellite Mobile Space Research (space-to-Earth) *Standard frequency and time signal-satellite (Earth-to-space) (secondary allocation)* Notes: Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space. (5.536) Administrations operating earth stations in the Earth exploration-satellite service or the space research service shall not claim protection from stations in the fixed and mobile services operated by other administrations. In addition, earth stations in the Earth exploration-satellite service or in the space research service should be operated taking into account the most recent version of Recommendation ITU-R SA.1862. (5.536A) Earth stations operating in the Earth exploration-satellite service in the frequency band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (5.536B)
27 – 27.5 GHz	Fixed Inter-satellite Mobile Note: Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space. (5.536)

Band	Allocation
27.5 – 28.5 GHz	Fixed Fixed Satellite (Earth to space) Mobile Notes: The use of the band by non-geostationary fixed satellite systems is subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. (5.484A) 27.5-27.82 GHz and 28.45-28.94 GHz are identified for use by high-density applications in the fixed-satellite service. (5.516B) The bands 27.500-27.501 GHz and 29.999-30.000 GHz are also allocated to the fixed-satellite service (space-to-Earth) on a primary basis for the beacon transmissions intended for up-link power control. Such space-to-Earth transmissions shall not exceed an equivalent isotopically radiated power (e.i.r.p.) of 10 dBW in the direction of adjacent satellites on the geostationary-satellite orbit. (5.538) The band 27.5-30 GHz may be used by the fixed-satellite service (Earth-to-space) for the provision of feeder links for the broadcasting-satellite service. (5.539) The band 27.501-29.999 GHz is also allocated to the fixed-satellite service (space to Earth) on a secondary basis for beacon transmissions intended for up-link power control. (5.540)

F.2 European Common Applications

In Europe there are a number of potential applications that may be deployed as shown in Figure F.2. The applications listed will not all be deployed in each EU country and therefore coexistence considerations may vary.

Figure F.2: Allocations and applications listed in European Common Allocation Table[175]

Frequency range	Applications
23.55 – 23.6 GHz	PMSE Fixed SRR
23.6 – 24 GHz	SRR Radio astronomy Passive sensors (satellite)
24 – 24.05 GHz	Amateur satellite Amateur ISM Non-specific SRDs SRR PMSE

[175] https://efis.cept.org/view/search-general.do

Frequency range	Applications
24.05 – 24.25 GHz	PMSE SRR Amateur ISM Active sensors (satellite) Radiolocation (military) TTT Non-specific SRDs Radiodetermination applications
24.25 – 25.25 GHz	Radiodetermination applications MFCN SRR Fixed PMSE
25.25 – 25.5 GHz	Radiodetermination applications MFCN SRR Fixed FWA Maritime military systems Aeronautical military systems Land military systems
25.5 – 26.5 GHz	Radiodetermination applications MFCN SRR Fixed FWA Maritime military systems Aeronautical military systems Land military systems Space research
26.5 – 27 GHz	SRR Space research Land military systems MFCN Radiodetermination applications
27 – 27.5 GHz	MFCN Land military systems
27.5 – 28.5 GHz	Feeder links FSS Earth Stations Fixed FWA NGSO ESOMPs GSO ESOMPs

F.2.4 Coexistence considerations

Co-existence between WBB ECS networks

Co-existence between WBB ECS systems has been addressed as part of harmonisation efforts in Europe. European Commission Implementing Decision (EU) 2019/784[176] (published in May 2019 and amended by European Commission Implementing Decision (EU) 2020/590[177] in April 2020) provides the essential technical conditions for the use of 24.25 – 27.5 GHz band in the European Union by WBB ECS. These conditions state that the duplex mode is TDD and the block size is 200 MHz although smaller blocks of 50, 100, 150 MHz are possible adjacent to the assigned block of another spectrum user.

In terms of mutual co-existence between WBB ECS systems, base station and user terminal transmissions within the band are restricted by 'block edge masks' which assume synchronised operation and comprise base station transitional region power limit of 12 dBm/50MHz applicable up to 50 MHz below or above an operator's block and base station baseline power limit of 4 dBm/50MHz applicable to frequency offsets greater than 50 MHz below or above an operator's block. The limits are defined in terms of total radiated power a composite antenna radiates. For the unsynchronised operation, it is stated that 'unsynchronised or semi synchronised operation also necessitates the geographical separation of neighbouring networks'.

These conditions originate from CEPT Report 68[178] (published in July 2018) which provides harmonised technical conditions for the 26 GHz band and also included in ECC Decision (18)06[179] published in July 2018[180].

Co-existence with fixed links

ECC Report 303 (published in July 2019) provides guidance to administrations for co-existence between 5G and fixed links in the 26 GHz band. The report is one of 'toolboxes' developed within CEPT ECC with the intention of helping administrations in the national decision process to support 5G systems in 26 GHz where fixed links are operating.

The report notes that co-existence studies have been performed between PP and PMP fixed links and 5G systems in the frequency band 24.25 - 27.5 GHz and adjacent bands to support the introduction of 5G systems according to the harmonised technical conditions given in ECC Decision (18)06. Interference scenarios examined include outdoor urban/sub-urban BS/UE and indoor BS interfering with fixed link receivers. MCL and Monte Carlo simulations have been used to analyse the co-existence conditions. MCL analysis derives the minimum protection distance required to satisfy the long-term protection criteria of fixed service (I/N = -10 dB for 20% of time). Monte Carlo simulations take account of dynamic pointing of BS antenna and clutter effects (P.2108). Path loss calculations are implemented according to P.1411 (for < 1 km) and P.452 (for > 1 km). For indoor scenarios, P.2109 is used for building entry loss calculations.

The report presents summaries of five studies together with key results obtained for co-channel and adjacent band co-existence scenarios.

In co-channel co-existence scenarios, calculated distances range widely from a few to tens of kilometres depending on assumptions (indoor/outdoor, urban/suburban, BS antenna configuration, antenna height and pointing). For example, one study reports separations of 20 – 70 km for a co-channel urban 5G deployment. Another study reports that co-channel separations of 22 – 39 km are required for scenarios where fixed link antennas at 15 m, 30 m and 60 m heights points towards a BS transmitter. When 5 degrees off-axis angle in the azimuth plane is introduced, co-channel distances are reduced to 5.5 km or less.

In the adjacent band scenarios, one study reports distances below 2 km with no guard band. With 20 MHz guard band, the required separation is reduced to less than 600 metres when the fixed link receiver and BS

[176] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019D0784
[177] https://eur-lex.europa.eu/eli/dec_impl/2020/590/oj
[178] https://www.ecodocdb.dk/document/3358
[179] https://www.ecodocdb.dk/document/3361
[180] Note this ECC Decision has been updated to reflect the outcome of WRC-19 and further discussions on coexistence in Europe and should be issued for public consultation if approved at the next ECC meeting.

transmitter are in the same azimuth plane. If 5-degrees azimuth off-axis is assumed separation requirements are below 300 metres.

A further study reports distances mainly below 1 km for indoor 5G deployment scenarios. In the case of Monte Carlo analysis, simulations have been performed for an assumed set of separation distances (0.3 km, 1 km, 5 km and 10 km). Calculated interference probabilities indicate that separation distances in excess of 10 km would be required to bring the probability of interference to acceptable levels for both urban and suburban co-channel 5G deployments. In the case of adjacent band urban deployment, a minimum of 1 km separation together with 28 MHz (for 15 & 30 m FS antenna height) / 56 MHz (for 60 m FS antenna height) would be required.

Based on the results, the following methods are proposed under 'shared approach'.

- *Sharing of frequency and space* – This allows the same area and frequency band operation by taking advantage of fixed link use in limited geography and parts of spectrum and 5G deployment in hotspots. It requires a case-by-case analysis which may be undertaken by the administration, operators or a third party.

- *Sharing of frequency, separation in space* – This is based on deploying 5G systems in urban areas while migrating affected fixed links to other bands. The use of 5G in sub-urban and rural areas is then on the basis of sharing of frequency and space. This approach may require establishing power limits and buffer areas as well as individual coordination of fixed links and 5G BSs.

- *Sharing of space, separation in frequency* – This envisages the deployment of both services in the same area within exclusive parts of the band. Mitigation measures including power limits and guard bands as well as individual coordination of fixed links and 5G BSs might be required.

- *Separation in frequency and space* – This approach is based on a migration of fixed links affected by urban 5G deployment and separation of fixed link and 5G use into exclusive bands in suburban and rural areas. There may be requirements to establish power limits, buffer areas, guard bands and individual coordination between fixed links and 5G BSs.

Under operational guidelines for administrations, the report states that "*in many CEPT administrations, the 26.5 - 27.5 GHz frequency range is less used by incumbent systems than the 24.5 - 26.5 GHz frequency range. Therefore, initial 5G system deployments in many CEPT administrations are expected in the 26.5 - 27.5 GHz frequency range*." The current use in Ireland is reflected in this statement. The report further states that "*An example for the shared approach "Sharing of space, separation in frequency" is the implementation of 5G systems in the upper 1 GHz of the band from 26.5 - 27.5 GHz, as a first step. This approach enables to maintain the FS in the lower part of the band in the same geographical area and gives administration the freedom to develop further their national strategy for the implementation of 5G systems while monitoring market demands.*"

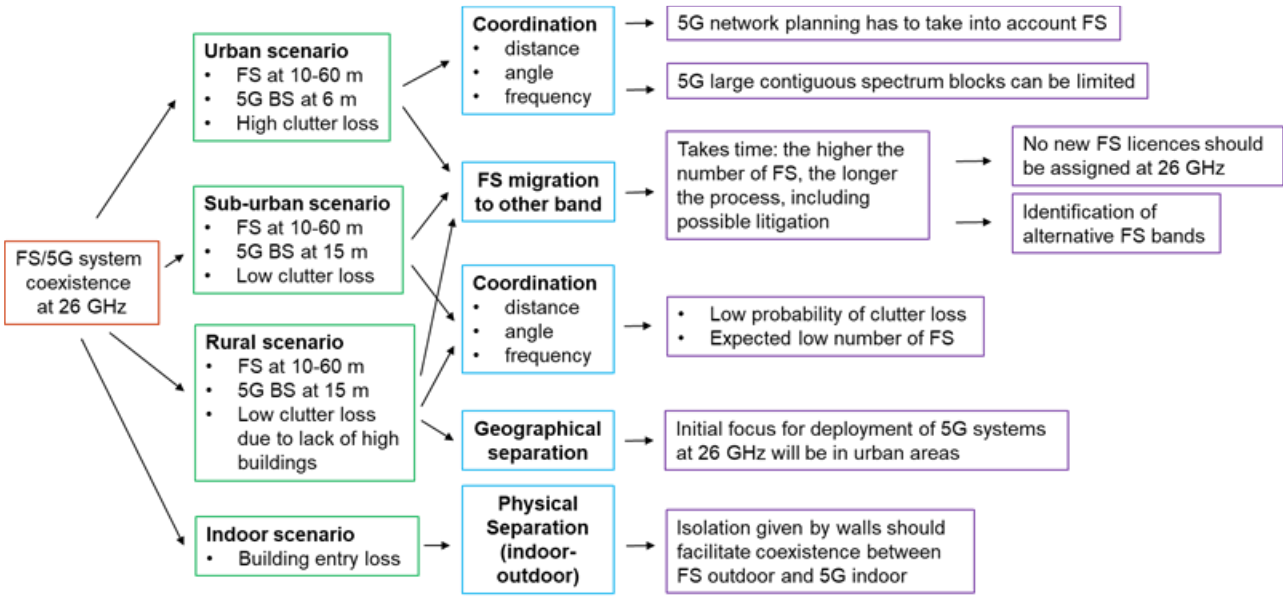
The report notes that the guard band between the fixed links operating within 24.5 - 26.5 GHz and 5G systems operating above 26.5 GHz will be at least 47 MHz as the uppermost channel edge is 26.453 GHz according to Recommendation T/R 13-02[181]. It is proposed that after the allocation of 1 GHz in the upper part of the band the remaining spectrum can be assigned to 5G networks by migrating FS links to other bands or replacing them with fibre links. These proposals are called 'phased approach'.

The complete or partial removal of fixed links from the 26 GHz band before the introduction of 5G networks is presented as 'migration approach'.

The report provides the following indicative examples based on the implementation of proposed approaches.

[181] https://docdb.cept.org/document/869

Figure F.3: Example use of proposed approaches (Source: ECC Report 303)



In terms of implementation, two methods are proposed.

- *Method 1* – the administration specifies direct restrictions on the deployment of 5G systems using one or combination of parameters that include separation distance, exclusion area, frequency separation, pointing angle separation, antenna height and transmit power. Case-by-case calculations by the administrator or a third party on behalf of the administration with the involvement 5G operators can be performed to define required co-existence restrictions.

- *Method 2* – the administrator can specify permitted interference levels at FS receivers and allow 5G operators to comply with the specified levels. Calculations for compliance can be performed by 5G operators or a third party acting on behalf of operators under the supervision of the administration with the possible involvement of fixed link stakeholders.

Co-existence between FS and IMT systems in the 26 GHz was also considered within ITU-R TG 5/1. The final chairman's report of ITU-R TG 5/1 (published in August 2018) includes an annex providing details of co-existence studies involving FS and IMT systems operating in the range 24.25 – 27.5 GHz (Annex 03 Part 5)[182]. These studies consider both co-channel and adjacent band scenarios undertaken for a range of analysis parameters using MCL and simulation analysis methods. The results presented in the report suggest that

- for co-channel scenarios, separation distances ranging from a few km to tens of kilometres are required depending on IMT deployment environment (e.g. urban / sub-urban hotspot); FS antenna type and height (e.g. PP / PMP; 15 / 30 / 60 m); IMT antenna height (e.g. 6 / 15 m); and assumed antenna gain and pointing.

- in the case of adjacent band scenarios, two studies provide analysis with an assumed 20 MHz guard band between a PP FS receiver and an IMT BS transmitter. Example results from the first study indicate that the co-channel separation distance of 25.25 km decreases to 3.5 km when there is no azimuth offset between the PP FS receiver and IMT BS transmitter. When there is an azimuth offset greater than 5 degrees required separations are a few hundred metres. Example results from the second study indicate that when a PP FS antenna with a maximum gain of 31.5 dBi (48 dBi) is assumed to be pointing at IMT base station transmitter the co-frequency separation requirement of 19.4 km (33.6 km) is reduced to 0.46 km (0.29 km).

[182] https://www.itu.int/md/R15-TG5.1-C-0478/en

These results reinforce CEPT conclusions in that the IMT and FS co-existence in the 26 GHz band requires case-by-case analysis. In the case of adjacent band co-existence, an assumed 20 MHz guard band reduces separation requirements significantly, a few hundred metres in most scenarios.

Co-existence with space services

Space services with allocations within 24.25 – 27.5 GHz include:

- Fixed Satellite Service (FSS) (Earth to space);
- Inter Satellite Service (ISS); and
- Earth Exploration Satellite Service (EESS) and Space Research Service (SRS) (space-to-Earth).

EC Decision 2019/784 states that "*Co-existence between terrestrial wireless broadband electronic communications services (including 5G) and earth stations in the EESS, SRS and FSS operating in the 26 GHz frequency band can be ensured by applying, where appropriate, technical constraints to the deployment of terrestrial services in a limited geographical area around a satellite earth station. In this regard, deploying new earth stations preferably away from locations with high population density or high human activity may represent a proportionate approach to facilitating such co- existence. Moreover, CEPT has been developing technical toolkits to support 5G deployment based on individual authorisation while allowing in a proportionate way the continued use of current and planned EESS/SRS receiving earth stations and FSS transmitting earth stations in the relevant portions of the 26 GHz frequency band. These toolkits can facilitate coexistence in fulfilling the obligations under this Decision*".

Co-existence conditions developed within CEPT toolkits are summarised in this section.

Fixed Satellite Service (Earth to space)

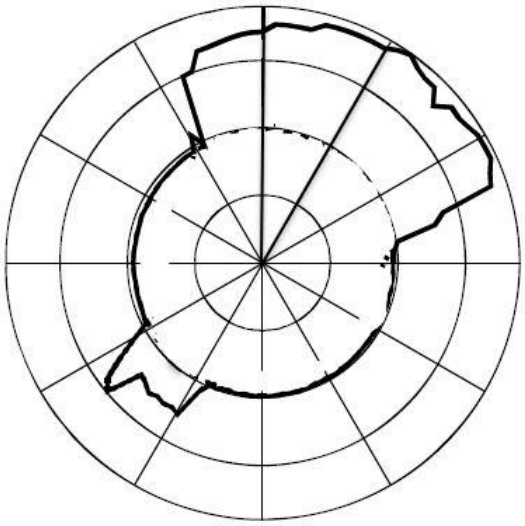
The Fixed Satellite Service (FSS) allocation is in the band 24.65 – 25.25 GHz in Earth-to-space direction. ITU RR footnote 5.532B states that "*Use of the band 24.65-25.25 GHz in Region 1 and the band 24.65-24.75 GHz in Region 3 by the fixed satellite service (Earth-to-space) is limited to earth stations using a minimum antenna diameter of 4.5 m.*" This is effectively to prevent the extensive of the band by FSS as earth stations with large antennas are expected to be sparse.

ECC Recommendation (20)01 (published in March 2020) provides guidelines to support the introduction of 5G systems in 24.65 – 25.25 GHz while ensuring the operation of existing and planned FSS earth station transmitters[183]. The recommendation states that coordination zones around FSS earth station transmitters need to be established to ensure co-existence with 5G systems. The exact coordination zone needs to be determined on a case-by-case basis by taking account of site location, elevation angle, transmission parameters, propagation effects (e.g. clutter and terrain profile) and 5G receiver parameters (e.g. protection criteria and antenna pointing statistics). Coordination zones are expected to be large given that they are largely based on generic and pessimistic assumptions. Outside coordination zones, 5G systems can be deployed without constraints. Within coordination zones, more detailed site-by-site analysis is required to enable 5G system operation.

The coordination area calculation methodology is based on the use of FSS transmitter characteristics to calculate interference in the area surrounding the FSS transmitter on a pixel-by-pixel basis. The coordination area contour is then drawn to indicate the area where the 5G system protection criterion is not satisfied. if 5G systems are to be deployed within the coordination area, a further detailed co-existence analysis is required. An example coordination zone is shown below.

[183] https://www.ecodocdb.dk/document/13860

Figure F.4: Example of coordination contour around an FSS earth station (Source: ECC Recommendation (20)01)



In terms of interference into FSS satellite receivers is concerned, CEPT Report 68 states that "*coexistence with FSS satellites is feasible (aggregate interference from 5G base stations to GSO FSS satellites will likely fall within the protection criteria for GSO FSS with a large margin) when considering the assumed technical and operational characteristics for 5G*". Furthermore, EC Decision 2019/784 provides an additional condition applying to Active Antenna System (AAS) outdoor base stations for the protection of space station receivers operating in FSS and Inter Satellite Service (ISS). This condition states that "*When deploying such base stations, it shall be ensured that each antenna is normally transmitting only with the 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*". With respect to the protection of satellite receivers, it is further stated that "*The use of unmanned aerial vehicles ('UAVs') such as drones with terrestrial wireless broadband electronic communications networks that use the 26 GHz frequency band could have an impact on existing use such as satellite receivers in the FSS and ISS. As a result, connectivity from base stations to terminal stations on board UAVs should be prohibited in the 26 GHz frequency band, and only connectivity from terminal stations on board UAVs to base stations should be allowed in compliance with applicable air traffic management regulation*".

Inter Satellite Service

Inter Satellite Service (ISS) allocations are in the bands 24.45 – 24.75 GHz and 25.25 – 27.5 GHz. According to ITU RR footnote 5.536, the use of the 25.25-27.5 GHz band by ISS is limited to Space Research and Earth Exploration Satellite applications, and also transmissions of data originating from industrial and medical activities in space.

CEPT Report 68 notes that ISS systems are used inter-orbit communications between LEO and GEO satellites. The European Data Relay System (EDRS) is an example of ISS and operates in the 25.25 – 27.5 GHz band. According to the report, studies have shown that co-existence between satellite data relay systems including EDRS and 5G networks is feasible with a large protection margin.

As mentioned in the preceding section, there is also a harmonised technical condition requiring that an outdoor base station antenna beam should normally be below the horizon and there should be no mechanical pointing above the horizon. This is reflected in EC Decision 2019/784 where it is stated that "*Coexistence between terrestrial wireless broadband electronic communications services (including 5G) and satellite receivers in the FSS and ISS, including EDRS, is currently feasible, subject to technical conditions that address the antenna elevation of wireless broadband base stations*".

EESS and Space Research Service (space-to-Earth)

EESS and Space Research Service (SRS) have primary allocations in the 25.5 – 27 GHz band. There are several ITU RR footnotes defining the use and co-existence regulations within the band.

- 5.536: Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space.

- 5.536A: Administrations operating earth stations in the Earth exploration-satellite service or the space research service shall not claim protection from stations in the fixed and mobile services operated by other administrations. In addition, earth stations in the Earth exploration-satellite service or in the space research service should be operated taking into account the most recent version of Recommendation ITU-R SA.1862.

- 5.536B: Earth stations operating in the Earth exploration-satellite service in the frequency band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (This is applicable to a list of countries including Ireland)

- 5.536C: Earth stations operating in the space research service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (This is applicable to a list of countries not including Ireland)

In generic terms, these footnotes imply that the use of the band by EESS/SRS earth station receivers should not constrain the deployment of mobile networks.

ECC Recommendation (19)01 is a technical toolkit published in March 2019 that addresses 5G and EESS/SRS co-existence in the 26 GHz band[184]. The recommendation states that compatibility between IMT-2020 and EESS/SRS earth stations can be achieved by establishing appropriate coordination zones around earth stations. The precise shape of the coordination zone needs to be determined on a case-by-case and is dependent on the terrain profile and the type of the earth station. Outside the coordination zone, IMT-2020 systems can be deployed without constraints. Within the coordination zone, IMT-2020 systems need to be deployed such that the protection of earth station receivers is ensured. To accommodate the differences between SRS, NGSO EESS and GSO EESS earth stations, the recommendation defines three methodologies for coordination zone calculations.

With respect to the deployment of UAVs in 5G networks, EC Decision 2019/784 states that "*the connectivity from terminal stations on board UAVs to base stations could have a significant impact on, for example, the separation distance to EESS/SRS earth stations co-using the 26 GHz band. This requires further study, which may deliver supplementary harmonised technical conditions. Using UAVs with wireless broadband electronic communications networks should not hinder the deployment of future EESS/SRS earth stations*".

Co-existence with licence-exempt devices

The main licence-exempt use is for automotive short-range radars (21.65 – 26.65 GHz) but there are also industrial probing radars (24.05 – 26.5 GHz); and tank level probing radars (24.05 – 27 GHz). According to CEPT Report 68 and EC Decision 2019/784.

- The use of 24.25 - 26.65 GHz band by automotive short-range radars is no longer available since January 2018 and radar equipment already in use should be gradually phased out by 1 January 2022. There is a steady trend in the market development for automotive short-range radars towards new deployments in

[184] https://www.ecodocdb.dk/document/9071

the 77 - 81 GHz frequency band harmonised at Union level. Therefore, no co-existence issues with automotive short-range radars are identified.

- The 24.25 - 24.5 GHz portion of the band is designated at EU level for transport and traffic telematics devices, in particular for automotive radars on a non-protected and non-interference basis. CEPT identified that there is no current or planned use of automotive radars in the band, while such use increases in the 76 - 81 GHz frequency range.

- The 24.25 - 27 GHz portion of the 26 GHz frequency band is used for radio determination devices, which operate in 'underlay' mode based on ultra-wide band technology. Such use should be adaptable to the evolution of use of the 26 GHz frequency band for terrestrial wireless broadband electronic communications services. (Note that this clause is related to the probing radars)

It is noted that ECC Decision (11)02 (July 2019)[185] provides regulatory and technical conditions for industrial Level Probing Radar (LPR) applications to avoid interference occurrences in the bands 6 – 8.5 GHz, 24.05 – 26.5 GHz, 57 – 64 GHz and 75 – 85 GHz. The Decision states that regulatory conditions set out in the document are derived from the findings of ECC Report 139 where detailed compatibility studies are presented for LPRs deployed outdoor and indoor (covered) industrial environments and a range of victim services including fixed links (PP and PMP), EESS and RAS[186]. The compatibility studies are based on conservative assumptions to ensure that associated conditions do not constrain future primary radio service development in these bands. These are accompanied by measurements to confirm expected levels of interfering signals. The Report concludes that LPR devices are installed and maintained in industrial environments by professionally trained personnel. They can be deployed on a licence-exempt basis subject to ensuring compliance with regulatory conditions which include the use of adaptive power control and limits associated with eirp, antenna orientation, antenna beamwidth and unwanted emissions. It is also noted that Annex 6 of ERC Recommendation 70-03 provides an eirp density limit for tank level probing radars (TLPRs) to be satisfied outside the tank structure[187].

Furthermore, ETSI TR 102 347 (1/2005)[188] and ETSI TR 102 601 (12/2007)[189] are ETSI technical reports developed for TLPRs and LPRs where system characteristics are provided. Both reports include a brief annex on compatibility issues.

- ETSI TR 102 347: Compatibility issues are not expected because TLPRs are installed in closed metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material, and the primary or secondary users in the same band co-exist without problems. The numbers of TLPR units will not proliferate to the point where aggregation could affect any of the primary services in the band and any detectable emissions outside the tank enclosure must meet the proposed limits. Over the last three decades there have been no reports or complaints about interference between TLPRs and other radio services. Furthermore, installation of the antenna inside the tanks pointing downwards mitigates any external emissions from interfering with TLPR systems. Tests have been performed on installed units as described above and no emission above the limits from TLPR was detectable outside the tank.

- ETSI TR 102 601: EIRP limits, installation requirements and the maximum duty cycle limit of 1 % should ensure LPR compatibility with other services. LPR equipment is a professional system strictly for commercial usage that is installed and maintained by professionally trained individuals. Their use is associated with new industrial construction and in retrofitting existing industrial facilities. Due to the external dimensions of applications that are not in closed metallic tanks, the average number of LPR units per square kilometre will

[185] https://www.ecodocdb.dk/document/429
[186] https://www.ecodocdb.dk/document/247
[187] https://www.ecodocdb.dk/document/845
[188] https://www.etsi.org/deliver/etsi_tr/102300_102399/102347/01.01.02_60/tr_102347v010102p.pdf
[189] https://www.etsi.org/deliver/etsi_tr/102600_102699/102601/01.01.01_60/tr_102601v010101p.pdf

be low. In addition, considering the overall transmitter activity at a given frequency, it can be assumed that aggregation effects from LPR are highly unlikely.

Co-existence with adjacent band services

The key issue that has been identified in the context of adjacent band co-existence with 5G networks is the protection of passive services in the band 23.6 – 24 GHz where all emissions are prohibited (ITU RR footnote 5.340), for example to enable observations of weather and climate from space.

EC Decision 2019/784 states that "*Terrestrial wireless broadband electronic communications services, including 5G, in the 26 GHz frequency band should provide appropriate protection to the EESS (passive) in the 23,6-24 GHz frequency band. Specific measures may be required at national level to ensure radio astronomy stations operating in the 23,6-24 GHz frequency band are protected. These measures are likely to constrain usability of the full 26 GHz band around such stations*".

CEPT Report 68 notes that passive sensors operate in 23.6 – 24 GHz in a number of ESA, EC Copernicus and EUMETSAT programmes. For the protection of EESS in the 23.6 – 24 GHz band, harmonised out-of-band emission limits are defined for 5G transmitters operating in 24.25 – 27.5 GHz band. These limits are specified in EC Decision 2020/590 (published in April 2020) which amends EC Decision 2019/784 to take account of the changes incorporated into the ITU-R Radio Regulations after WRC-19 where 5G global unwanted emission limits are introduced (in two stages). Accordingly, 5G base station unwanted emission limits (in terms of total radiated power a composite antenna radiates) are -33 dBW/200MHz for deployments before 1 January 2024 and -39 dBW/200MHz for deployments after 1 January 2024. For the user terminals, the corresponding levels are -29 dBW/200MHz and -35 dBW/200MHz.

For protection of Radio Astronomy Service (RAS), CEPT Report 68 states that "*generic compatibility studies between RAS in the passive band 23.6-24 GHz and IMT systems in the frequency band 24.25-27.5 GHz show emission-free zones around RAS stations are required to protect this service from IMT unwanted emissions. These would be managed on a national basis and the size of the zone would be dependent on the IMT unwanted emission limits into the 23.6-24 GHz band and local environment*".

