



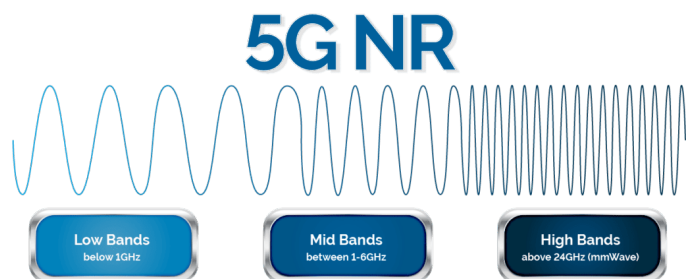
SPECTRUM AUCTIONS: MMWAVE FREQUENCIES FOR 5G MOBILE

Regulators and governments around the world are opening up mmWave spectrum to further develop 5G mobile services. Ofcom in the UK has confirmed its intention to make mmWave spectrum available for mobile use by 2024 and is minded to award licences through a combination of auctioned citywide licences, and local first come, first served Shared Access licences.

In this note we look at market developments in mmWave bands across the world and describe some of the licence award approaches. While some have speculated innovative services might promote new interest in mmWave spectrum, demand for frequencies in most countries has largely come from established mobile operators.

At present, the dollar per MHz per pop value of mmWave spectrum is a small fraction of higher value mid-band spectrum. Further, recent auctions indicate demand for mmWave spectrum has waned. Some European mobile operators are even suggesting its release for mobile in countries that have yet to award licences would benefit from delay.

If Ofcom were to award fixed term 10-year city wide licences, in the current market climate it would likely need to apply relatively low reserve prices. This was done by the Federal Communications Commission (FCC) in the US back in 2019. Using similar reserve prices, we calculate a reserve price for a 100 MHz lot of 26 GHz in London at around £1 million.



Auctioning all of the 2.4 GHz of bandwidth in the 26 GHz band in the UK - in the top 80 areas of high demand identified by Ofcom (covering 47% of the UK population) - would likely present a total reserve price value in the region of £100 million.

But the experience of Spain's mmWave auction at the end of 2022 is a cautionary tale. Despite setting low reserve prices, the auction was not competitive and many lots went unsold.

An auction in the UK for 26 GHz frequencies, especially if combined with 3 GHz bandwidth of frequencies in the 40 GHz band, could result in many unsold lots. Further, proceeds in the auction would lie far below amounts raised in earlier auctions for mid-band mobile spectrum.

However, maximising auction revenues is not part of spectrum management policy in the UK. Ofcom's proposed auction is designed to achieve efficiency: ensuring those who win licences for mmWave spectrum value it the most. We await with interest to see Ofcom's detailed auction rules.

The crown jewels of mobile telcos are radio frequencies. Early generation mobile services were standardised to work on low-band and mid-band radio frequencies¹, striking a balance between coverage, capacity and latency.^{2,3}

To accommodate rising demand for mobile data services and increasing use of mobile apps, 5G mobile has been developed to operate with greater spectral efficiency than earlier mobile standards and to function on a wider range of frequencies, including high-frequency bands.⁴

The high-frequency bands allocated for 5G are mmWave frequencies, which traditionally have been used for backhauling services in telecoms and other specialised purposes. Spectrum managers around the world - including Ofcom in the UK - are re-farming these mmWave frequencies for 5G mobile use.^{5,6}

Emerging mmWave 5G

mmWave 5G services allow very high throughput. For data hungry users this is attractive. But with low propagation, ubiquitous services require costly *densification*.⁷ As such, mmWave frequency bands are largely seen as potentially commercially attractive where they add incremental mobile capacity and performance in mobile hot spots, concentrated areas of high demand, and where such incremental capacity is important for customers.⁸

Most commercial deployments of 5G mmWave focus on mobile hot spots, though Verizon and T-Mobile in the US initially chose a different route. They launched mmWave 5G cellular services in 2019, prompted in part by competition to grow market share in new 5G services. Despite Verizon installing around 33,000 small mmWave cells by end 2021⁹, the average Verizon customer only spent 0.8% of connection time on the 5G mmWave frequencies.¹⁰ After Verizon acquired additional mid-band 3.7 GHz spectrum in a

¹ Low band radio frequencies are below 1 GHz, mid-band frequencies in the range 1 – 6 GHz, high-band frequencies above 6 GHz and include millimeter wave (mmWave) spectrum in the frequency range of 30 – 300 GHz. In spectrum policy discussions, mmWave is usually understood to mean the frequency range 24 – 100 GHz.

² Coverage is the geographic area covered by a radio signal, capacity is the amount of data a network can handle at one time. More capacity means the network can handle more simultaneous users and/or faster data speeds. Latency (sometimes called ping) is the delay users experience as data makes a round trip through a network. If the latency of a network is high, it will feel less responsive and be slower to react to requests – what gamers call *lag*.

³ Low-band frequencies have good propagation characteristics and good coverage. Mid-band frequencies have lower propagation and higher capacity and are good for deployment in urban or sub-urban contexts.

⁴ When 5G operates above 6 GHz it facilitates greater capacity and lower latency at the price of poorer propagation (lower coverage). 5G services in high-frequency bands are therefore best suited for dense urban environments and for serving facilities with high density footfall ("hot-spot" type of coverage) such as airports, mainline rail stations, sports stadia, large festivals, etc.

⁵ The frequency bands currently deployed for mmWave services vary slightly across the world. In the US *n261*, 28 GHz (27.5 – 28.35 GHz) and *n260*, 39 GHz (37 – 40 GHz) are currently used. In South Korea and Japan, it is similar to the US, *n257* (26.5 – 29.5 GHz). In Australia, Europe and China, the initial emphasis has been in *n258*, 26 GHz (24.25 – 27.5 GHz).

⁶ Ofcom (2022) "Enabling mmWave spectrum for new uses: Making the 26 GHz and 40 GHz bands available for mobile technology" Public Consultation, May https://www.ofcom.org.uk/data/assets/pdf_file/0027/237258/mmwave-spectrum-condoc.pdf

⁷ Network densification is the adding of more cell sites within an existing mobile infrastructure to increase the amount of available capacity. An early report on the economics of 5G mmWave sets out the cost of densification, see GSMA (2021) "The economics of mmWave 5G: An assessment of total cost of ownership in the period to 2025" <https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=59768858&file=210121-Economics-of-mmWave.pdf>

⁸ In the current economic headwinds of higher interest rates and supply-chain challenges, there is mounting pressure to improve the economics of mmWave 5G. Qualcomm, a leading vendor in the mmWave space, has sought to develop new products addressing high costs of densification. At the end of 2022 it announced a new compact macro 5G radio access network (RAN) on mmWave frequencies will be available in H2 2023 that will boost coverage and *lower overhead costs*. <https://www.fiercewireless.com/5g/qualcomm-boosts-mmwave-coverage-compact-macro-cell-site>

⁹ <https://www.verizon.com/about/news/verizon-ends-2021-strong-wireless-service-revenue-and-eps-growth>

¹⁰ T-Mobile switched its 5G strategy to low- and mid-band frequencies by 2020. "Quantifying the mmWave 5G experience in the US" Opensignal, April 2021 <https://www.opensignal.com/2021/04/28/quantifying-the-mmwave-5g-experience-in-the-us>

FCC auction in 2021, it started to re-brand its 5G service away from emphasising mmWave.¹¹

In addition to 5G mobile deployments, US Cellular and Verizon, among others, have also developed Fixed Wireless Access (FWA) 5G services in the US using mmWave frequencies to compete with fixed-line broadband products.¹²

In Italy the 26 GHz band of frequencies were auctioned by the government in 2018, with five operators winning lots. TIM has started to deploy mobile service in the band “*offering next-generation solutions to citizens*” such as immersive experiences at cultural events and live entertainment, with augmented and virtual reality services using 5G mmWave¹³ and Fastweb¹⁴ offers FWA services.

Japan is one of the most advanced countries in regard to 5G mmWave deployments. In 2019 the Japanese government assigned 400 MHz of 28 GHz spectrum to each of the four major operators: KDDI, NTT DoCoMo, Rakuten Mobile and Softbank.¹⁵ All the operators have launched 5G mmWave services, largely as incremental capacity in hot spots.¹⁶

In Australia, the 26 GHz band of frequencies were auctioned in 2021 and the two largest operators Telstra and Optus have since launched commercial 5G services using these frequencies in a few localities.¹⁷ A subsidiary of a small UK based company, Dense Air, also won two licences, one each in Melbourne and Sydney, to deliver neutral host small cell wireless infrastructure services.¹⁸

South Korea promoted mmWave 5G services at an early stage and in 2018, auctioned three 800 MHz national five-year licences in the 28 GHz band. The three main operators LGU+, KT and SKT won, paying around USD\$186 million each.¹⁹ As part of the conditions attached to their licences, the Korean operators were required to install and deploy 15,000 base stations each by 2021. In late 2022, following a government audit, KT and LGU+ have had their licences revoked for failing to comply with the rollout requirements. This spectrum will in due course be re-auctioned. SK Telecom has had its licence term shortened by six months.²⁰

¹¹ Verizon launched mobile *Ultra Wide Band 5G* on its mmWave frequencies 28 GHz and 39 GHz in 2019. https://www.ericsson.com/4ac68f/assets/local/reports-papers/mobility-report/documents/2020/emr-june2020-verizontransformingbroadband_article.pdf In 2021 Verizon won 3,511 licences in 3.7 GHz mid-band spectrum and has since re-branded its 5G service away from mmWave into these *C Band* frequencies. See “5G’s false start is over and the iPhone SE proves it” <https://www.theverge.com/22968066/apple-iphone-se-5g-mmwave-verizon-uw> March 2022 and <https://www.fcc.gov/auction/107/factsheet>

¹² <https://www.fiercewireless.com/tech/uscellular-launches-mmwave-based-fwa-10-cities>

¹³ October 2022 <https://connect-world.com/tim-and-qualcomm-collaborate-to-launch-new-5g-services/#:~:text=TIM%20and%20Qualcomm%20Technologies%20Inc.technology%20in%20selected%20Italian%20cities>.

¹⁴ “Fastweb and Qualcomm Announce Collaboration to Commercialize 5G Standalone mmWave Services in Italy” <https://www.qualcomm.com/news/releases/2022/02/fastweb-and-qualcomm-announce-collaboration-commercialize-5g-standalone> February 2022

¹⁵ <https://5gobservatory.eu/japan-assigns-5g-spectrum-to-four-operators/>

¹⁶ “KDDI, NTT DoCoMo, Rakuten Mobile and Softbank have all deployed mmWave 5G” August 2022 <https://www.rcrwireless.com/20220810/5g/how-are-japanese-operators-approaching-mmwave-5g>

¹⁷ RCR Wireless News (2021) “Optus deploys initial 5G mmWave commercial sites in Australia” <https://www.rcrwireless.com/20210521/business/optus-deploys-initial-5g-mmwave-commercial-sites-australia>

¹⁸ Dense Air won the licences for around USD \$21.5million or around USD \$0.006 MHz/pop. Throughout this note we express MHz/pop by normalising with reference to a licence duration of 10 years. Dense Air won licences for 200 MHz bandwidth of duration 15 years, covering a population of 11.4m in Melbourne and Sydney. We normalise its MHz/pop price by multiplying USD \$0.009 by 66% to get a 10 year equivalent licence value. Dense Air has negotiated payment over five years at around USD \$4.2m per annum. As far we understand, commercial deployment in the 26 GHz band has not been undertaken by Dense Air Networks Australia Pty. See <https://denseair.net/about-us/>

¹⁹ “South Korea wraps 5G auction for 3.5, 28 GHz” June 2018, <https://www.fiercewireless.com/wireless/south-korea-wraps-5g-auction-for-3-5-28-ghz> The amount paid by each operator was equal to the reserve price for a five year licence The MHz/pop price for the spectrum was around USD \$0.009. See Frank Rayal (2020) “Spectrum Pricing Trends in Millimeter Wave Bands” <https://frankrayal.com/2020/04/23/spectrum-pricing-trends-in-millimeter-wave-bands/>

²⁰ ““Very worrisome”: South Korean govt revokes mmWave 5G licences” November 2022 <https://totaltele.com/very-worrisome-south-korean-govt-revokes-mmwave-5g-licences/>

Hong Kong, with the fourth highest population density²¹ in the world and having a high per capita income status²² would seem an obvious candidate for 5G mmWave deployment. In March 2019 the regulator in Hong Kong administratively awarded 400MHz of spectrum in the 26GHz and 28GHz bands to each of HKT, China Mobile Hong Kong (CMHK) and SmarTone with the obligation that they should each install a minimum of 2,500 radio units by end-2024.²³ Towards the end of 2021 the operators requested a relaxation in the various obligations that had been applied “due to later-than-expected availability of compatible network equipment and handsets”.²⁴

High costs of densification have clearly impacted the rollout of mmWave 5G mobile networks and the small number of relatively expensive customer devices tuned to operate on mmWave 5G frequencies is holding back demand. Some commentators were suggesting as early as 2021 that “The age of mmWave 5G sputters to a dusty death”.²⁵

The role of auctions and administrative awards in mmWave frequency bands

As Ofcom in the UK prepares to consult publicly on how it will auction and administratively award mmWave frequencies in the 26 GHz and 40 GHz bands, we can look to other spectrum agencies that have already awarded licences by auction, administratively, or by a mixture of the two in various mmWave bands.

The justification for awarding spectrum licences by auction is excess demand, efficiency and

competition. If demand for spectrum is expected to exceed supply at opportunity cost²⁶, and where it is not known how much spectrum is needed by different potential users at prices above opportunity cost, well-designed auctions are a way to achieve public policy goals consistent with efficiency and competition.²⁷

In the case of mmWave frequencies, the big issues for auction design relate to the geographic packaging of licences, the quantity of bandwidth to release onto the market, when to release the spectrum and whether to allocate some frequencies into special categories – e.g. allocate some spectrum for uses other than wide area use.

We look at the approaches taken towards awarding 5G mmWave frequency licences in three areas of the world, each providing valuable insights in to how an award might be conducted in the UK.

United States FCC Auction 103 (37,39 & 47 GHz)

The FCC released a swathe of mmWave frequencies in three spectrum auctions 101, 102 and 103 between 2018-20.²⁸ At the time, some of the main players in the US mobile market (especially Verizon) were keen for mmWave spectrum to be released for

²¹ <https://worldpopulationreview.com/country-rankings/countries-by-density>

²²

<https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=HK>

²³ The Office of the Communications Authority in Hong Kong determined that demand for mmWave frequencies was not sufficiently high to warrant award by auction. The 1.2 GHz bandwidth awarded meant a further 2.5 GHz of bandwidth has been held back for future release. https://www.ofca.gov.hk/en/industry_focus/radio_spectrum/administrative_assignment_of_spectrum/26_ghz_and_28_ghz_bands_licensing/index.html

²⁴ “HK pushes back mmWave deployment deadline” November 2021 <https://www.mobileworldlive.com/asia/asia-news/hk-pushes-back-mmwave-deployment-deadline/>

²⁵ <https://www.lightreading.com/5g/the-age-of-mmwave-5g-sputters-to-dusty-death/a/d-id/770838> July 2021

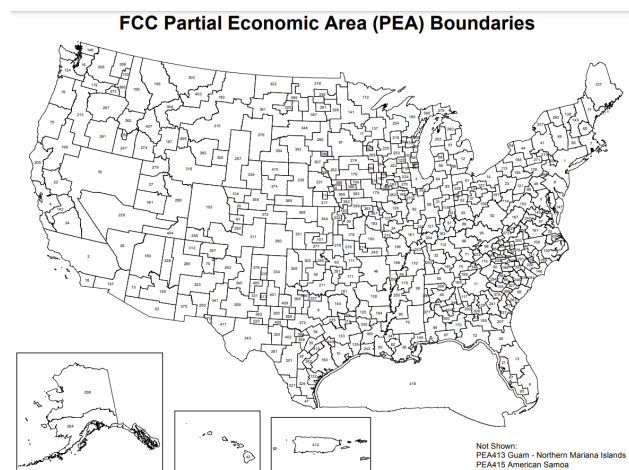
²⁶ Here opportunity cost refers to the highest price the spectrum would command in an alternative use outside of 5G.

²⁷ This is discussed in further detail in our briefing paper “Spectrum auctions: thirty years in the making” <https://www.cepa.co.uk/news-insights/view/spectrum-auctions-thirty-years-in-the-making>

²⁸ FCC Auctions 101, 102 and 103. <https://www.fcc.gov/auctions-summary>

5G high speed mobile broadband, as there was a shortage of ‘sweet spot’ mid-band spectrum.²⁹

Auction 103 in 2019 involved the release of up to 3.4 GHz bandwidth across three bands: 37 GHz, 39 GHz and 47 GHz.³⁰ Licences were offered in 100 MHz lots in Partial Economic Areas (PEAs) – covering the whole of the United States.³¹ The areas differed in size, both in regard to population and geography.



Two categories of spectrum were offered in each PEA, twenty-four contiguous 100 MHz blocks of ‘M/N’ spectrum in the 37 and 39 GHz bands and ten 100 MHz blocks of spectrum in the 47 GHz band. Each

block in each PEA is a licence, giving $34 \times 416 = 14,444$ licences in total.

The starting prices in the auction were proposed to be set at USD \$0.002 MHz/pop for the PEAs 1-50, USD \$0.0004 MHz/pop for PEAs 51-100 and USD \$0.0002 for all other PEAs.³² Following public consultation, the starting prices were reduced by around one half to USD \$0.001, \$0.0002 and \$0.0001 in the PEAs respectively.³³

The duration of licences was set at 10 years, the standard term length of the FCC. Winners of licences know there is a strong presumption of licence renewal if they show evidence of sufficient commercial rollout.

As with most FCC auctions, small bidders (measured by average gross turnover) and rural bidders were eligible for bidder credits. For example, a small business having an average gross turnover of no more than USD \$20 million over the last three years was eligible for a 25% discount on the auction price.³⁴

Thirty-five applicants qualified and four failed to qualify to bid in the auction. Seven bidders were small businesses and ten rural providers. All the major providers qualified as bidders. The auction started on 10 December 2019 and ended 5 March 2020.

The auction format was an ascending clock auction, which comprised an initial clock-phase followed by an

²⁹ However, as noted above early enthusiasm for mmWave has since dampened: “Verizon, a loud and early supporter of mmWave, based much of its initial 5G story on the short-range wireless technology. But mmWave 5G failed to deliver substantive changes. Verizon backed off a plan to charge extra for its mmWave network. And when midband spectrum in the 3GHz range became available in the US, all the mobile providers in the country immediately pivoted to a 5G effort centered on midband.” Mike Dano (2022) “6G spectrum: A game of centimeters” 28 November: <https://www.lightreading.com/6g/6g-spectrum-game-of-centimeters/a/d-id/781917>

³⁰ The frequencies offered were: 37.6-38.6 GHz (Upper 37 GHz), 38.6-40 GHz (39 GHz), and 47.2-48.2 GHz (47 GHz) bands. 5G has been standardised to operate in the 28 GHz and 39 GHz bands in North America. At present an ecosystem is not developed in 5G to operate at 47 GHz. <https://halberdbastion.com/technology/cellular/5g-nr/5g-frequency-bands>

³¹ The FCC has, since the inception of the Cellular Market Areas in 1982, assigned area-based radio licences. There are 416 PEAs (which includes Puerto Rico, Guam, US

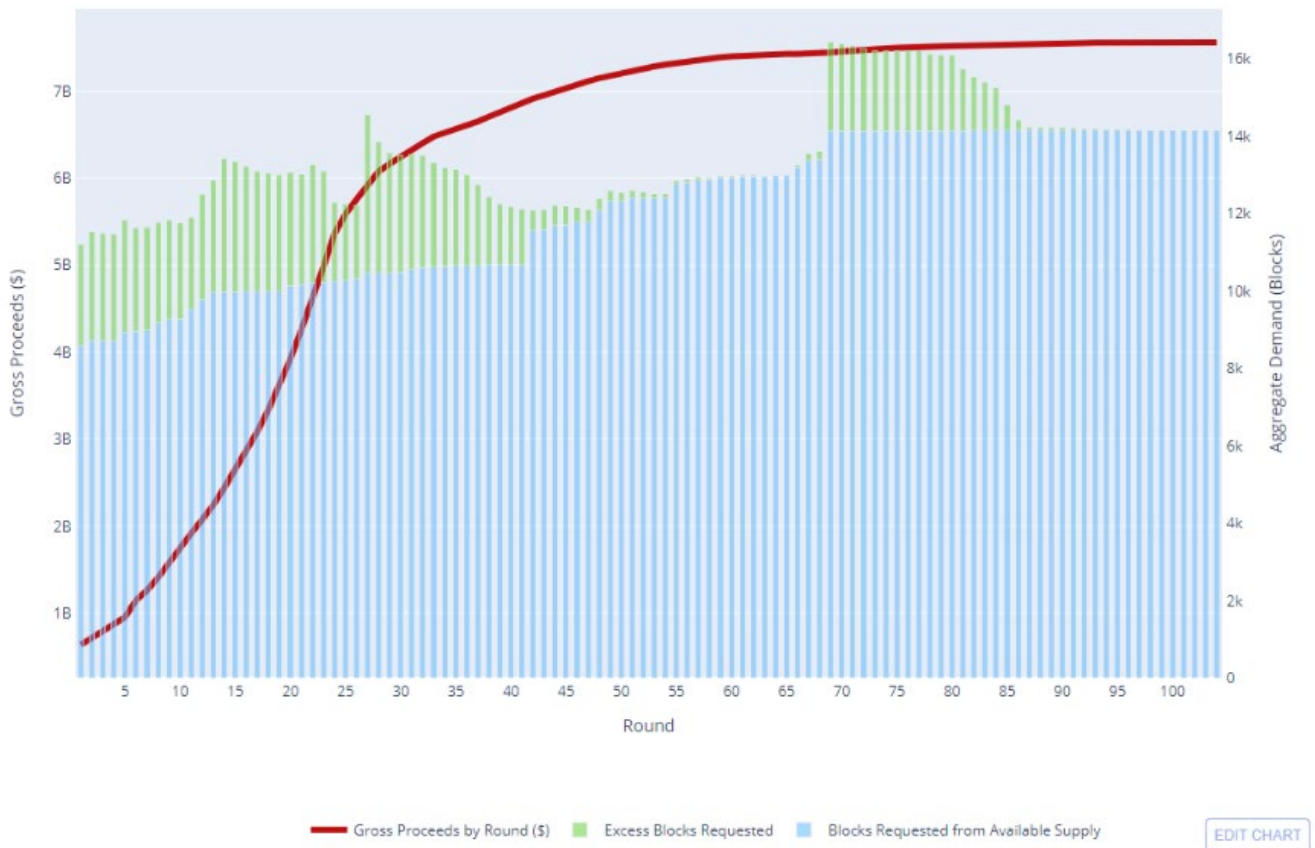
Virgin Islands, Samoa and the Gulf of Mexico) identified by the FCC, the largest by population are New York and Los Angeles (25.2m and 19.4m respectively), see <https://www.fcc.gov/oet/maps/areas> and <https://docs.fcc.gov/public/attachments/DA-14-759A2.pdf>

³² See para. 66 in “FCC FACT SHEET Spectrum Frontiers Auction 103 Public Notice – AU Docket No. 19-59” 2019 at <https://docs.fcc.gov/public/attachments/DOC-356692A1.pdf>

³³ See para. 197 in “INCENTIVE AUCTION OF UPPER MICROWAVE FLEXIBLE USE SERVICE LICENSES IN THE UPPER 37 GHZ, 39 GHZ, AND 47 GHZ BANDS FOR NEXT-GENERATION WIRELESS SERVICES, NOTICE AND FILING REQUIREMENTS, MINIMUM OPENING BIDS, UPFRONT PAYMENTS, AND OTHER PROCEDURES FOR AUCTION 103 BIDDING IN AUCTION 103 SCHEDULED TO BEGIN DECEMBER 10, 2019” AU Docket No. 19-59, GN Docket No. 14-177”, <https://docs.fcc.gov/public/attachments/FCC-19-63A1.pdf>

³⁴ The maximum amount of discount available for such a small bidder was capped at USD \$25 million. A bidder cannot obtain both a small business credit and a rural area credit.

Auction 103 - Gross Proceeds (\$) and Aggregate Demand (Blocks) By Round



assignment phase.³⁵ In the clock phase, the FCC offered the two categories of spectrum in each PEA and increased the price of a category whenever aggregate demand exceeded supply for the category in a PEA. Subject to the auction rules, bidding continued until demand was no greater than supply in every category in every PEA.³⁶

The auction had an interesting incentive component, as incumbent licensees operated in the 39 GHz band (mainly fixed links for backhauling mobile traffic, FWA

services, etc.). Each 39 GHz incumbent submitted an *Initial Commitment* setting out how much it needed to relinquish licences in the band. The auction implemented a *net revenue requirement* such that licences would only be issued in the auction if the proceeds of the clock phase were sufficient to cover the incentive payments owed. In the event, the net revenue requirement was easily satisfied.

The clock phase lasted for 104 rounds, with PEA #209 (Green Bay, Wisconsin) being the last market

³⁵ For more information on how ascending clock auctions work, see our briefing note [Spectrum Auctions: Thirty Years in the Making](#).

³⁶ The key auction activity rules included: (i) applicants needed to specify the PEAs they were interested in bidding on their application form and make an upfront deposit (refunded to losing bidders and used as offset for winning bidders) – and could only bid in the areas listed; (ii) in the opening round bidders could only bid for lots at the opening price; (iii) bid activity had to meet an eligibility requirement; (iv) bidders could only post intra-round bids

after round 1 that were ‘one-directional’ – demand increases or decreases in order of price, not both directions; (v) bidders could place switch bids after round 1 within a PEA by specifying a price on the from product – such that the auction system would compute how much could switch while ensuring aggregate demand in the from category did not fall below supply. Bidder identities were anonymous throughout the auction and aggregate demand was revealed in full to promote price discovery. Further details at <https://www.fcc.gov/file/16481/download>

with excess demand. Bidding in the clock phase ended on 30 January 2020. As seen in the chart, reproduced by kind permission of Sasha Javid³⁷, gross proceeds slowly increased from around midway. Furthermore, the FCC accelerated auction progression in round 69 by increasing the bidder activity requirement to 100% of eligible points, up from 95%, which prompted bidders to reveal demands (evidenced by the increase in excess demand for blocks at round 69 onwards). The FCC also increased the clock price increment towards the end from 10% to 15%, and increased the number of rounds per day from 5 to 7.³⁸

The auction then proceeded to the assignment phase, where winning bidders could submit bids expressing preferred frequency locations for their winning blocks in each category. The assignment phase was a sequence of single round bidding for each geographic grouping of licences aimed at assigning frequencies to specific licences.

The system grouped PEAs such that each winning bidder held the same number of blocks in each category across the PEAs. Each grouping became an *assignment phase market* (APM).³⁹ For each PEA in an APM, the same winning bidders need to be assigned the same number of blocks in each category. An APM lies in one of six regional economic area groupings (REAGs).⁴⁰

The assignment phase started with the largest PEA #1 (by population – New York) and sequentially proceeded through to PEA #20. Thereafter, the FCC offered groupings of APMs across up to six REAGs in

each assignment round. The process is illustrated in FCC guidance, as follows.⁴¹

Table 2: Sequencing of assignment phase markets with grouping

Round	PEA(s)					
1	001					
2	002					
...	...					
20	020					
	REAG 1	REAG 2	REAG 3	REAG 4	REAG 5	REAG 6
21	041; 044	412	023	024	028	022; 034
22	048	021; 029; 033	025	030	035	026
...

In Auction 103 there were 71 assignment rounds. The winning bidders in the assignment phase would pay no more than they bid for a location, with the final price being determined as a second-price.⁴²

After the assignment phase ended in March 2020 the auction grossed USD \$7.56 billion, more than covering the USD \$3.08 billion needed for the incentive payments for incumbent licensees in the 39 GHz band. The net revenue raised was USD \$4.47 billion.

Australia 26 GHz auction

The Australian Communications and Media Authority (ACMA) auctioned 2.4 GHz of bandwidth in the 26 GHz band in April 2021.⁴³ ACMA’s view was that doing so “would best maximise the overall public benefit derived from the use of the band and aid the introduction of new technologies in mmWave spectrum for services such as 5G”.⁴⁴

To facilitate the highest value uses of the band, ACMA chose to auction spectrum licences of 15-year duration in “towns/cities with a population over

³⁷ https://sashajavid.com/FCC_Auction103.php

³⁸ https://auctiondata.fcc.gov/public/projects/auction103/reports/clock_announcements

³⁹ The top twenty PEAs were treated sequentially and individually.

⁴⁰ <https://transition.fcc.gov/oet/info/maps/bea/reagwsc.pdf>

⁴¹ See page 4 in <https://www.fcc.gov/file/16139/download>

⁴² Winner determination was based on the best combination of bids yielding the highest value, and price determination was based on Vickrey (second-price) pricing. Given the complexity, where appropriate the Vickrey prices were calculated using an algorithm applying nearest-Vickrey prices through what is known as *core adjustment*, see section 5.2 in <https://www.fcc.gov/file/16139/download> The amount raised in the assignment phase was small relative to the clock phase. For example, in round 25 of the

assignment phase, PEA #37 (Columbus, Ohio) in REAG #3, Verizon bid USD \$6.2 million for its 16 M/N blocks in location A; AT&T bid USD \$1,858 for location B for its 8 blocks in M/N. Each bidder won its preferred location for zero.

https://auctiondata.fcc.gov/public/projects/auction103/reports/assignment_results

⁴³ ACMA offered three categories of spectrum product. Category 1 in all areas excluding Greater Perth, Hobart, Margaret River: 25.1 GHz -27.5 GHz frequencies in 200 MHz blocks (12 lots in each area). Category 2 and 3 in Greater Perth, Hobart, Margaret River for lower and upper frequencies 25.1 GHz-27.0 GHz and 27.0 GHz-27.5 GHz respectively in 100 MHz blocks (24 lots in each area). https://www.legislation.gov.au/Details/F2020L01450/Html/Txt#_Toc55975119 The auction started 12 April 2021 and ended on 21 April 2021.

⁴⁴ <https://www.acma.gov.au/auction-summary-26-ghz-band-2021>

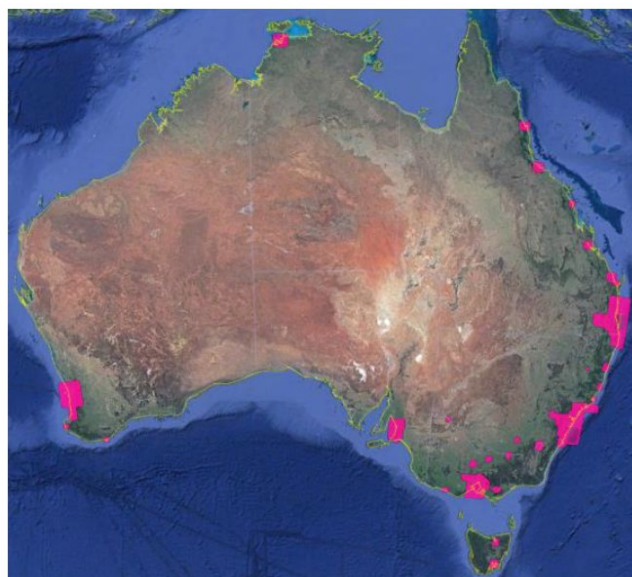
50,000 as well as smaller towns/cities which, due to them being either holiday locations or having university campuses, were expected to require the deployment of high-density wireless broadband services”.⁴⁵ Twenty-seven areas in the auction, as shown on the map⁴⁶, represented around 82% of the population as at the end of December 2020.⁴⁷

In twenty-four of the areas, ACMA offered twelve 200 MHz blocks of generic frequency. The starting price of a block in these areas was set at AUD \$0.004 MHz/pop (about USD \$0.0031 MHz/pop).⁴⁸ In three areas, ACMA offered 24 100 MHz blocks at a starting price AUD \$0.003 MHz/pop). A spectrum cap of 1 GHz in all geographic areas was applied to safeguard competition.

In three regions: Greater Perth, Hobart and Margaret River, ACMA split the frequency band into upper and lower products due to the presence of fixed satellite service uplinks operating in the upper range 27 – 27.5 GHz. It offered generic 100 MHz blocks in these lower and upper categories. To mitigate the risk of interference between these satellite users and new 5G users, ACMA imposed additional licence conditions in the three regions.

For those who wish to utilise frequencies in the 26 GHz band in areas outside the 27 regions in the

auction, ACMA has applied an administrative process where applicants can seek an apparatus licence.⁴⁹



Of the 360 fifteen-year area licences offered in the auction, 358 sold raising a total revenue of AUD \$647.6m (2x100 MHz went unsold in Hobart Upper). The main winners were the three MNOs: Telstra, Optus and TPG, who acquired 150, 116 and 86 lots respectively.⁵⁰ The other winners were Pentanet (a regional FWA provider) with 4 lots and Dense Air (a network infrastructure provider) with 2 lots.⁵¹ The

⁴⁵ ACMA (2019) “Future use of the 26 GHz band: Planning decisions and preliminary views” p.5 https://www.acma.gov.au/sites/default/files/2019-08/IFC_32-2018-Future%20use%20of%20the%2026%20GHz%20band%E2%80%9494Planning%20decisions%20and%20preliminary%20views.docx

⁴⁶ See ACMA (2019) Annex D at https://www.acma.gov.au/sites/default/files/2019-08/IFC_32-2018-Future%20use%20of%20the%2026%20GHz%20band%E2%80%9494Planning%20decisions%20and%20preliminary%20views.docx

⁴⁷ ACMA (2020) “26 GHz band auction, April 2021: Auction guide” Table 4, p. 22 at <https://www.acma.gov.au/sites/default/files/2020-12/26%20GHz%20Applicant%20information%20package.zip>

⁴⁸ Starting prices were guided by ACMA’s analysis of international auctions for mmWave spectrum, see ACMA (2020) “Apparatus licences in the 26 GHz and 28 GHz bands: Licensing, technical framework and pricing arrangements” consultation paper [https://www.acma.gov.au/consultations/2020-08/proposed-](https://www.acma.gov.au/consultations/2020-08/proposed-licensing-arrangements-26-ghz-and-28-ghz-bands-consultation-252020)

[licensing-arrangements-26-ghz-and-28-ghz-bands-consultation-252020](https://www.acma.gov.au/consultations/2020-08/proposed-licensing-arrangements-26-ghz-and-28-ghz-bands-consultation-252020)

⁴⁹ A person, government, or incorporated company is able to obtain an apparatus licence which specifies an exact location and frequency range the user can operate certain transmitters or receivers. A standard licence period for an apparatus licence is one year but such licences can be issued for up to 20 years. Users must pay a licence fee which covers administrative costs borne by the regulator. <https://www.acma.gov.au/apparatus-licences#:~:text=An%20apparatus%20licence%20lets%20you,a%20non%20assigned%20licence>

⁵⁰ Bidding details for the auction have not been made public. However, the final bid price for the area covering Sydney (population 6.2m) suggests a value around three times the reserve. <https://www.acma.gov.au/auction-summary-26-ghz-band-2021>

⁵¹ Price paid per winner was as follows: Dense Air Australia Pty Ltd: 2 lots for \$28,689,900; Mobile JV Pty Limited (a subsidiary wholly owned by TPG): 86 lots for AUD \$108,186,700; Optus Mobile Pty Ltd: 116 lots for AUD \$226,203,100; Pentanet Limited: 4 lots for AUD \$7,986,200; Telstra Corporation Limited: 150 lots for AUD \$276,576,200. <https://www.acma.gov.au/auction-summary-26-ghz-band-2021>

award was conducted using what ACMA calls an enhanced simultaneous multi-round ascending auction (ESMRA) consisting of three stages:

- 1) Primary stage – a clock auction offering frequency-generic lots to determine the quantity of spectrum won by each bidder. The primary stage included a pre-bidding phase where bidders could confirm or, subject to some limits, change provisional start demands.
- 2) Secondary stage – a simple clock auction to auction unallocated lots from the primary stage. ACMA rules determined that unallocated lots would be offered via the secondary stage if it was the only unallocated lot in that particular product. No secondary stage was used for the 26 GHz auction.
- 3) Assignment stage – a single round sealed-bid second-price auction across each area.

The ESMRA has the property of no standing high bidders and during the primary stage, the clock price increased whenever demand exceeded supply in a product category.⁵²

A spectrum cap⁵³ of 1 GHz applied in each area.⁵⁴ This cap may have been binding, as Telstra won exactly 1 GHz in all areas in the auction.⁵⁵ In contrast,

Optus secured 600 – 800 MHz of spectrum⁵⁶ and TPG acquired 400 – 600 MHz in all areas.⁵⁷

The use of area licences in this auction may have facilitated new entry, with Dense Air winning 200 MHz in Melbourne and Sydney respectively and Pentanet winning 200 MHz in Greater Perth and Margaret River.⁵⁸

European auctions for 26 GHz

At least 1 GHz of spectrum in the 26 GHz band has been auctioned in a number of European countries including Croatia, Denmark, Finland, Greece, Italy, Slovenia and Spain.^{59,60}

Italy was the first EU Member State to auction 1 GHz in the upper part of the 26 GHz band in 2018, offering five national 200 MHz lots (licences) of 18 years term. No winner could have more than two lots (400 MHz). An SMRA auction raised €167.3m or USD \$0.002 MHz/pop, around 5% above the reserve price.

The cap of 400 MHz led the Italian authorities to apply a *club model* such that each licensee is allowed to make use of another licensee's spectrum in a specified area if the spectrum is unused in that area.⁶¹

⁵² See the ACMA 26 GHz band auction guide for more detail. <https://www.acma.gov.au/auction-summary-26-ghz-band-2021>

⁵³ A spectrum cap (also referred to as allocation or competition limits) limits the total amount of spectrum that a single bidder can acquire in a band by any allocation process.

⁵⁴ <https://www.legislation.gov.au/Details/F2020L01016>

⁵⁵ <https://www.acma.gov.au/sites/default/files/2022-02/26%20GHz%20band%20auction%20results.pdf>

In the Greater Perth, Hobart and Margaret River areas, the two products in each area were treated as a single product for applying the 1 GHz allocation limit.

⁵⁶ Optus acquired 800MHz of 26GHz spectrum in Sydney, Melbourne, Brisbane, Perth, Adelaide, Canberra and a range of regional areas, and 600MHz in Hobart and Margaret River https://www.optus.com.au/about/media-centre/media-releases/2021/04/Optus_secures_golden_GHz_and_unlock_s_ultrafast_5G_future_with_26GHz_spectrum_acquisition

⁵⁷ Through its wholly owned subsidiary, Mobile JV Pty Ltd, TPG acquired 400 MHz in Sydney, Melbourne and Perth, and 600 MHz licenses in Brisbane and all other metropolitan and regional areas.

[https://www.openbriefing.com/AsxDownload.aspx?pdfUrl=R](https://www.openbriefing.com/AsxDownload.aspx?pdfUrl=Report%2FComNews%2F20210423%2F02366395.pdf)

⁵⁸ <https://www.acma.gov.au/sites/default/files/2022-02/26%20GHz%20band%20auction%20results.pdf>

⁵⁹ Material in this section is based on CEPA calculations and following sources: <https://www.nokia.com/sites/default/files/2021-08/stimulating-demand-for-26-ghz-in-europe.pdf>, <https://www.akos-rs.si/en/radio-frequency-spectrum/explore/public-tenders-for-mobile-networks>, https://ens.dk/sites/ens.dk/files/Tele/information_memorandum_1.pdf, <https://specure.com/croatia-awards-5g-spectrum-to-operators/> and <https://5gobservatory.eu/>

⁶⁰ In 2016 the EU published a 5G Action Plan in which the EU Commission proposed establishing a list of pioneer spectrum bands for the initial launch of 5G services. By 2019 this included the 26 GHz band. See https://5gobservatory.eu/wp-content/uploads/2021/11/5G-Obs-PhaseIII_Quarterly-report-13_final-version-11112021.pdf

⁶¹ See <https://pixl8-cloud-techuk.s3.eu-west-2.amazonaws.com/prod/public/49b05d14-cea7-4fc2-aec459ab68c8e2c5/SPF-Report-for-26-GHz-release-and-shared-spectrum-access.pdf>

Finland awarded 2.4 GHz of bandwidth for three 800 MHz 13-year national licences in 2020 (reserving 850 MHz for private networks). An SMRA took place with licences won by the three MNOs at reserve for €21 million or USD \$0.0014 MHz/pop.

Greece held a multiband auction in 2020, including 1 GHz of bandwidth in 26 GHz for five national 200 MHz lots. Three MNOs won licences (15+5 years), two winning 400 MHz at €6.5m each and one winning 200 MHz at €3.2m or USD \$0.0009 MHz/pop.

Slovenia awarded 1 GHz bandwidth in five national 200 MHz lots in 2021 as part of a multiband SMRA auction (15-year licences and a cap of 800 MHz). Three MNOs won licences fractionally above reserve (due to assignment stage bids), paying USD \$0.0007 MHz/pop.

Denmark auctioned 2.85 GHz of bandwidth in the 26 GHz band in April 2021 (setting aside 400 MHz for private use), with 200 MHz national lots available for 20-year licences. MNOs won 1.25 GHz, 1 GHz and 600 MHz. The reserve was set at USD \$0.00035 MHz/pop.

Later in 2021, Croatia awarded five 200 MHz national 15-year plus five licences in 26 GHz, going to five winners (three MNOs and two others). Licences went for reserve (or fractionally above in assignment stage) for USD \$0.0007 MHz/pop.

At the end of last year Spain was the most recent European country to auction frequencies in the 26 GHz band. The Spanish Ministry of Economic Affairs and Digital Transaction (MINECO) held the auction in December 2022, having received advice from the competition authority Comisión Nacional de los Mercados y la Competencia (CNMC).⁶²

MINECO departed from other European awards and auctioned national and area lots.⁶³ Frequencies in the range 25.1 – 27.5 GHz were auctioned using 12 national lots of 200 MHz each, with a further 400 MHz

(2 x 200MHz) of spectrum (24.7 – 25.1 GHz) offered in 19 areas.⁶⁴ The licence duration was set at 20 years with a maximum renewal of a further 20 years.

Incumbent MNOs Telefónica, Orange and Vodafone called for the auction to be delayed until at least 2023, claiming current immaturity of the 26 GHz ecosystem. Rather than postponing the auction, MINECO reduced the total reserve price from €127 million to €56 million, in an attempt to appease prospective bidders.⁶⁵

The reserve price at around USD \$0.00025 MHz/pop was equivalent broadly in alignment with the lower reserve values set in FCC Auction 103 and in the Danish multiband auction, but significantly below the Australian starting prices.⁶⁶ Each national 200 MHz lot had a reserve price of €4 million.

The auction was not competitive, with a quarter (or 600 MHz) of national lots unsold. Telefónica bid for 1 GHz, with Orange and Vodafone each bidding for 400 MHz. Only one bidder participated in the area licences, winning 200 MHz spectrum for €0.2 million in Castilla-León. All winners obtained licences at reserve price, with the auction raising a total of €36.2 million, significantly below the target of €105 million set by MINECO.⁶⁷

26 GHz and 40 GHz mmWave bands in the UK

In May 2022, Ofcom published a consultation setting out proposals for awarding licences covering over 6

⁶² See <https://www.cnmc.es/sites/default/files/4398154.pdf> and <https://portal.mineco.gob.es/en-us/comunicacion/Pages/subasta-de-26-GHz.aspx>

⁶³ Offering a mix of area licences in the same frequency band has occurred in many US spectrum auctions. For example, FCC Auction 73 for 700 MHz in 2008 featured five different areas from nationwide to 734 cellular market areas, see <https://www.fcc.gov/auction/73/factsheet>

⁶⁴ <https://portal.mineco.gob.es/RecursosNoticia/mineco/prens>

a/noticias/2022/20221221_ndp_completada_subasta_26gh_z.pdf

⁶⁵ <https://advanced-television.com/2022/12/19/spain-5g-licences-half-price/>

⁶⁶ See footnote 62.

⁶⁷ The reserve price for a national lot (200 MHz) was €4m meaning prices paid by the MNOs were the following. Telefónica: 5 lots for €20m; Orange: 2 lots for €8m; Vodafone: 2 lots for €8m. Globe Operator Telecom won 200 MHz in Castilla-León for €200,000. *Op cit.*

GHz of bandwidth in the 26 GHz and 40 GHz bands.⁶⁸ Ofcom is considering an auction by 2024 for many of the frequencies in these bands.⁶⁹

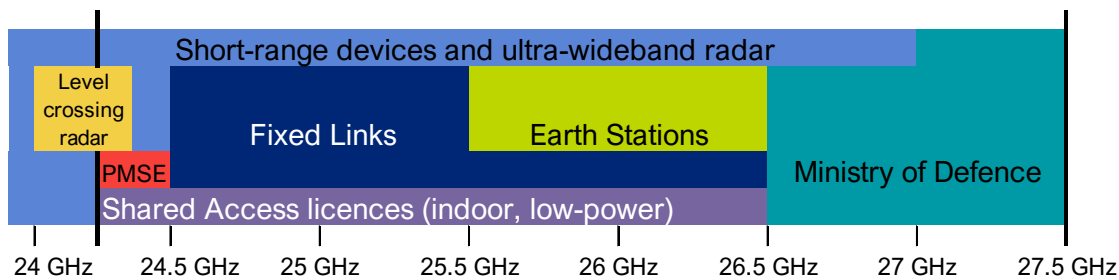
We look briefly at the current uses in the bands and assess how this might affect future 5G use. Box 1 shows existing uses and users.⁷⁰

In most of the 26 GHz band, Ofcom has permitted

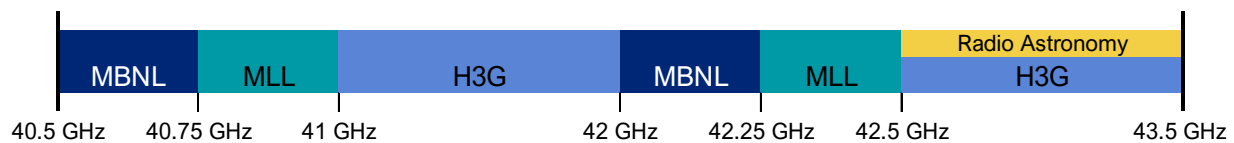
2019.⁷¹ Any existing users that cannot coexist with new 5G deployments without causing interference will need to be cleared and moved to a different band. For instance, Ofcom has proposed the clearance of fixed point-to-point links in high density areas from 26 GHz, citing the alternative as potentially leading to less optimal use of the spectrum and reduced benefits to consumers and business

Box 1: UK mmWave current band plans with existing authorised uses and users

26 GHz (24.25 – 27.5 GHz):



40 GHz (40.5 – 43.5 GHz):



Source: Ofcom (PMSE, Programme Making and Special Events – e.g. wireless microphones; MBNL, Mobile Broadband Network Limited, jointly owned by MNOs EE and Three; MLL, provider of managed Wide Area Networks and telecommunication services; H3G or 3 is a MNO owned by Hutchison 3G Enterprises S.A.R.L.)

low-powered indoor shared mobile access since

from new uses.⁷² Other users, such as Network Rail

⁶⁸ The 40 GHz band in 5G is more commonly known as 42 GHz (or n259) and extends over 39.5 – 43.5 GHz frequencies. Currently the band is under development for 5G services and commercial deployments have yet to occur.

⁶⁹ See https://www.ofcom.org.uk/data/assets/pdf_file/0027/237258/mmwave-spectrum-condoc.pdf

⁷⁰ Existing uses of the 26 GHz band include fixed point-to-point links, a satellite earth station, Network Rail level crossing radar, ultra-wideband radar and a range of licence-exempt short-range devices. There are also allocations for programme-making and special events (PMSE) and the Ministry of Defence (MOD).

The 40 GHz band is encumbered by three existing licensees who each hold national licences: H3G, MBNL and MLL. There is also a radio astronomy grant.

⁷¹ Ofcom’s Shared Access Licence (SAL) model opened up 24.25 – 26.5 GHz for low-powered indoor mobile. See Ofcom (2022)

https://www.ofcom.org.uk/data/assets/pdf_file/0035/157886/shared-access-licence-guidance.pdf According to Ofcom’s spectrum portal as at 24/2/2023, there are two shared access licensees in the 26 GHz band (Blue Wave and ‘Fixed Links Unit’), see <https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal>

⁷² Ofcom’s proposal on existing users in 26 GHz is the following: “In summary, we propose that most existing uses would remain in the band, as we believe managing coexistence between new services and existing uses (other than fixed links, as set out in section 5) would be straightforward.” p.64 of https://www.ofcom.org.uk/data/assets/pdf_file/0027/237258/mmwave-spectrum-condoc.pdf

who utilise some of 26 GHz to run level crossing radar, will not need to be relocated based on Ofcom's coexistence analysis.

Regarding 40 GHz, there are currently three licensees that hold national licences: H3G (the MNO trading as Three), MBNL and MLL. These were awarded by auction in 2008 with indefinite licences having an initial term of 15 years.^{73,74} There is also a grant for Recognised Spectrum Access (RSA) for a radio astronomy site at Cambridge.^{75,76}

Current licence terms in 40 GHz prohibit use for mobile services, meaning deployment of 5G mobile is not an option unless existing licences are varied or revoked by Ofcom. The existing 40 GHz licences are used for fixed link services.

UK mmWave auction

Ofcom's public consultation in May 2022 proposed for 26 GHz identifying 'high density' and 'low density' areas of current mobile use to allow for different

authorisation approaches depending on demand and supply-side conditions. Ofcom's approach is similar to that used by ACMA in its 26 GHz auction.

Ofcom stated that *"In these areas we consider that there would be a benefit to allocating wide area licences, alongside local licences. We think wide area licences would enable operators to use the spectrum more efficiently (as frequency reuse distances are reduced) and facilitate investment by providing certainty of spectrum access for ease of network planning."*⁷⁷

High density areas are identified as towns and cities with high data demand, and these are ranked by Ofcom based on peak mobile data traffic and mobile base station density, with up to 80 high density areas identified.⁷⁸

In high density areas, Ofcom propose to make both local and citywide 10-15 year fixed term licences available in different portions of the 26 GHz band.⁷⁹ The bottom 850 MHz (24.25 – 25.1 GHz) would be available on a first come first served basis via the Shared Access licensing framework.⁸⁰ In other words,

⁷³ The original winners of 40 GHz in the 2008 auction were UK Broadband (UKB), T-Mobile and MLL. UKB was acquired by H3G in 2017, MBNL is a joint venture between EE (formed via a merger between Orange and T-Mobile in 2010 and now owned by BT) and H3G, and MLL is a provider of managed network services. Auction results can be found at <https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2008/results-of-ofcoms-fourth-spectrum-auction>

⁷⁴ An indefinite licence is a licence usually awarded by auction having an initial term specifying the period associated with the auction fee, and all subsequent periods subject to annual licence fees (ALFs) based on market value (opportunity cost). For example, in 2021 Ofcom announced ALFs to apply from January 2022 for 2100 MHz licences auctioned in 2000 as mobile 3G licences, see https://www.ofcom.org.uk/data/assets/pdf_file/0027/229428/1900_2100-mhz-statement.pdf.

⁷⁵ The Cambridge astronomy site has an exclusion zone of 50km for the frequencies 42.5 – 43.5 GHz. Outside this range, the spectrum can be used by H3G. Further information on this licence can be found at https://www.ofcom.org.uk/data/assets/pdf_file/0010/103303/fat-space-science-meteorology.pdf

⁷⁶ Recognised spectrum access ("RSA") is available in circumstances specified by Ofcom in regulations to persons who transmit radio signals for reception in the UK, but who are not, for whatever reason, required to hold a licence under the Wireless Telegraphy Acts. Possible examples include certain satellite services, radio astronomy and Crown users of spectrum.

⁷⁷

https://www.ofcom.org.uk/data/assets/pdf_file/0027/237258/mmwave-spectrum-condoc.pdf

⁷⁸ Ofcom defines high density areas as "the major towns and cities where we expect the most widespread deployment of mmWave spectrum for new uses to occur" and low density areas as "the rest of the UK, outside high density areas, where we expect deployments to be sparser and more highly localised." The top 80 areas cover around 47% of the UK population. See p.22 and Table 4.1 on p.41 Ofcom (2022) *op cit*.

⁷⁹ The proposal to grant fixed term licences is a significant departure from the policy of awarding indefinite licences and relying on spectrum trading to maintain efficiency. In para. 10.5 of Ofcom (2022) it is stated: "In general, a fixed term licence ... when compared to an indefinite licence, would mitigate the risk that [spectrum] trading alone may not be sufficient to maintain ongoing efficient allocation of spectrum. This is because Ofcom would have the opportunity to re-allocate the spectrum at the end of the term more readily and flexibly than under an indefinite licence approach."

⁸⁰ Shared Access licences are part of Ofcom's framework for enabling shared use of spectrum. The aim of this is to support innovation and enable new use of spectrum by

this 850 MHz can be thought of as set aside spectrum. The remaining 2.4 GHz of spectrum in the 26 GHz band (25.1 – 27.5 GHz) in high density areas is proposed to be awarded via auction.

In low density areas, Ofcom propose to authorise the entire 26 GHz band through the Shared Access licensing framework.

In regard of the 40 GHz band, the options to award spectrum licences in this band are at an earlier stage. Currently a 5G ecosystem does not operate in this band anywhere, so the appetite for its use in 5G is very limited. Furthermore, there are several incumbents in the band that were awarded in 2008 by auction. These were national indefinite licences with an initial term of 15 years and they may be revoked by Ofcom with 5 years notice from 2023.

Ofcom have also outlined initial views on auction design, with aspects of this due to be consulted on later this year. The headlines so far, in addition to the 850 MHz set aside spectrum, are that Ofcom is planning to use a clock format, which in our view conforms with best practice, and use of geographic lot categories, with one lot (or more, if there are two frequency lot categories in 26 GHz) corresponding to each high density area.

Geographic lot categories or area licences are a more controversial stance for Ofcom to take. Ofcom state *“We are proposing to have geographic lot categories for each high density area, so that bidders can reflect potential differences in demand in different high density areas.”*⁸¹

While area mobile spectrum licences are the norm in many countries like the US, Australia and Canada, this has only happened previously in the UK in 2000 and 2007.⁸²

While Ofcom propose local licensing due to characteristics of mmWave, they could still auction

geographic licences via ‘subnational’ lots – where all the high density areas are aggregated into a single lot category. This would simplify the auction process for bidders with a national footprint (e.g. MNOs) and Ofcom.

While area licensing can promote entry by smaller players, Australia and Spain’s 26 GHz auctions saw very limited entry.⁸³ However, accommodating the possibility of entry, no matter how small, can often be desirable from a competition perspective.

A further concern is the level of set aside spectrum for Ofcom’s mmWave auction, which is currently proposed to be 850 MHz at the bottom of the 26 GHz band. One problem with this is that Ofcom acts as the market judge and risks making a mistake by either setting aside too much or too little. BT’s consultation response echoes this concern:

*“Concerning the bottom 850 MHz of the 26 GHz band in high traffic density areas, we consider it more likely to secure optimal use of spectrum if Ofcom includes it in the auction, rather than limiting it to low power shared access licences managed by Ofcom.”*⁸⁴

If all the 26 GHz band spectrum in high demand areas were included in an auction, Ofcom could apply different tools to determine whether smaller players are able to compete against larger MNOs. For example, bidder credits alongside spectrum caps could be applied. As discussed above, the FCC applies bidder credits for small or rural-based bidders. Ofcom could also consider the approach used in Spain and offer both national and area licences.

providing access to spectrum bands where consumer equipment was or is becoming available.
<https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/shared-access#:~:text=The%20shared%20access%20licence%20is,of%20local%20wireless%20connectivity%20applications.>

⁸¹ Ofcom consultation May 2022 *Op cit.*

⁸² In 2000 the UK Radiocommunications Agency and in 2007 Ofcom auctioned geographic licences in the 28 GHz band using a SMRA format.

<https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards>

⁸³ One of the two small entrants into the Australian market went live on its 26 GHz frequencies in Perth in June 2022, offering FWA gaming services:

<https://www.itnews.com.au/news/pentanet-mmwave-service-goes-live-in-perth-581734>

⁸⁴ BT’s published response to Ofcom’s consultation Enabling mmWave for new uses

https://www.ofcom.org.uk/data/assets/pdf_file/0028/243586/BT-EE.pdf

Table 1: Normalised MHz/pop prices in mmWave auctions for mobile 5G

Country	Year	Band	USD \$ MHz/pop
US	2018	28 GHz	0.0113
Italy	2018	26 GHz	0.002
South Korea	2018	28 GHz	0.009
US	2019/20	37 – 39 GHz	0.014
Finland	2020	26 GHz	0.0014
Greece	2020	26 GHz	0.0009
Australia	2021	26 GHz	0.006
Denmark	2021	26 GHz	0.0004
Slovenia	2021	26 GHz	0.0007
Croatia	2021	26 GHz	0.0007
Spain	2022	26 GHz	0.00025

Based on CEPA calculations and sources cited in this report. The estimated USD \$ MHz/pop price is normalised for a ten-year licence. For countries with licence terms other than ten years, the estimate is adjusted up (if the term is less than ten years) or down (if more than ten years).

Table 2: Select mmWave auction summaries

Country	Date of auction	Band	Auction	Licence duration	Set aside
US	October 2019 – May 2020	37 GHz (37.6-38.6 GHz), 39 GHz (38.6-40 GHz) and 47 GHz (47.2-48.2 GHz)	Area licensing (100% of population)	10 years	None, instead provide discounted price to smaller bidders with bidder credits
Australia	April 2021	26 GHz (25.1-27.5 GHz)	Area licensing, high density areas only (82% of population)	15 years	400 MHz (24.7-25.1 GHz) set aside for area-wide licences (AWL)
Spain	December 2022	26 GHz (24.7-27.5 GHz)	National and regional licensing (100% of population)	20 years	850 MHz of which 400 MHz (24.7-25.1 GHz) for regional licences in auction and 450 MHz for verticals
UK (proposed)	2023/2024	26 GHz (24.25-27.5 GHz) and 40 GHz (40.5-43.5 GHz)	Local licensing, high density areas only (up to 47% of population)	10-15 years	850 MHz (24.25-25.1 GHz) set aside for local licences via Shared Access

Table 3: FCC Auction 103 Outcome

Verizon, bidding as Straight Path Spectrum LCC, was the biggest aggregate bidder. It won 4,940 licences across 411 PEAs (mainland US) after bidding around USD \$3.4 billion. After receiving an incentive payment of about USD \$1.8 billion, Verizon made a net payment of about USD \$1.6 billion. It typically won 10 blocks (1 GHz) in most of the PEAs in the M/N category (37,39 GHz).

AT&T, bidding as FiberTower Spectrum Holdings, won 3,267 licences also in 411 PEAs, bidding around USD \$2.4 billion. After accounting for the incentive payment, AT&T spent about USD \$1.2 billion. Like Verizon, AT&T only targeted the M/N category, winning around 8 blocks (800 MHz) in each PEA.

T-Mobile bid about USD \$931 million to win 2,384 licences in 399 PEAs, purchasing both 47 GHz and 37-39 GHz spectrum. It received a small incentive payment of about USD \$59,000. During the auction, T-Mobile was in the process of merging with Sprint who bid as ATI Sub and won only licences in the 47 GHz spectrum, spending about USD \$114 million for 127 licenses in 38 PEAs. Sprint received 5 blocks (500MHz) in the top 10 PEAs.

Dish Network, bidding as Window Wireless LLC, spent USD \$202.5 million for 2,651 licenses in all 416 PEAs. U.S. Cellular, the fourth-largest carrier, spent USD 146 million on 237 licenses, obtaining between five and two blocks of 37-39 GHz spectrum in 69 PEAs.

Of the other 29 qualified bidders, 22 won 536 licences; two bidders each won only 2 blocks in 1 PEA each (LICT Wireless Broadband, OptimERA Inc.) and the largest Monarch Wireless (a small business bidder) won licences in the M/N category across the country (173 licences) in 46 PEAs.⁸⁵

⁸⁵ A complete list of winners is at <https://www.fcc.gov/document/auction-103-winning-bidders-and-incentive-payments>

In summary, 28 qualified bidders won a total of 14,142 licences (2 were held by the FCC) for a gross bid amount net of credits of USD \$7.6 billion (credits totalled USD \$11.3 million) and net of incentive payments the net proceeds were around USD \$4.47 billion.⁸⁶

The sums raised in the auction, when measured on a per MHz per pop basis, were modest relative to the amounts raised in mid-band auctions – in the top PEA #1 (New York) it was USD \$0.014 for the M/N category. In FCC Auction 107 a year later, Verizon paid almost USD \$1 MHz/pop for 3.7 GHz C-Band – that’s over 70 times more!⁸⁷ In Auction 103, the P category 47 GHz frequency was typically bid at only around 12% of the M/N category bid price.

Auction 103 occurred at a time when mmWave was regarded as commercially attractive by some bidders. However, its value has probably fallen further relative to mid-band in light of early commercial experience.⁸⁸

Auction 103 accommodated re-farming of 39 GHz spectrum via an incentive scheme, and addressed concerns of both small and rural bidders through bidder credits. The ascending clock format provided flexibility to award thousands of area licences. Whether 104 rounds were needed to achieve the outcome is debateable, as auction progression could have been pushed along sooner and faster by the FCC. Further, most of the auction activity, measured by licences won and bid proceeds, involved the then four largest mobile phone operators.

⁸⁶ <https://auctiondata.fcc.gov/public/projects/auction103>

⁸⁷ The 3.7 GHz C-Band auction in the US (FCC Auction 107) was the highest value auction in the US on a MHz/pop basis. See <https://www.verizon.com/about/news/verizon-announces-c-band-auction-results> and https://sashajavid.com/FCC_Auction107.php

⁸⁸ In the two FCC mmWave auctions that have released spectrum for 5G mobile, Auctions 101 (28 GHz) and 103 (37 & 39 GHz) had average per MHz per pop (MHz/pop) winning bids of USD \$0.0113 and \$0.01 respectively. Auction 101 occurred at the end of 2018 into the beginning of 2019. See https://sashajavid.com/FCC_Auctions.php Other auctions for mmWave spectrum around the world have closed around the reserve price. Up to 2020 this was at an average of about USD \$0.002 MHz/pop, or around 20% of the winning prices in the US. See Exhibit 1 in Graham Friend (2020) “5G and mmWave spectrum: Regulatory approaches to the assignment of mmWave spectrum” <http://www.coleago.com/app/uploads/2020/09/Approaches-to-mmWave-spectrum-assignment-0420.pdf> More recently Virgin Media O2, in a submission made in July 2022 to Ofcom, shows 26 GHz auctions have closed at reserve in several European awards at around USD \$0.0018 MHz/pop, p. 24 in “Virgin Media O2 response to Ofcom’s consultation: Enabling mmWave spectrum for new uses: Making the 26 GHz and 40 GHz bands available for mobile technology” at https://www.ofcom.org.uk/data/assets/pdf_file/0028/243559/vmo2.pdf

Table 4: How certain policy objectives are achieved under different regimes

Country	Efficient allocation of spectrum licences	Sustain strong competition in mobile markets	Encourage investment	Facilitate innovation
US	Auction area licences to accommodate local, regional and nationwide operators	Different providers have differing frequency portfolios, further motivating area licence offerings	Typically auction 10-year licences with strong presumption of renewal	Small bidders can win spectrum at a discounted price with bidder credits
Australia	Award area licences via competitive auction process whenever demand exceeds supply	Use precautionary caps e.g. 1 GHz cap per region in 26 GHz auction	Auction licences with 15-year duration	Allow area-wide apparatus licences (AWLs)
UK	Auction licences when demand exceeds supply, national licences usually default	Different providers have relatively similar spectrum portfolios, providing more encouragement for national licences	Nationwide licences ensure sufficient scale economies to motivate investment. Propose to auction 10-15 year fixed-term licences	In 26 GHz, enable localised access for any potential user with set aside spectrum (“first come, first served”)

CEPA TELECOMS

CEPA advises on issues where economics, finance and public policy overlap. Our team of economists and financial consultants apply economic concepts with judgement, integrity and skill for the benefit of our clients. We leverage our in-depth knowledge of the communications sector to produce robust analysis and advice in the areas of competition law, regulation, policy, spectrum auctions, transactions, compliance and evaluation.

Our team offers clients advice on auction design, bid strategy and bid support, competitor analysis, public consultation support and financial modelling. We also offer bespoke bid tracking tools to aid managers and senior executives preparing for and participating in high-stakes spectrum auctions.



chris.doyle@cepa.co.uk

Chris Doyle heads the CEPA Telecoms practice with more than 25 years' consulting experience. He has advised on auctions to blue-chip clients and governments across the world. He has been involved in shaping the design of auctions, advising on bid strategy and participating with bid teams. Prior to joining CEPA, Chris worked at Ofcom, the UK media and communications regulator, on market design and auction related matters. Over the years he has worked with Paul Milgrom and Peter Cramton among others.

Jonathan Mirrlees-Black is a director of CEPA and leads CEPA's Australia office.

He is a highly experienced economist and finance professional providing advisory services to clients in telecoms, energy and other infrastructure sectors. He has advised investors on the implications of auction processes, and on significant asset transactions in infrastructure sectors. He has extensive global experience advising on design of energy and related markets (including creating markets for ancillary services and transmission), where applying economic theory of contracts is crucial.



jonathan.mirrlees-black@cepa.net.au



chris.sutcliffe@cepa.co.uk

Chris Sutcliffe is a consultant who works in the CEPA Telecoms practice. His recent work at CEPA includes providing analysis to Optus on network and sharing agreements between Telstra and TPG. Prior to joining CEPA, Chris worked as an economist at Ofcom, where his work included auction design and related auction design policy issues. Specifically, he led the proposed design of the assignment stage of Ofcom's upcoming mmWave auction and also contributed to other areas including the clock format, lot categories, bid processing, eligibility and reserve prices.

VISIT: WWW.CEPA.CO.UK

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UK

Queens House
55-56 Lincoln's Inn Fields
London WC2A 3LJ

T. **+44 (0)20 7269 0210**

E. info@cepa.co.uk

www.cepa.co.uk

Australia

Level 20, Tower 2 Darling Park
201 Sussex Street
Sydney NSW2000

T. **+61 2 9006 1308**

E. info@cepa.net.au

www.cepa.net.au