Presentation for the UK Spectrum Policy Forum

Investigation into spectrum for 6G – key findings from a study for Qualcomm

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Qualcomm asked Analysys Mason to investigate spectrum bands that might be relevant for further study in the context of future mobile/6G use

Purpose of the study

- Academic and industry research into 6G concepts, use cases and technologies are underway
  - Qualcomm asked us to investigate bands that might be considered for future mobile use (beyond 5G, or 6G), both regionally and globally
- We were asked to consider whether there is interest in the market in pursuing future spectrum options for 6G within the following frequency ranges:
  - low-band spectrum (380MHz–1GHz)
  - mid-band spectrum (1–24GHz)
  - high-band spectrum (24–275GHz)
- The main objective was to identify a shortlist of promising frequency ranges/bands, taking account of potential regional differences
- In this presentation, the following navigation panes are used to highlight the frequency ranges under discussion

Approach to the study

- The study was based on inputs from:
  - **desk research of published material:** we reviewed published reports, presentations and white papers from universities, industrial bodies and 6G research programmes, describing early-stage research into 6G concepts, use cases and requirements, and how those might influence spectrum needs
  - **primary research interviews:** we conducted a series of one-to-one interviews with stakeholders from industry, regulatory authorities and the academic community, with particular focus on gaining inputs from within different International Telecommunication Union (ITU) regions and markets
    - we have completed over 20 primary research interviews, with final interviews to be completed shortly
    - interviewees included academics in the UK and elsewhere, regulators in Europe, Africa, Asia and Latin America, mobile industry bodies, mobile network operators and equipment vendors
  - **review of the ITU frequency allocation table (FAT) by region:** we used this to review current use of bands within ranges identified from our research as being of interest for future mobile use

Note: as per ITU Radio Regulations, Region 1 covers Europe, Africa and the Middle East, Region 2 covers the Americas and Region 3 covers Asia/Australasia

WRC-23 (and also WRC-27) will consider several agenda items on mobile/IMT and it seems likely the bands shown below may be viewed as candidates for early 6G use

- The agenda for the World Radiocommunication Conference 2023 (WRC-23) includes the review of several spectrum bands for IMT/mobile use (see table below)
  - there will also be discussions during WRC-23 on the agenda for the next conference in 2027 (WRC-27), with expectation that future mobile bands for 6G might be part of the agenda
  - mobile harmonisation in some regions might progress ahead of the WRC-27 process, or outside of the ITU process via regional agreement (e.g. similar to 3.4–3.8GHz harmonisation in Europe)

Bands already under study in the context of future mobile use as per WRC-23 agenda

WRC-23 agenda item (WRC Resolution)	Band	Region(s) of interest	Comments
1.1 (Res. 223, Rev. WRC-19)	4.8–4.99GHz	Global	▪ This band already includes a global mobile allocation (on a primary basis) and was identified for IMT use in selected countries at WRC-19 ▪ At WRC-23, the potential for a wider range of countries to identify this band for IMT use will be reviewed
1.2 (Res. 245, WRC-19)	3.3–3.4GHz	Regions 1 and 2	▪ Under consideration for primary allocation to mobile and/or IMT identification, and with a view to improving harmonisation within bands already used for 5G (e.g. 3.4–3.8GHz)
	3.6–3.8GHz	Region 2	
	6.425–7.025GHz	Region 1	
	7.025–7.125GHz	Global	
	10–10.5GHz	Region 2	
1.3 (Res. 246, WRC-19)	3.6–3.8GHz	Region 1	▪ Potential change to global primary mobile allocation
1.5 (Res. 235, WRC-15)	470–960MHz	Region 1	▪ Future use of ultra high-frequency (UHF) spectrum between 470MHz and 960MHz and potential for co-primary allocations for mobile use is under discussion in Region 1 countries

Source: Resolution 811 (WRC-19) contains the WRC-23 agenda; see https://www.itu.int/en/ITU-R/study-groups/rcpm/Pages/wrc-23-studies.aspx

In the low bands, 600MHz is the most promising 'new' band option, with some interest in future mobile technologies for PMR in 380–400MHz/410–430MHz

Shortlist of potential candidate bands for mobile/6G

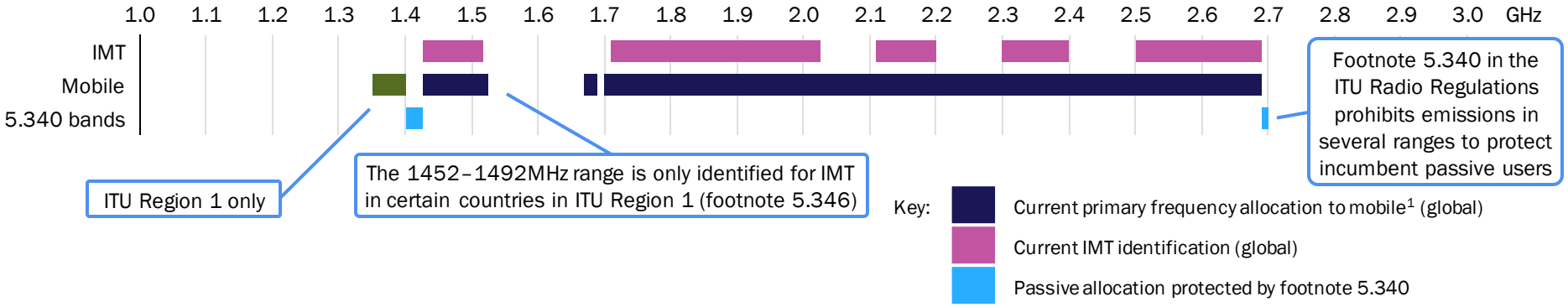
Category (low/mid/high)	Band	Current allocation status/use	Comments
Low	380–400MHz	• Allocated for mobile use globally • In the UK, civil use (Emergency Services/PMR[1]) is shared with defence	▪ Some interest in future mobile technologies/6G supporting this band as an option for PMR users to transition to mobile broadband or 6G
Low	410–430MHz	• Allocated for mobile use globally	▪ Some interest in future mobile technologies/6G supporting this band as an option for PMR users to transition to mobile broadband or 6G
Low	Approximately 617–698MHz (600MHz band)	• Allocated for terrestrial broadcasting globally • Co-primary mobile allocation and identification of use by IMT systems in certain countries located in ITU Regions 2 and 3 • Already assigned for commercial mobile use in Canada and the USA (3GPP band n71)	▪ Future use of the 470–960MHz range in Region 1 will be discussed at WRC-23 – our primary research identifies there is interest from regulators and industry in a co-primary mobile allocation being added for Region 1 ▪ There was a range of reasons for interest in a 600MHz mobile allocation – some regulators/operators indicated demand to use the band for public mobile use – evolution of terrestrial broadcasting (e.g. broadcasting direct to devices) might be considered in some markets based on market demand – some regulators do not foresee changing the use of this band in their own markets from current broadcast use, but did not object to the band being used for mobile services in other markets ▪ Some regulators questioned whether there would be demand for additional UHF spectrum for public mobile use, or whether demand might be concentrated into mid/higher bands more suited for high-capacity deployment ▪ There is widespread acknowledgement that UHF spectrum has been important to provide coverage over more sparsely populated locations – challenges remain in providing wider coverage footprints with terrestrial deployments – non-terrestrial networks/direct-to-satellite services as an alternative

Interviewees agreed that 6G technologies should natively support existing mobile bands below 1GHz (700MHz, 800MHz, 900MHz, etc.)

[1] Private mobile radio; refers to 6G technology being standardised for use in land mobile systems currently assigned in these bands

In the 1–3GHz range, new mobile band options are limited; 1300–1350MHz, 1780–1830MHz and 960–1164MHz could be considered for mobile/6G in the USA

1–3GHz: Region 1 primary mobile[1] allocations and IMT identifications



- In some countries, there may be opportunities to make further mobile spectrum available within bands already identified for IMT
  - the 1780–1850MHz range lies between spectrum assigned for 'Advanced Wireless Services' (AWS) and 'Personal Communications Service' (PCS) use in the USA and other markets in ITU Region 2, and could potentially be made available in those markets
  - many countries have not yet assigned spectrum identified for IMT in the 2.3GHz band and L-band (1427–1518MHz) and some interviewees thought this band could be used for 6G
  - an interviewee focused on the US market commented that in some bands allocated to federal agencies in the 1–3GHz range , technologies are approaching the end of their lifecycle (e.g. 960–1164MHz, 1300–1350MHz, 1780–1830MHz) and might be considered for a change of use – timescales and feasibility of a change of use as yet undetermined

Existing IMT identifications between 1GHz and 3GHz are already highly harmonised globally and interviewees assumed 6G technologies and architectures will natively support these bands in future

[1] Mobile includes both 'mobile' and 'mobile excluding aeronautical mobile' services

Source: ITU Radio Regulations, Edition of 2020 (Article 5)

In the 3–9GHz range, several bands were identified by interviewees as being potentially of interest for 6G in different markets

3.3–4.2MHz

- 3.4–3.8GHz is currently the focus of 5G deployment globally
- There is potential for the bandwidth of spectrum available for mobile use to be increased in some markets across the 3.3–4.2GHz band, and these bands are already incorporated into the 5G 3GPP specifications (bands n77 and n78)
- The 3.3–3.4GHz range will be discussed again at WRC-23 with a view to expanding the countries that use it
- Some markets have already made spectrum available for commercial mobile use above 3.8GHz, including
  - the USA (up to 3.98GHz on a wide-area exclusive basis)
  - the UK (up to 4.2GHz for local licensing)
  - Japan (up to 4.1GHz on a wide-area exclusive basis)

4.4–4.99GHz

- The 4.4–4.9GHz band is allocated for fixed and mobile use globally (fixed satellite between 4.4 and 4.8GHz), and use of the 4.8–4.99GHz band is to be examined at WRC-23
  - 4.84–4.92GHz has been licensed in Hong Kong (with an auction upcoming to extend the range to 4.8–4.96GHz)
  - 4.8–4.9GHz has been licensed for mobile use in China
- Some stakeholders noted that the band could feasibly be used for 6G

Upper 6GHz

- Some markets (including the USA, Brazil and Saudi Arabia) have made the upper 6GHz (6.425–7.125GHz) band available for unlicensed use, whereas in Europe, it is only the lower 6GHz (5.925–6.425GHz), with use of the upper 6GHz under discussions ahead of WRC-23
- Countries elsewhere are still to decide whether to change the use of the upper 6GHz band so that it is no longer focused on fixed links
  - some regulators we interviewed are sceptical about there being sufficient demand for national mobile allocation; others considered that there would be demand, both for national and sub-national/local deployments
- In ITU Region 1, the upper 6GHz band will be considered at WRC-23 for possible mobile/IMT use
  - however, recent reports suggest the UK regulator is considering making the band available on a local licensed basis, potentially to expand the spectrum available for 5G local use and/or industrial purposes

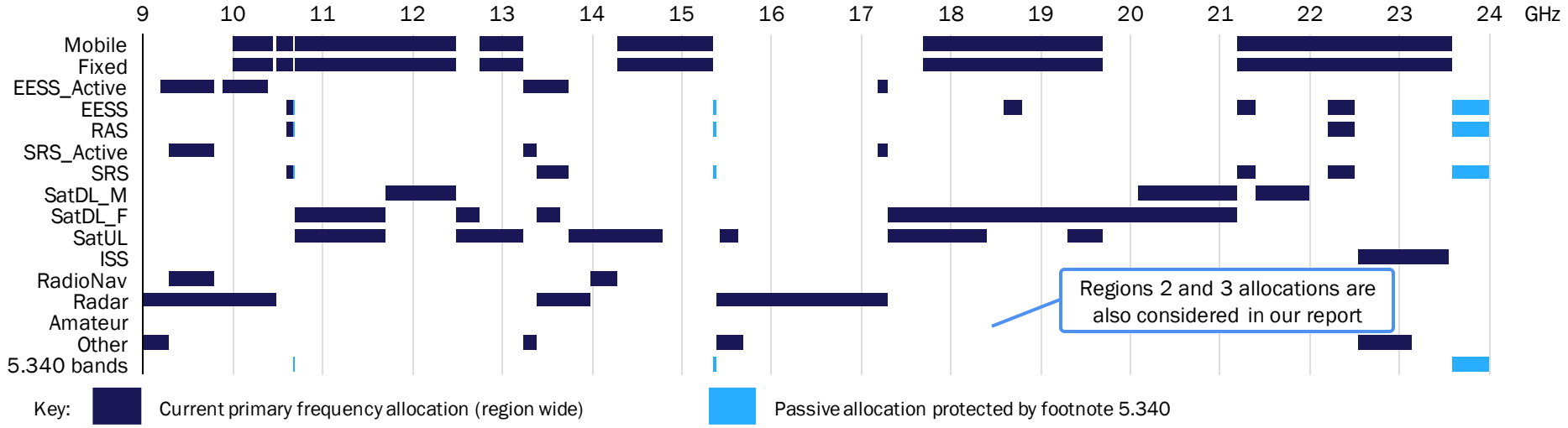
7–8GHz

- Some interviewees referred to preliminary feasibility analysis that examines the possibility of spectrum being shared by mobile systems
  - existing uses in the 7–8GHz bands include fixed and satellite services, and the feasibility of sharing will depend on how extensively spectrum is used for existing services
- In all regions, 7–8.5GHz is currently allocated for fixed and mobile together with various satellite allocations in different bands within this range (fixed satellite, maritime mobile satellite, meteorological satellite)

Source: Analysys Mason

Spectrum in the 10GHz/12GHz/15GHz bands was also identified by some interviewees as of interest for 6G technologies; no interest identified in 15–24GHz

9–24GHz: Region 1 primary allocations (Source: ITU Radio Regulations Article 5, Edition of 2020)



10–10.5GHz

- Primary mobile allocation in the 10–10.45GHz band in Regions 1 and 3, but not Region 2. Footnote 5.480 allocates it to mobile use in selected Region 2 countries (including Brazil)
- Some interest in 10GHz band being identified for IMT use in selected countries in Region 2 at WRC-23

12GHz

- In the USA, the FCC issued a Notice of Proposed Rulemaking in 2021 to seek comments on how best to maximise efficient use of the 12.2–12.7GHz band. Other views were that the 12GHz band is an important band for satellite services and is being planned to accommodate future broadband satellite networks

15GHz

- Change of use of the 15GHz band was suggested by one regulator on the basis that point-to-point links could be migrated to other available bands such as 18GHz and 23GHz. However, other regulators commented that this would not be feasible and/or that other uses (non-fixed) in this range would preclude consideration for mobile use

There is a range of different existing uses globally up to 15GHz, and thus viability studies into the feasibility of wider tuning ranges for future mobile equipment (such as 6–8GHz and/or 10–12GHz) could be a helpful area of future research

Note: Above 24GHz, it is assumed that existing mmWave bands already identified for 5G use (such as 26GHz) will evolve into 6G; see next slide

Many interviewees commented that future mobile technologies/6G should natively support mmWave bands already identified for IMT use at WRC-19

26GHz (24.25–27.5GHz) and 28GHz

- 26GHz was identified for mobile/IMT use at WRC-19
- It has subsequently been assigned for mobile use in various markets worldwide such as Greece, Italy, Australia, the UAE and Finland
- Upcoming awards are also expected in countries such as Spain, Sweden and Saudi Arabia
- Interviewees assumed use of this band will evolve into 6G use

45.5–47GHz, 47.2–48.2GHz

- Neither the 45.5–47GHz range nor the 47.2–48.2GHz range has been identified for IMT globally; however:
  - 45.5–47GHz has been identified by some countries across all three ITU regions
  - 47.2–48.2GHz has been identified in Region 2 as well as selected countries in Regions 1 and 3
- There is potential for this IMT identification to be expanded to additional countries in the future, and this may present opportunities for 6G
- The 47.2–48.2GHz band has so far been assigned in the USA only

37–43.5GHz

- 37–43.5GHz was identified for IMT globally at WRC-19 and it has also been included within 3GPP specifications for 5G use (n259 and n260)
- The band has so far been assigned in fewer markets than the 26GHz band but is available for 5G use in the USA and Japan
- Assignment of the band is also being considered in markets such as China, Canada and Brazil
- There may be opportunities for this band to be considered for 6G

57–71GHz

- 57–66GHz is not identified for IMT but is available for terrestrial use in numerous markets on an unlicensed basis
- 66–71GHz has a global IMT identification and has also been made available for unlicensed use in some markets such as the UK, Canada and USA, and could be used for 6G technologies

Other bands discussed at WRC-19 (such as 71–76GHz and 81–86GHz) might be reconsidered for future mobile use and, if so, 6G technologies might be designed to support those

Source: Analysys Mason

Academic research projects are underway on the sub-THz and THz ranges, but commercial interest is lacking without a clearer view of how the bands can be used

- During the primary research, interviewees expressed concern regarding the commercial use cases for the sub-THz and THz bands and noted that greater understanding of use cases and architectures would be needed to build wider support:
  - some interviewees felt that sub-THz spectrum should not be seen as mobile spectrum due to limited 'mobility' potential
  - commercial viability of these bands would depend on a range of factors that are as yet undetermined, such as use cases, proposed network architectures and types of device
- A few regulators, including Ofcom, have opened up some bands for terrestrial use (see opposite) – avoiding passive allocations is a key factor affecting the choice of band
  - other key considerations are propagation factors, oxygen absorption, availability of test equipment and uses cases
- Certain bands in the sub-THz range are currently protected by footnote 5.340, where emissions are prohibited
  - 100–102GHz
  - 109.5–111.8GHz
  - 114.25–116GHz
  - 148.5–151.5GHz
  - 164–167GHz
  - 182–185GHz
  - 190–191.8GHz
  - 200–209GHz
  - 226–231.5GHz
  - 250–252GHz

Potential terrestrial use of sub-THz and THz: USA/UK/Japan examples

- Certain regulators have begun to permit terrestrial use of sub-THz and THz for experimentation/innovation:
  - Ofcom (UK): 116–122GHz, 174.8–182GHz and 185–190GHz
  - FCC (USA): 116–123GHz, 174.8–182GHz, 185–190GHz and 244–246GHz
  - MIC (Japan): 116–134GHz, 152–164GHz (experimental) and 287.5–312.5GHz (experimental)
- The licensing regimes for these bands vary from country to country
  - FCC has opted for an unlicensed regime and Ofcom has opted for a licensed approach
  - in Japan, the 152–164GHz and 287.5–312.5GHz bands were made available for experimental testing in 2020
- From our understanding and interviews conducted, the choice of the bands above has been guided by the desire to avoid co-existence issues with passive satellite allocations
- One regulator commented that bandwidth consumption will be a key deciding factor when selecting sub-THz candidate ranges, but noted the trade-offs to be considered between bandwidth, use cases[1] and power consumption

[1] For example, based on potential use cases for sub-THz and THz spanning communications, localisation and sensing, devices designed for these combined use cases might benefit from having access to wide bands (e.g. for sensing applications)

Source: Analysys Mason

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