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DRAFT CEPT BRIEF ON AGENDA ITEM 1.13

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

# ISSUE

This agenda item considers possible new spectrum allocations suitable for delivery of terrestrial wireless broadband in the frequency range between 24.25 GHz and 86 GHz. This will encompass the following elements, set out in full in Resolution 238 (WRC-15):

* Spectrum needs for the terrestrial component of IMT
* Sharing and compatibility studies[[1]](#footnote-1) for the following frequency bands:

24.25-27.5 GHz[[2]](#footnote-2), 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz

31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz

# Preliminary CEPT position

CEPT supports the results of the ITU-R studies[[3]](#footnote-3) on IMT spectrum needs in the range 24.25-86 GHz. CEPT supports sharing and compatibility studies for the bands listed in Resolves 2 of Resolution **238** (24.25-27.5 GHz, 31.8-33.4 GHz, 37-43.5 GHz, 45.5-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz), with the focus on the frequency bands 24.25-27.5 GHz, 40.5-43.5 GHz and 66-71 GHz.

CEPT supports the identification of global bands for IMT among the bands listed in resolves to invite ITU‑R 2 of Resolution **238**, taking into account the results of sharing and compatibility studies with existing services. Bands outside those listed in resolves to invite ITU-R 2 of Resolution **238** are not supported for consideration under this Agenda item. The following bands are supported for IMT identification and where appropriate, allocation to the Mobile Service on a primary basis:

* 24.25-27.5 GHz

CEPT has confirmed the clear priority for this band through the adoption of a harmonisation decision (ECC Decision (18)06) including relevant conditions for the protection of other services in the band and adjacent bands. The Decision was developed based on studies that assumed an individual authorisation regime.

CEPT supports the unwanted emission limits of −42 dBW/200 MHz Total Radiated Power (TRP) for base stations and −38 dBW/200 MHz TRP for mobile terminals, into the 23.6-24 GHz band, to be included as mandatory limits in Resolution **750**.

CEPT is considering RR N° **5.536A**, **5.536B** and **5.536C** in relation with coexistence with EESS and SRS earth stations

* 40.5 – 43.5 GHz

CEPT proposes an IMT identification for 40.5-43.5 GHz. This is a priority band for CEPT and already identified for future harmonisation in Europe. CEPT considers that the bands 40.5-43.5 GHz has good potential for future harmonisation in Europe. The process for developing harmonisation decisions for additional bands (other than 26 GHz) may be launched immediately after WRC-19, under the assumption of an individual authorisation regime.

* 66 – 71 GHz

CEPT supports that IMT and MGWS/WAS should have equal access to the frequency band 66-71 GHz. An identification should not confer any priority to IMT and this should be emphasized in the footnote identifying the band and associated WRC Resolution. CEPT supports modifying No. **5.553** to remove the frequency band 66-71 GHz from this footnote.

Other candidate bands considered:

* 37-40.5 GHz

Whilst CEPT will not propose identification and has no intention of using 37-40.5 GHz for IMT, CEPT will not oppose a global IMT identification for the full 37-43.5 GHz range.

 The following bands are not supported for the IMT identification and CEPT is proposing NOC:

31.8-33.4 GHz

71-76 GHz

81-86 GHz.

Note: CEPT has developed a Roadmap on 5G (<http://cept.org/ecc/topics/spectrum-for-wireless-broadband-5g#roadmap>). In this respect it is noted that “Europe has harmonised the 27.5-29.5 GHz band for broadband satellite and is supportive of the worldwide use of this band for ESIM. This band is therefore not available for 5G”.

# Background

This agenda item received widespread worldwide support at WRC-15.

The Agenda item considers new spectrum allocations to the mobile service and identification of frequency bands for IMT. The rationale for this agenda item is to address demand for terrestrial wireless broadband, where terrestrial wireless provides a key means of delivery, alongside cable, fibre and satellite.

RSPG has agreed two Opinions on spectrum related aspects for next-generation wireless systems (5G). ECC has approved a comprehensive list of actions regarding the fifth generation of mobile technology (5G) named “CEPT roadmap for 5G”. ECC has approved ECC Decision (18)06 which provides the harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz. In addition to the 26 GHz band, CEPT considers that the bands 40.5-43.5 GHz and 66-71 GHz have good potential for future harmonisation in Europe. The process for developing harmonisation decisions for the additional bands may be launched immediately after WRC-19.

## ESTIMATES ON SPECTRUM NEEDS

Studies for WRC-19 Agenda item 1.13 estimated the spectrum needs for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz, in accordance with Resolution 238 (WRC-15) and [CA/226](http://www.itu.int/md/R00-CA-CIR-0226/en).

Terrestrial IMT-2020 systems will incorporate the use of new technologies that benefit from the physical characteristics of the frequencies in the frequency range from 24.25 to 86 GHz and the large bandwidths potentially available which will provide higher data rates and lower latencies. A number of approaches were considered and the results obtained using the application-based and the technical performance-based approaches are summarized in Table 6 of ITU-R TG5/1 Document 5-1/36 Attachment 1. The estimated spectrum needs would be different based on the approaches used together with the assumptions thereof.

Furthermore, some administrations provided information on spectrum needs in their countries based on their national considerations, which is also summarized in Table 6 of ITU-R TG5/1 Document 5-1/36 Attachment 1.

As indicated in these approaches, for the spectrum needs of IMT-2020 in the range of 24.25 and 86 GHz, different channel propagation characteristics and available channel bandwidth should be taken into account. With a view to accommodating the wide range of usage and deployment scenarios for IMT-2020, it is important to consider different frequencies within the range 24.25 and 86 GHz.

The spectrum needs for IMT-2020 are summarised within the draft CPM text developed by ITU-R TG5/1 (ITU-R TG5/1 Document 5-1/478 Annex 2).

## deployment scenarios for 5G in the bands above 24 GHz

In the bands above 24 GHz, mobile communication services will mainly target urban and sub-urban hotspot areas. The deployment of MFCN is expected to target only cells with a small range. There is no expectation that the bands above 24 GHz will be used for contiguous nationwide coverage of MFCN networks. There may be a need for hotspots also in rural areas. MFCN networks could be deployed indoor and/or outdoor.

ITU-R WP 5D has developed “Characteristics of terrestrial IMT systems for frequency sharing/interference analyses in the frequency range between 24.25 GHz and 86 GHz”. This includes the assumptions on typical deployment environments for IMT-2020 to be used in sharing studies in the bands 24.25-86 GHz[[4]](#footnote-4). Information is provided for the environments: Outdoor Suburban hotspot, Outdoor Urban hotspot and Indoor. Furthermore, an optional Outdoor suburban open space hotspot scenario is provided.

System parameters and propagation models used in sharing and compatibility studies within the ITU-R can be found in ITU-R TG5/1 Document 5-1/478 Annex 1.

## **Consideration of frequency bands**

### 24.25-27.5 GHz

The studies under this Agenda item for this band have been undertaken on the assumption that the IMT-2020 networks are operated on an individual licensed basis.

Decision ECC/DEC/(18)06 provides the harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz.

EESS (passive)

Adjacent band: According to ECC Decision (18)06 the IMT-2020 unwanted emissions levels in the 23.6-24 GHz band need to be limited to a maximum total radiated power of -42 dBW/200 MHz for BS and a maximum total radiated power of -38 dBW/200 MHz for UE. CEPT supports inclusion of these limits in Resolution **750** as mandatory limits (i.e. in Table 1-1) from mobile service stations (both BS and UE) in the band 24.25-27.50 GHz.

2nd Harmonic: The protection of the Earth Exploration Satellite Service (EESS) passive in the band 50.2-50.4 GHz and 52.6-54.25 GHz from IMT-2020 in the 24.25–27.5 GHz band is ensured by the current spurious emission limit of -30 dBm/MHz applying to base stations (as currently contained in Recommendations ERC 74-01 and ITU-R SM.329-12 category B).

By stating the limit in the WRC Resolution corresponding to the IMT identification of the 24.25-27.5 GHz frequency band, it would give the adequate rationale for ITU-R and standardization body to ensure that the applicable spurious limit would be compliant. The draft ECP on 26 GHz implements this.

EESS(s-E)/SRS(s-E)

Studies have shown that the separation distances around several EESS/SRS earth stations locations within Europe would be in the order of:

* 4 km around earth stations supporting NGSO EESS satellites
* 10 km around earth stations supporting GSO EESS satellites
* 30 to 70 km around the two earth stations supporting SRS spacecraft in Europe (90 km for ESA station in Malargüe in Argentina)

These separation distances were calculated for a single urban/suburban base station with a power per antenna element of 10 dBm/200 MHz and a 8x8 elements antenna (i.e. a maximum BS e.i.r.p. of 48 dBm/200 MHz assumed in the study). When considering an increase of power by 5 dB or a 16 x 16 antenna the distances increase by a factor 2 to 3 respectively. It should be noted that the coordination zones around EESS and SRS receiving earth stations have been established on the assumption that the IMT-2020 networks are operated on an individual licensed basis. A study has shown that the probability of aggregate interference for a random deployment of IMT-2020 stations around a specific earth station supporting a GSO EESS satellite is small. For the deployment scenarios specified in the study, the probability of interference is approximately 0.1% (1 in 1000) or less. In general, when considering the aggregation of multiple BS and associated UE, the distances indicated above are not expected to increase as long as BS antenna panels are not concurrently pointing towards the earth station in azimuth. Since the deployment of IMT-2020 at 26 GHz is expected in hot spots only and there are only a small number of EESS/SRS earth stations, then it is considered that co-existence is technically feasible. ECC administrations will need to maintain, with appropriate provisions in their authorisation for MFCN, the possibility for existing and future EESS/SRS receiving earth stations in the 25.5-27 GHz band to be used and to safeguard their future operations, taking into account the Radio Regulations. Relevant methodology to assess the coexistence of these earth stations with MFCN deployments is currently addressed in ECC and in ITU-R in order to aid the process. The final versions of draft ECC Recommendation (19)01 and PDNR ITU-R SA.[IMT-EESS/SRS coordination] will contain the methods to be used to ensure the protection of the EESS and SRS earth stations by means of suitable separation/coordination areas or other suitable solutions.

In this respect, CEPT is currently investigating various options on ways to address RR N° **5.536A**, **5.536B** and **5.536C** (deletion, revisions or NOC).

**Radio astronomy**

A generic compatibility study between the RAS in the passive band 23.6-24 GHz and IMT systems in the band 24.25-27.5 GHz considering both single-entry and multiple-entry (aggregate) scenarios show that separation distances around RAS stations are required to protect this service from IMT spurious emissions. For this study a flat terrain profile was considered. For spurious emissions of IMT systems at the -13 dBm/MHz level, separation distances of up to 48 km and 27 km radius will be needed for a single base station and user equipment respectively. In the aggregate scenario where a number of base stations and user equipment are considered in a clustered deployment density, the separation distance becomes 52 km. For the -30 dBm/MHz emission level as specified for Category B devices, the separation distances may be reduced to about 18 km and 5 km for single-entry base station and user equipment, respectively, and 33 km for the aggregate scenario. Another study considered a single-entry worst-case with the composite antenna pattern (without normalization), assuming IMT-2020 out-of-band emission levels of -42 dBW/200 MHz for base stations and ‑38 dBW/200 MHz for user equipment, the result showed a separation distance of up to 5 km for user equipment and up to 9 km for base stations. Separation distances for individual RAS stations need to be calculated using the IMT-2020 out-of-band limits decided from the EESS (passive) study for the same band and site-specific terrain and clutter information. It is considered that the protection of radio astronomy observations is a national issue to be addressed on a case by case basis.

**Inter-Satellite Service**

Most aggregated sharing studies have shown that the ISS would be protected with a margin of more than 12 dB and in some cases up to 27 dB, based on agreed assumptions, and it will be necessary to ensure that these services remain protected.

ECC Decision (18)06) contains some measures (e.g. elevation of main beam of IMT base stations) to address long term protection of ISS satellites taking into account the compatibility studies. ECC Decision (18)06 also recognises that a regular assessment of the evolution of MFCN system characteristics, including network deployments, in a timeline consistent with the 5 years review process of the Decision, or sooner if necessary, will provide additional confidence that the Least Restrictive Technical Conditions (LRTC) ensure adequate protection of other services, in particular space services.

Hence CEPT concludes that coexistence would be feasible with ISS, if those assumption made in the studies are met.

Fixed Satellite Service (E-s)

All baseline sharing studies, using the agreed parameters, have shown that Fixed-Satellite Service (FSS) would be protected with a positive margin and it was concluded that sharing is feasible. All but one study showed I/N values ranged from -32.8 dB I/N to -24.3 dB I/N for elevations between 10 and 50 degrees for the worst case space station assessed. One study gave result of -19.2 dB I/N which was not in line with other studies. When compared with the -10.5 dB I/N (exceeded up to 20% or I/N average) protection criteria, all studies show a positive margin. Sensitivity analysis, in line with the agreed methodology on how to vary the parameters, found that interference could increase by 3-5 dB but a positive margin compared to the protection criteria is maintained. It will be necessary to ensure that these services remain protected.

ECC Decision (18)06) contains some measures (e.g. elevation of main beam of IMT base stations) to address long term protection of FSS satellites taking into account the compatibility studies. ECC Decision (18)06 also recognises that a regular assessment of the evolution of MFCN system characteristics, including network deployments, in a timeline consistent with the 5 years review process of the Decision, or sooner if necessary, will provide additional confidence that the LRTC ensure adequate protection of other services, in particular space services.

FSS into IMT: Studies show separation distances between IMT base stations and FSS Earth stations are from less than 100 m up to 10 km. CEPT is developing an ECC Recommendation to support introduction of 5G while ensuring, in a proportionate way, the use of existing and planned FSS transmitting earth stations in the 26 GHz band and the possibility for future deployment of these earth stations. This will include development of a technical toolkit in order to help administrations to define how existing, planned and future earth stations will continue to operate or have the opportunity to be installed without significant impact on 5G deployment.

Conclusion for 26 GHz

CEPT has harmonised the 24.25-27.5 GHz band for Europe through the adoption of a harmonisation decision (Decision ECC/DEC/(18)06). CEPT supports the band for worldwide harmonisation by an IMT identification under certain conditions as shown in the ECC Decision. Therefore, CEPT supports to allocate the 24.25-25.25 GHz frequency band to the MS on a primary basis in Regions 1 and 2 and to identify the 24.25-27.5 GHz frequency band for IMT in Regions 1, 2 and 3, subject to the conditions as shown in Resolution Draft New Resolution **[EUR-A113-IMT 26 GHZ] (WRC-19)** and the revision to Resolution **750**.

### 31.8-33.4 GHz

Radionavigation

Radionavigation service is allocated on a worldwide basis and used in a number of countries for ground-based airport surface detection equipment (ASDE) radar, mainly to detect traffic at airports and by aircraft radars for ground mapping, weather avoidance, to calibrate aircraft on-board navigation systems for accurate aerial delivery in adverse weather conditions and for Enhanced Flight Visibility Systems (EFVS).

EFVS system generates navigation information and a synthesis image of the external scene in the cockpit with the main purpose to permit, in poor visibility conditions, landing (and potentially providing assistance for taxiing), where landing would not be safe otherwise (in particular for airport not equipped with ground landing assistance systems such as ILS).

The band offers a good compromise between resolution and atmosphere penetration in bad weather conditions.

All technical studies presented in TG 5/1 have shown the incompatibility between IMT and radionavigation service in the 32 GHz band, in particular in the case of aircraft radars for which coordination/exclusion zones approaching 100 km around any small airport cannot be envisaged.

EESS (passive)

The studies presented in CEPT and in ITU-R so far consistently show that the current IMT-2020 unwanted emissions levels would be insufficient to ensure protection of the EESS (passive) sensors in the 31.3‑31.8 GHz band and that only a drastic reduction of the IMT-2020 emissions in this band can ensure such protection. These studies show that required emission levels in this band should be in the range -55.8 to – 59.8 dBW/200 MHz for BS and -53.7 to -59.2 dBW/200 MHz for UE.

SRS(s-E)

SRS(s-E) is allocated in the band 31.8-32.3 GHz. Studies show that the maximum separation distances required to protect SRS (s-to-E) earth stations operating in the band 31.8-32.3 GHz would be in the order of 24 to 83 km.

Radio astronomy

A generic compatibility study between the RAS in the band 31.3-31.8 GHz and IMT systems in the band 31.8-33.4 GHz shows that separation distances around RAS stations are required to protect this service from IMT spurious emissions. For this study a flat terrain profile was considered. For spurious emissions of IMT systems at the -13 dBm/MHz level, separation distances of up to 49 km radius are required. For the ‑30 dBm/MHz emission level as specified for Category B devices, the separation distances may be reduced to about 15 km. Separation distances for individual RAS stations need to be calculated using site-specific terrain and clutter information. It is considered that the protection of radio astronomy observations is a national issue to be addressed on a case by case basis.

Fixed service

If this band is not used for IMT/5G, it may be used to accommodate fixed links which may be migrated from the 26 GHz band.

Conclusion for 32 GHz

CEPT is of the view that, based on the results of the ITU-R compatibility studies between IMT and the radionavigation service in the 32 GHz band, this band shall not be identified for IMT.

ITU-R TG 5/1 agreed that only the ‘No Change’ method is included in the draft CPM text.

### 37-40.5 GHz

Industry has indicated that 40.5-43.5 GHz is expected to be part of a tuning range for equipment from 37-43.5 GHz. The potential of this tuning range would enable different countries outside CEPT to identify the most appropriate frequencies to be used for 5G.

On the other hand, CEPT also notes that a number of other services are operating in the 37-40.5 GHz band or adjacent 36-37 GHz band.

Whilst CEPT will not propose identification and has no intention of using 37-40.5 GHz for IMT, CEPT recognises that the frequency range 37-43.5 GHz may have strong potential to become a 5G tuning range, facilitating harmonisation of equipment. CEPT is focusing on the top part of the range (40.5-43.5 GHz) while other countries outside of CEPT could focus on other parts of the range. In this respect, should it be proposed at WRC-19, CEPT would not oppose a global IMT identification for the full 37-43.5 GHz range (see also CEPT position above on 40.5-43.5 GHz), provided that the relevant conditions to ensure protection of incumbent services in the 37-40.5 GHz band and EESS (passive) in the 36-37 GHz band are included.

The benefit of identifying this wide tuning range that can be harmonised globally is that equipment manufacturers and vendors can serve the global market with the same products, thus maximising economies of scale, while allowing different administrations/regions the ability to identify the most appropriate frequencies within the range to be used for 5G. National regulators can make spectrum for 5G available when and where required.

EESS(passive)

Studies submitted to ITU-R TG 5/1 between IMT in 37-40.5 GHz and EESS (passive) in 36-37 GHz give IMT-2020 unwanted emissions levels in the range -28 to -47 dBW/100 MHz for BS and -23 to ‑46 dBW/100 MHz for UE.

[There are different views regarding whether currently-specified IMT-2020 unwanted emission limits (i.e. ‑13 dBm/MHz) are sufficient to protect EESS (passive) in this band, or if tighter unwanted emissions limits are needed.

36-37 GHz is shared between both active (FS and MS) and passive (EESS) services, and is covered by WRC Resolution **752 (WRC-07)**. According to the first view, it is considered that IMT-2020 is designed to provide hotspot and not ubiquitous coverage, and that the EESS protection criterion for this band in Rec. ITU-R RS.2017 (with 0.1% percentage and 10000000 km2 measurement area) provides for a significant exclusion area, and that this criterion would not be exceeded and it is unnecessary to include this band in WRC Resolution **750**.

Under the second view, it is considered that Resolution **752 (WRC-07)** only addresses in-band sharing and is hence not relevant to unwanted emissions issues, further noting that the deployment of IMT-2020 is order of magnitude denser than the fixed and mobile systems considered in the development of this Resolution (see ITU-R Report RS.2095).

or

Under the second view, it is first highlighted that ITU-R RS.2017 does not provide any exclusion area, only a certain portion (0.1 %) of a 10,000,000 km² in which the EESS (passive) protection criteria may be exceeded. It is reminded that 10,000,000 km² is the size of the whole Europe and that 0.1% only represent 10000 km².

It is not expected that IMT-2020 deployment would be limited to such a small area.

It is considered that Resolution 752 (WRC-07) only addresses in-band sharing and is hence not relevant to unwanted emissions issues. It is further stressed that the deployment of IMT-2020 is order of magnitude denser than the fixed and mobile systems considered in the development of this Resolution (see ITU-R Report RS.2095). Indeed, between 2 and 50 mobile stations within 10 000 000 km² were considered for the development of conditions in Resolution 752 (WRC-07) whereas when considering IMT-2020 deployment conditions provided by WP5D, 1.2 Millions stations would be deployed within the same area.]

1. The options on the text above should be considered by ECC PT1.

Further consideration is required in CEPT regarding this matter.

SRS (s-to-E)

Studies show that the maximum separation distances required to protect SRS (s-to-E) earth stations operating in the band 37-38 GHz would be in the order of 30 to 100 km.

These separation distances were calculated for a single urban/suburban base station with a power per antenna element of 10 dBm/200 MHz and a 8x8 elements antenna (i.e. a maximum BS e.i.r.p. of 48 dBm/200 MHz).

**Fixed Satellite Service (s-E)**

ITU-R TG5/1 sharing studies between IMT and FSS (space-to-Earth) in this band provide results in terms of separation distances between an IMT network and an FSS earth station, and probabilities that an IMT network may have the potential to cause interference to an FSS earth station at different separation distances. Separation distances calculated in these studies are between 210 metres, up to a maximum of around 2 kilometres, with low probabilities that the levels of aggregate emissions from an IMT network may potentially cause interference to an FSS earth station.

Separation distances for individual FSS earth stations need to be calculated using site-specific terrain and clutter information. It is considered that the protection of FSS (s-E) in this band is a national issue to be addressed on a case by case basis. In cases of small FSS earth stations at unspecified locations and IMT stations in the same geographical area, the separation distance cannot be ensured. Therefore, sharing may or may not be feasible and could be dealt with on a case-by-case basis.

There are existing ECC Decisions that are relevant to this band.

### 40.5- 42.5 GHz

**FSS (s-E)**

ITU-R TG5/1 sharing studies between IMT and FSS (space-to-Earth) in this band provide results in terms of separation distances between an IMT network and an FSS earth station, and probabilities that an IMT network may have the potential to cause interference to an FSS earth station at different separation distances. Separation distances calculated in these studies are between 210 metres, up to a maximum of around 2 kilometres, with low probabilities that the levels of aggregate emissions from an IMT network may potentially cause interference to an FSS earth station.

Separation distances for individual Earth stations need to be calculated using site-specific terrain and clutter information. It is considered that the protection of FSS (s-E) in this band is a national issue to be addressed on a case by case basis since the use of the band by FSS is limited to coordinated Earth stations.

### 42.5-43.5 GHz

Radio astronomy

A generic in-band sharing study between the RAS in the band 42.5-43.5 GHz and IMT systems in the same band shows that separation distances around RAS stations are required to protect this service from IMT operations, with radii of up to 56 km. A generic compatibility study between the RAS in the band 42.5‑43.5 GHz and IMT systems in the band 40.5-42.5 GHz shows that separation distances around RAS stations are required to protect this service from IMT spurious emissions. For spurious emissions of IMT systems at the -13 dBm/MHz level, separation distances of up to 44 km radius are required. For the ‑30 dBm/MHz emission level as specified for Category B devices, the separation distances may be reduced to about 7 km. For both studies a flat terrain profile was considered. Separation distances for individual RAS stations need to be calculated using site-specific terrain and clutter information. It is considered that the protection of radio astronomy observations is a national issue, for both the in-band sharing and the spurious emission scenarios, to be addressed on a case-by-case basis.

Fixed Satellite Service (E-s)

FSS GSO: All baseline sharing studies, using the agreed parameters, have shown that GSO Fixed-Satellite Service (FSS) would be protected with a positive margin. Study showed I/N values ranging from -43.46 dB I/N to -26.5 dB I/N. When compared with the -10.5 dB I/N (exceeded up to 20% or I/N average) protection criterion, all studies show a positive margin. Sensitivity analysis, in line with the agreed methodology on how to vary the parameters, found a positive margin compared to the protection criterion is maintained.

FSS non-GSO: All baseline sharing studies, using the agreed parameters, have shown that non-GSO Fixed Satellite Service (FSS) would be protected with a positive margin. Studies have showed I/N values ranging from -34.8 dB I/N to -38.2 dB I/N for both fixed orbit positions and dynamic cases. One study showed a worst case I/N value of -21.3 dB I/N. However, several other simulations under similar assumptions have resulted in an I/N below -30 dB instead of -21.3 dB. When compared with the -10.5 dB I/N (20% or I/N average) protection criterion, all studies show a positive margin.

ECC Decision (18)06) contains some measures (e.g. elevation of main beam of IMT base stations) to address long term protection of FSS satellites taking into account the compatibility studies. ECC Decision (18)06 also recognises that a regular assessment of the evolution of MFCN system characteristics, including network deployments, in a timeline consistent with the 5 years review process of the Decision, or sooner if necessary, will provide additional confidence that the LRTC ensure adequate protection of other services, in particular space services. Although ECC Decision (18)06 applies to 26 GHz, it is suggested that similar measures could be applied to 42.5–43.5 GHz and this has been implemented in the draft ECP for this band.

FSS into IMT: Studies showed separation distances between IMT base stations and FSS Earth stations are from 160 m to 4 km.

### 45.5-47 GHz

No studies for this band were performed in ITU-R.

### 47-47.2 GHz

No studies for this band were performed in ITU-R.

### 47.2-50.2 GHz

EESS(passive)

Adjacent band: Studies submitted to ITU-R TG 5/1 indicate that IMT-2020 unwanted emissions levels for IMT operating in the band 47.2-50.2 GHz to protect EESS (passive) sensors in the 50.2-50.4 GHz band should be in the range -24.8 to -49.3 dBW/200 MHz for BS and -23.1 to -47.6 dBW/200 MHz for UE.

Further work is required in CEPT to consider the relevant unwanted emission levels.

Note: See section 3.3.1 for positioning on 2nd Harmonic from IMT-2020 in the 24.25 – 27.5 GHz band.

Fixed Satellite Service (E-s)

FSS GSO: All baseline ITU-R studies, using the assumptions provided by the responsible group GSO Fixed-Satellite Service (FSS) would be protected with a positive margin. Results showed that the calculated I/N ranged from -37 dB to -30 dB. The difference relates to the used FSS boresight elevation angles and if IMT deployment is in -3 dB satellite footprint or the whole satellite visible earth view. One study calculated probability distributions of IMT gain towards the space station and presumed the worst-case value for each IMT transmitter (elevation and azimuth) in the satellite beam and found an I/N of -19 dB without clutter considerations. When compared with the -10.5 dB I/N (exceeded up to 20% or I/N average) protection criteria, all studies show a positive margin.

FSS non-GSO: Two deterministic ITU-R studies using both static scenario and single low elevation angle (i.e. 10°) of the non-GSO satellite led to an I/N of -21.7 dB and -35.6 dB. Another study, using a statistical analysis and the baseline parameters found an I/N of -37 dB. When compared with the -10.5 dB I/N (exceeded up to 20% or I/N average) protection criteria, all studies show a positive margin.

FSS Earth stations into IMT: For the case of an FSS earth station interfering into IMT, the results concluded there is a need for a separation distance between 160m and 5000m, based on the assumption used between the FSS earth station and the IMT stations’ deployed area.

FSS/BSS/MSS (space-to-Earth) and IMT

See Section 3.3.4. ITU-R TG5/1 sharing studies between IMT and FSS (space-to-Earth) provide results in terms of separation distances between an IMT network and an FSS earth station, and probabilities that an IMT network may have the potential to cause interference to an FSS earth station at different separation distances. Separation distances calculated in these studies are between 210 m, up to around 1 or 2 kilometres in some cases, with extremely low probabilities that the levels of aggregate emissions from an IMT network may potentially cause interference to an FSS earth station.

Separation distances for individual Earth stations need to be calculated using site-specific terrain and clutter information. It is therefore considered that the protection of FSS (s-E) is a national issue to be addressed on a case by case basis.

### 50.4-52.6 GHz

EESS(passive)

Adjacent band: Studies submitted to ITU-R TG 5/1 indicate that IMT-2020 unwanted emissions levels from IMT operating in the 50.4-52.6 GHz band to protect EESS (passive) sensors in the 50.2-50.4 GHz and 52.6‑53.25 GHz bands should be:

* in the range -24.8 to -49.3 dBW/200 MHz for BS and -23.1 to -47.6 dBW/200 MHz for UE for EESS (passive) in 50.2-50.4 GHz;
* no tighter than -45.3 dBW/200 MHz for BS and -44.3 dBW/200 MHz for UE for EESS (passive) in 52.6-54.25 GHz.

Further investigations are necessary to evaluate the impact of such unwanted emission levels on IMT-2020 systems in this frequency range and to evaluate whether it could render this band unattractive for IMT-2020 systems operations by limiting their operations to a narrow portion of the 50.4-52.6 GHz range.

Note: See section 3.3.1 for positioning on 2nd Harmonic from IMT-2020 in the 24.25 – 27.5 GHz band.

Fixed Satellite Service (E-s)

All baseline ITU-R studies, using the assumptions provided by the responsible group GSO Fixed-Satellite Service (FSS) would be protected with a positive margin. One study concluded that for the worst-case scenario, the mean I/N is -34 dB for GSO. Another study calculated a value of -30.4 dB mean I/N for a GSO satellite and -21.7 dB for a non-GSO satellite. Another study calculated probability distributions of IMT gain towards the space station and presumed the worst-case value for each IMT transmitter (elevation and azimuth) in the satellite beam and found an I/N of -19 dB without clutter considerations.

Sensitivity analyses were carried out using parameters’ assumptions and the agreed course of action on how to vary these parameters developed by the ITU-R on how to use the parameters provided in sharing and compatibility studies such as up to a 5 dB higher antenna element conducted power than that specified in the baseline or 16×16 antenna array. These studies found that the protection criteria were not exceeded with a positive margin.

For the case of an FSS earth station interfering into IMT, the results concluded there is a need for a separation distance from 160 metres to 5 km.

### 66-71 GHz

This band may already be used by MGWS/WAS systems, including WiGig. IMT and MGWS/WAS should have equal access to this frequency band. An identification should not confer any priority to IMT and this should be emphasised in the footnote identifying the band and associated WRC Resolution.

A study has been presented in CEPT and ITU-R between IMT systems in the 66-71 GHz frequency range with the inter-satellite service. This study shows that there is significant margin towards the Data Relay Satellite. The study provides the single-entry worst case analysis for both the BS and UE case for the interference scenario where the ISS data relay satellite (DRS) is at 1° elevation and at 80° elevation. At 1° elevation, the DRS will be in the main-beam (near peak power) of the base station while the atmospheric loss is significantly lower compared to 0° elevation (horizon). 80° elevation was chosen for the 2nd analysis to ensure that the IMT-2020 base station beam towards the satellite is in front of the antenna panel where the antenna gain reduces significantly in the back panel. Study A shows a margin towards the DRS in the range of 38 dB to 127 dB.

A study has been presented in CEPT and ITU-R between IMT systems in the 66 - 71 GHz frequency range with the Mobile-Satellite Service (MSS). The study provides a single-entry interference analysis from the IMT-2020 Base Station (BS) and User Equipment (UE) to the MSS in a geostationary orbit (GSO); where the range of elevation angle to the MSS satellite is from the horizon at 0° elevation to 90° elevation (zenith). The analysis shows that the interference level from IMT-2020 to MSS is very low from -347 dBW/MHz to ‑176 dBW/MHz, which equates to an interference to noise ratio between -207 dB and -36 dB. This analysis does not include loss due to clutter and other effects which would further reduce the interference level from IMT-2020.

### 71 – 76 GHz

This band (paired with 81–86 GHz) is used for Fixed Links and is also considered suitable for backhauling of IMT-2020 stations.

Radiolocation

Automotive radars are operating in the frequency band 76-81 GHz under radiolocation service.

A study has been submitted to CEPT in order to assess the impact of spurious emission of IMT-2020 BS and UE into the automotive radar in case of operation in particular of urban street in the frequency band 71‑76 GHz considering shielding factor effect, TDD ratio impact, dual band impact. This has highlighted the issue of respecting the ERC/REC 74-01.

To protect automotive radars in the 76-81 GHz band, the study shows that it is necessary that the spurious emissions of both BS and UE IMT-2020 in the 71-76 GHz do not exceed the value of -30 dBm/MHz.

### 81-86 GHz

This band (paired with 71–76 GHz) is used for Fixed Links and is also considered suitable for backhauling of IMT-2020 stations.

Radiolocation

Automotive radars are operating in the frequency band 76-81 GHz under radiolocation service.

A study has been submitted to CEPT in order to assess the impact of spurious emission of IMT-2020 BS and UE into the automotive radar in case of operation in particular of urban street in the frequency band 81‑86 GHz considering shielding factor effect, TDD ratio impact, dual band impact. This has highlighted the issue of respecting the ERC/REC 74-01.

To protect automotive radars in the 76-81GHz band, the study shows that it is necessary that the spurious emissions of both BS and UE IMT-2020 in the 81-86 GHz do not exceed the value of -30 dBm/MHz.

EESS(passive)

The studies presented in CEPT and in ITU-R so far consistently show that the current IMT-2020 unwanted emissions levels would be insufficient to ensure protection of the EESS (passive) sensors in the 86-92 GHz band and that only a drastic reduction of the IMT-2020 emissions in this band can ensure such protection. These studies show that required emission levels in this band should be in the range -55.4 to ‑60.2 dBW/100 MHz for BS and -55.2 to –60 dBW/100 MHz for UE.

Radio astronomy

A generic in-band sharing study between the RAS in the band 81-86 GHz and IMT systems in the same band shows that separation distances around RAS stations are required to protect this service from IMT operations, with radii of up to 49 km. A generic compatibility study between the RAS in the band 81-86 GHz and IMT systems in the bands 76-81 and 86-94 GHz shows that separation distances around RAS stations are required to protect this service from IMT spurious emissions. For spurious emissions of IMT systems at the -13 dBm/MHz level, separation distances of up to 29 km radius are required. For the -30 dBm/MHz emission level as specified for Category B devices, the separation distances may be reduced to about 4 km. For both studies a flat terrain profile was considered. Separation distances for individual RAS stations need to be calculated using site-specific terrain and clutter information. It is considered that the protection of radio astronomy observations is a national issue, for both the in-band sharing and the spurious emission scenarios, to be addressed on a case-by-case basis.

# List of relevant documents

ITU-Documentation (Recommendations, Reports, other)

* ITU-R TG5/1 Document 5-1/36: Spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz
* Recommendation ITU-R M.2101, “Methodology for modelling and simulation of IMT networks for use in sharing and compatibility studies between IMT and other systems and/or applications”
* ITU-R TG5/1 Document 5-1/478: Chairman’s Report of the Final meeting of TG5/1
* Draft CPM text: [Doc. CPM19-2/1](https://www.itu.int/md/R15-CPM19.02-C-0001/en)
* ITU-R REC M.2003-2 (01/2018) “Multiple Gigabit Wireless Systems in frequencies around 60 GHz”
* Draft revision Report ITU-R M.2227-1 “Multiple Gigabit Wireless Systems in frequencies around 60 GHz”
* Liaison from ITU-R WP4A – ITU-R TG5/1 Document 5-1/411-E

CEPT and/or ECC Documentation (Decisions, Recommendations, Reports)

* ECC PT1 (16)133 Annex 31Rev1 Summary of responses to questionnaire on bands for AI 1.13
* ECC PT1 (16)133 Annex 33 Table of information for AI 1.13
* CEPT roadmap for 5G
* ECC Decision (18)06 on the harmonised technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz

EU Documentation (Directives, Decisions, Recommendations, other), if applicable

* 5G action plan – COM(2016)588
* RSPG 1st Opinion (16-032) - Opinion on spectrum related aspects for next-generation wireless systems (5G)
* RSPG Second Opinion on 5G networks (18-005) - Strategic Spectrum Road Map Towards 5G for Europe
* RSPG Opinion on the ITU-R World Radiocommunication Conference 2019 (18-038)
* RSCOM16-40rev3 - Mandate to CEPT to develop harmonised technical conditions for spectrum use in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union

# Actions to be taken

* Carry out sharing and compatibility studies for the bands listed in Resolves 2 of Resolution **238**.
* Review positions of other regional groups and promote conditions in ECC Decision (18)06 in other regions
* Positions to be developed

45.5-47.0 GHz and 47.0-47.2 GHz

It should be noted that there are currently no studies for 45.5-47.2 GHz.

47.2-50.2 GHz and 50.4-52.6 GHz

* Consider contributions to CPM
* Consider the implication of Nos 5.536A, 5.536B and 5.536C
* Develop draft ECP(s) for the bands listed in Resolution **238** in particular 26 GHz, 32 GHz, 42 GHz, and 66-71 GHz

# Relevant information from outside CEPT (examples of these are below)

## European Union (date of proposal)

[placeholder]

## Regional telecommunication organisations

APT (March 2018)

Preliminary view

APT Members support the consideration of additional frequency bands for International Mobile Telecommunications (IMT), including possible additional mobile allocations on a primary basis, in accordance with Resolution 238 (WRC-15).

APT Members also support ITU-R studies on spectrum needs for the terrestrial component of IMT and sharing and compatibility studies in accordance with Resolution 238 (WRC-15). It is important for these sharing and compatibility studies to take into account protection of services to which the band is allocated on a primary basis.

Subject to satisfactory results of sharing and compatibility studies, APT Members have a preference in prioritizing considerations for IMT identification in the 24.25-27.5 GHz frequency band or portions thereof.

Regarding the overlapping issue of the frequency bands within the scope of agenda item 1.13 associated with Resolution 238 (WRC-15) and those within the scope of agenda items 1.6, 1.14 and 9.1 (issue 9.1.9), APT Members are of the view that this issue would be handled by WRC-19 based on proposals submitted to the conference, discussion on these agenda items and WRC-19’s decision on use of each frequency band mentioned in the corresponding Resolutions.

Other views

In addition to the APT preliminary views mentioned above, subject to satisfactory results of sharing and compatibility studies, some APT Members have a preference in prioritizing considerations for IMT identification in the 31.8-33.4 GHz and/or 37-43.5 GHz frequency bands or portions thereof.

Subject to satisfactory results of sharing and compatibility studies, some APT Members are also considering other candidate bands above 43.5 GHz, such as, the 66-71 GHz, 71-76 GHz and 81-86 GHz frequency bands or portions thereof.

ATU (17 to 21 September, 2018)

A) For the band 24.25-27.5 GHz (Band A):

1. Method A2, Alternative 2, Condition A2a: Option 1which entails the following:

* Allocating the band 24.25-25.25 GHz to the mobile service (except aeronautical mobile) on a primary basis in Regions 1 and 2.
* Identifying, globally, the band 24.25-27.5 GHz for IMT by a new footnote.
* Revising Resolution 750 (WRC-15), Table 1-1, to include the following IMT unwanted emission limits for the 23.6 to 24.0 GHz frequency band to protect EESS(passive):

BS: -32 to -37 dBW/200 MHz

UE: -28 to -30 dBW/200 MHz

2. The following conditions and options with respect to other services:

* Condition A2b: Option 3 –no condition necessary
* Condition A2c: Option 4 –no condition necessary
* Condition A2d: Option 4 –no condition necessary
* Condition A2e: Option 9 –no condition necessary
* Condition A2f: Option 3 –no condition necessary
* Condition A2g: Option 4 –no condition necessary

B) For the band 31.8-33.4 GHz (Band B):

Method B1 (No Change)

C) For the band 37-40.5 GHz (Band C):

1. Method C2, Alternative 2 Condition C2a: Option 4which entails the following:

* Identifying of the band 37-40.5 GHz to terrestrial component of IMT.
* No condition necessary with respect to EESS in the lower adjacent band:

2. The following conditions and options with respect to other services:

* Condition C2b: Option 6
* Condition C2c: Option 3
* Condition C2d: Option 2
* Condition C2e: Option 3

D) For the band 40.5-42.5 GHz (Band D):

1. Method D2, Alternative 2, which entails upgrading the mobile allocation to a primary service in the Table of Frequency allocations and identifying the frequency band for IMT by a new footnote in the frequency band 40.5-42.5 GHz.

2. The following conditions and options with respect to other services:

* Condition D2a: Option 5 –no condition necessary
* Condition D2b: Option 3–no condition necessary
* Condition D2c: Option 3 –no condition necessary

E) For the band 42.5-43.5 GHz (Band E):

1. Method E2, Alternative 2, which entails identifying the 42.5-43.5 GHz to terrestrial component of IMT.

2. Take the following conditions and options:

* Condition E2a: Option 7 –no condition necessary
* Condition E2b: Option 3 –no condition necessary
* Condition E2c: Option 4 –no condition necessary

F) For the band 45.5-47.0 GHz (Band F):

To be developed.

G) For the band 47-47.2 GHz (Band G):

To be developed.

H) For the band 47.2-50.2 GHz (Band H):

1. Method H2, Alternative 2, which entails identifying the 47.2-50.2 GHz frequency band for the terrestrial component of IMT.

2. The following conditions and options:

* Condition H2a: Option 2 –Resolution 750 (Rev. WRC-19) in Table 1-1, taking into account RR No. 5.340.1
* Condition H2b: Option 8 –no condition necessary
* Condition H2c: Option 3 –no condition necessary
* Condition H2d: Option 4 –no condition necessary

I) For the band 50.4-52.6 GHz (Band I):

1. Method I2, Alternative 2which entails identification to terrestrial component of IMT in 50.4-52.6 GHz (in the mobile service)

2. The following conditions and options:

* Condition I2a: Option 2 –Resolution 750 (Rev. WRC-19) in Table 1-1, taking into account RR No. 5.340.1.
* Condition I2b: Option 7 –no condition necessary
* Condition I2c: Option 4 –no condition necessary

J) For the band 66 -71 GHz (Band J):

3. Support Method J2, Alternative 2, which entails identifying identification to terrestrial component of IMT in 66-71 GHz (in the mobile service).

4. The following conditions and options:

* Condition J2a: Option 1

take into account the latest technical characteristics of IMT and MGWS/WAS

to invite ITU-R to develop Recommendations and Reports that will assist administrations in ensuring that applications and services in the band 66-71 GHz can utilize the band efficiently including the development of appropriate sharing protocols between IMT and MGWS/WAS where needed

* Condition J2b: Option 1 – Revise RR No. 5.553 to remove the 66-71 GHz frequency band from that footnote.
* Condition J2c: Option 3 – no condition necessary.

K) For the band 71- 76 GHz (Band K):

To be developed.

L) For the band 81- 86 GHz (Band L):

To be developed.

ASMG (7-11 April 2018)

Support identification of IMT2020 within the frequency band 24.25 - 27.5 GHz with studying the following OOBE limits in TG5/1:

* BS OOBE Limits: - 32 to - 37 dBW/200 MHz
* UE OOBE Limits: - 28 to - 30 dBW/200 MHz With no restrictions on the use of IMT in this band

Support identification of IMT2020 within the following frequency bands:

* 40.5 - 42.5 GHz
* 42.5 - 43.5 GHz

Following up the ongoing studies on the other candidate bands as included in Resolution 238 (WRC 15)

Does not support discussing any study or contribution on the frequency bands such as 28 GHz (27.5 – 29.5 GHz).

Protection of the existing services within the candidate band considering the protection of the existing services within the adjacent bands

CITEL (December 2017)

Brazil:

Agenda Item 1.13 is key to the future development of IMT systems for the delivery of IMT-2020 services.. The aim of IMT-2020 is to create a more ‘hyper connected’ society by more comprehensively, and intelligently, integrating LTE, Wi-Fi and cellular IoT technologies, together with at least one new IMT-2020 radio interface. This will allow mobile networks to dynamically allocate resources to support the varying needs of a diverse set of connections – ranging from industrial machinery in factories, to automated vehicles as well as smartphones. A central component in the evolution of all mobile technology generations has been the use of increasingly wide frequency bands to support higher speeds and larger amounts of traffic. IMT-2020 is no different, ultra-fast IMT-2020 services will require large amounts of spectrum including above 24 GHz where wide bandwidths are more readily available. Spectrum above 24 GHz is well recognized worldwide as being the key component for the data intensive IMT-2020 services. Without them, IMT-2020 won’t be able to deliver significantly faster data speeds or support projected extensive mobile traffic growth.

With that in mind, we support appropriate sharing and compatibility studies under Agenda Item 1.13 in the bands 24.25-27.5 GHz, 31.8-33.4 GHz, 37-43.5 GHz, 45.5-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz. Such studies should consider that the significant extra capacity of IMT-2020 systems will need to be perfectly integrated with heterogenous networks, including fibre, satellite and microwave systems, taking into account their specific benefits which are crucial to developing countries.

Canada:

Canada supports and is participating in the studies under WRC-19 agenda item 1.13, taking place in ITU-R TG 5/1, in the following frequency bands:

24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

Canada is of the view that passive services in frequency bands adjacent to those under study in AI 1.13 should be protected taking into account the relevant provisions of the Radio Regulations.

USA:

Support studies under WRC-19 agenda item 1.13 and take appropriate action based on the results of these sharing and compatibility studies in accordance with Resolution 238 in the following bands:

24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

Colombia:

While all bands remain suitable for identification at this stage, Colombia would like to make the following observations regarding the lower portions of the range, from 24.25 GHz to 43.5 GHz:

* Responses received until the previous meeting of CCP.II to the questionnaire show that, except for a few cases, there are either no services licensed in these bands or the services belong to the fixed service category. When they belong to other service categories (such as FSS), most of them occupy a relatively small (500MHz or less) bandwidth with-respect-to the total range being considered for study (e.g. 3.25 GHz for 24.25GHz – 27.5GHz).
* Other regions initiated discussions on suitable bands among the lists of candidate bands. As an example, Europe ([2], [3]) identified the 24.25 GHz – 27.5 GHz as a “pioneer band”, while other bands up to 43.5 GHz have been positively considered. With the view of seeking not only regional but global frequency harmonization to the possible extent, it is positive to take under consideration activities of other regions.
* The lower portions of the range would provide comparatively more suitable propagation characteristics for deployment compared to the upper portions, considering that some installations could cover outdoor and indoor environments with some Non-Line-of-Sight (NLoS) situations.

Based on the considerations above, Colombia is of the initial view that the lower portions of the frequency range (from 24.25 GHz to 43.5 GHz) provide good opportunities in terms of availability, technical performance and potential for global harmonization. Colombia would like to invite other members to consider this initial view for consideration and collaboration towards a regional (and possibly global) harmonization of the frequency bands.

Mexico:

Regional harmonization for this item on the agenda should consider similar approaches in terms of allocations and plans for the radio spectrum, in order to favor cost reduction and encourage the development of a sustainable ecosystem for the deployment of IMT systems.

A public survey is currently being prepared in Mexico to identify the IMT spectrum requirements from 24.25 GHz to 86 GHz. To this end, we plan to study the discussions and documents issued by the different working groups of both the International Telecommunication Union (ITU) and CITEL regarding regional and global spectral requirements for IMT at the frequencies of 24.25 to 86 GHz.

For this reason, we deem it necessary to conduct, in the best terms possible, the planned studies on sharing and compatibility in the bands agreed on through Resolution 238 (WRC-15), i.e., the segments of 24.25-27.5 GHz, 31.8-33.4 GHz, 37-43.5 GHz, 45.5-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, in order for the CITEL administrations to make better, more fully-grounded decisions to achieve regional or global harmonization for the future development of IMT-2020 systems.

RCC (November 2018)

The RCC Administrations consider that when developing technical conditions and regulatory provisions for the allocation of frequency bands to the MS and their identification for IMT it is necessary to ensure protection of other services having allocation in the considered and adjacent frequency bands taking into account the need in their development, first of all for existing systems or those planned to be used by RCC Administrations.

The RCC Administrations do not oppose the allocation of the frequency band 24.25-25.25GHz to mobile, excluding aeronautical mobile, service on a primary global basis, as well as the identification of the frequency band 24.25-27.5GHz for IMT, subject to incorporating the conditions in the Radio Regulations for IMT stations to protect:

space stations in the Earth exploration-satellite service (EESS)(passive) in the frequency bands 23.6-24GHz, 50.2-50.4GHz and 52.6-54.25GHz from unwanted emissions of IMT stations;

space stations in the fixed-satellite service and inter-satellite service.

The RCC Administrations consider that to ensure this protection it is necessary to limit the emission from IMT base stations in upper hemisphere, as well as to limit unwanted emissions of IMT base and subscriber stations in frequency bands 23.6−24.0GHz, 50.2−50.4GHz and 52.6−54.25GHz allocated to EESS (passive).

The RCC Administrations do not support allocation of the frequency band 31.8-33.4GHz to mobile service on a primary basis and identification of the frequency bands 31.8-33.4GHz and 42.5-43.5GHz, 71−76GHz and 81−86GHz, as the results of ITU-R studies in these bands have concluded that IMT systems are incompatible with the stations of the incumbent services.

The RCC Administrations do not support the identification of the frequency bands 45.5−47.0GHz and 66−71GHz for IMT systems until the compatibility studies with existing primary radio services in ITU-R are completed.

Position of the RCC Administrations on frequency bands 37.0−40.5GHz, 40.5−42.5GHz, 47.0−50.2GHz and 50.4−52.6GHz included in Resolution 238(WRC-15), is specified taking into account the need to protect both passive and active services.

The RCC Administrations oppose the consideration of frequency bands not specified in Resolution 238(WRC-19) for IMT systems in this WRC-19 agenda item.

## International organisations

IARU (27th June 2017)

The IARU is of the view that the spectrum requirements identified for IMT in the frequency range between 24.25 GHz and 86 GHz can be fully met in the frequency bands that are already allocated to the mobile service on a primary basis, and do not justify the allocation of 47.0-47.2 GHz to the mobile service. This narrow primary allocation to the amateur service is the only spectrum in which amateur experimentation with millimeter wavelengths can be conducted without practical constraints imposed by sharing with other services. Therefore, the IARU opposes additional allocations in this band to other services, including the mobile service. If either or both of the bands that are adjacent to 47.0-47.2 GHz are identified for the terrestrial component of IMT, suitable emission limits must be included in order to ensure the protection of existing and future amateur and amateur-satellite stations in the 47.0-47.2 GHz band. IARU is further of the view that any allocation to IMT in the frequency range 24.25-27.5 GHz shall include full consideration and protection for the amateur and amateur-satellite service’s primary allocation at 24-24.05 GHz.

IATA (date of proposal)

[placeholder]

ICAO (16/09/2017)

Document PTC(16)INFO003 provides the following draft position of ICAO:

The frequency band 24.25-24.65 GHz is used for airport surface detection equipment (ASDE) in some countries. Additionally, the frequency range 31.8-33.4 GHz is identified in the “Handbook on Radio Frequency Spectrum Requirements for Civil Aviation”[[5]](#footnote-5) as also being used for ASDE. The higher frequency ranges give greater resolution; a factor that is gaining greater importance with the ever increasing density of traffic at airports.

The 31.8-33.4 GHz frequency range is also used for embedded systems that generate navigation information and a video image of the external scene and provide them to the pilot. The band offers a good compromise between resolution and atmosphere penetration in bad weather conditions.

The frequency range 76-81 GHz is allocated to the radiolocation service on a primary basis in all three ITU Regions and is planned to be used for non safety-critical, advisory applications on the airport surface such as wing-tip radar. According to Resolution 238 (WRC‑15) the frequency range 76-81 GHz is excluded from consideration for IMT, however, any new identification for the terrestrial component of IMT should ensure adjacent band protection of these aviation applications.

Finally, the frequency bands 43.5-47 GHz and 66-71 GHz have allocations to the Radionavigation and/or Radionavigation-Satellite services. However no aeronautical systems have currently been identified as operating in those frequency bands.

ICAO Position:

To oppose any identification of a frequency band for IMT that could impact aviation systems, within a new or existing allocation to the mobile service in the frequency range 24.25 GHz to 86 GHz, unless agreed ITU-R studies demonstrate no adverse impact to those systems.

IMO (date of proposal)

NATO (22nd November 2018)

This is a High Priority WRC AI for NATO, due to the operation of various types of military application across the entire 24.25-86 GHz frequency range. NATO uses of frequencies in this range are as follows:

24.05-24.25 GHz is an important NATO harmonised band used for Radiolocation

25.25-27.5 GHz is an important NATO harmonised band used for Fixed strategic and mobile communications

31.8-33.4 GHz is used for Radionavigation service systems by some NATO nations

33.4-36 GHz is an important NATO harmonised band used by Short-range imagery radars in the radiolocation service

43.5-45.5 GHz is an essential NATO harmonized band paired with 20.2-21.2 GHz used for Satellite up-links in the mobile-satellite (E-s) services

45.5-47.2 GHz is used for Aeronautical mobile applications by some NATO nations

From a military perspective, studies will need to show that sharing of the proposed IMT bands with existing services is possible and that the introduction of IMT in these bands has no harmful impact on military usage in these and adjacent NATO harmonised bands.

NATO Position

NATO recognises the European harmonisation in the band 24.25-27.5 GHz for IMT 5G associated with technical conditions. NATO acknowledges the proposed IMT identification in this band, noting that NATO may continue to use the band for military purposes.

NATO supports NOC in the following frequency bands:

- 31.8-33.4 GHz

- 71-76 GHz

- 81-86 GHz.

NATO is monitoring further consideration in other frequency bands.

SFCG (08/2018)

SFCG supports the protection of existing space science service allocations. No new allocation/identification of spectrum to support mobile broadband systems (IMT-2020) should be made in or adjacent to bands allocated to space science services unless acceptable criteria and mandatory conditions are developed and implemented that ensure the protection and future usability of the concerned bands by those services. SFCG does not support consideration of any frequency band that is not included in the list of potential candidate bands as identified in Resolution 238 (WRC-15).

With regard to the issue of in-band sharing, a particularly critical situation concerns the band 25.5-27 GHz which constitutes the only frequency bands allocated to EESS and SRS (space –to-Earth) that allows for the downlink of the large data volume required by many current and future EESS and SRS satellite missions. As recognized in Resolution 238 (WRC-15) (footnote 2 of resolves 2) for the 25.5-27 GHz band, it is fundamental for SFCG Member Agencies to be assured that EESS and SRS earth stations will continue to be able to expand in the future both in terms of number of satellites serviced and number of earth stations. Licences for these earth stations, which inherently provide protection from interference by IMT-2020 systems, must not be denied or restricted on the basis that such action may limit the IMT-2020 operational areas. Negative licensing experiences in the past with earlier cellular mobile systems in the band 2110-2120 MHz must not be repeated.

Internationally agreed mandatory mechanisms and criteria should therefore be identified to ensure the future availability of these earth station licences. It is necessary to ensure that the IMT-2020 systems will be deployed only in urban and suburban areas, as is assumed in all of the compatibility studies and as stated by WP 5D. Further, protection of earth stations needs to be codified in the Radio Regulations to ensure consistency across administrations; protection of earth stations should not be considered as strictly a domestic issue.

Protection of the various EESS (passive) bands adjacent to bands studied under this Agenda Item (23.6-24 GHz, 31.3-31.8 GHz, 36-37 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz and 86-92 GHz) has to be ensured. For this appropriate mandatory unwanted emission limits for IMT-2020 devices have to be established. For some of these bands RR No.5.340 applies.

All studies presented in ITU-R confirm that only a drastic reduction in IMT-2020 unwanted emissions provided by WP 5D (in particular in the band 23.6-24 GHz) can ensure protection of EESS (passive). The SFCG is concerned that the current operational specifications for IMT-2020 indicate that the IMT-2020 systems will be unable to comply with the unwanted emission levels determined in the studies. The SFCG is of the view that an IMT allocation/identification should not be made unless the proponents of IMT-2020 clearly demonstrate the ability to comply with the needed unwanted emission limits to ensure the protection of the EESS (passive). Relevant unwanted emission limits will have to be implemented in the Radio Regulations by inclusion in Table 1 of Resolution 750 (Rev.WRC-15).

Other specific concerns of SFCG are:

Protection of the 25.25-27.5 GHz band allocated to inter-satellite service (ISS) on primary basis, used for data relay satellite return links;

Protection of the 31.8-32.3 GHz band allocated to SRS deep space (s-E) on primary basis, used for transmitting data to the Earth from distant locations in space;

Protection of the 37-38 GHz band allocated to SRS (space-to-Earth), and the 40-40.5 GHz band allocated to EESS/SRS (Earth-to-space).

Frequency overlaps with other WRC-19 AI’s (1.6 and 1.14) need to be taken into account.

WMO and EUMETNET (8th June 2018)

WMO does not oppose new IMT2020 identification/allocations provided that protection of EESS (Earth-to-space and space-to-Earth) and EESS (passive) is ensured.

WMO requests that the long-term usage and future deployment of receiving EESS Earth stations (in particular in the 25.5-27 GHz band) should not be constrained by the IMT2020 usage. WMO supports establishment of a methodology for administrations to use for the definition of the required separation distance between IMT2020 and EESS stations.

WMO also requests that the necessary IMT2020 unwanted emission limits be established to ensure the protection of all current and future EESS (passive) sensors and included in table 1 of Resolution 750 (rev. WRC-15).

Furthermore, WMO would appreciate the development of a solution to ensure the continued operation of the ground-based radiometers in the 24.25-27.5 GHz and 50.4-51.4 GHz frequency bands.

## Regional organisations

ESA

See SFCG

EUMETSAT (September 2017)

EUMETSAT operates a number of passive microwave sensors in adjacent or nearby bands (mostly covered by the RR footnote 5.340) considered under Agenda Item 1.13 which could suffer from harmful interference caused by unwanted emissions of 5G (IMT-2020) deployments. These passive microwave sensors are indispensable for observations of weather and climate from space, requiring access to uncontaminated frequency bands that each provides essential information on specific phenomenology. This is because passive microwave sensors use specific frequencies that uniquely correspond to resonances of important atmospheric molecules and cannot be changed, as they are fixed by nature. These frequency bands need to be free of radio interference to ensure the usefulness and correctness of the measurements which is acknowledged through RR FN 5.340. Thus, it is of outmost importance to limit 5G systems unwanted emissions into the passive sensing frequency bands (namely 23.6-24 GHz, 31.3-31.8 GHz, 36-37 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz and 86-92 GHz bands) o the extent required to protect these measurements.

Furthermore, meteorological and Earth exploration satellite systems currently in operation or under development have to rely on the availability of the EESS frequency allocation in the band 25.5-27 GHz (26 GHz band) for ensuring that dedicated Earth stations are able to acquire the measurement data. This is also the case for the next generation geostationary and non-geostationary MetSat systems of EUMETSAT, namely MTG and EPS-SG. To ensure that Earth stations are able to be deployed and protected in the presence of potential 5G deployments in this frequency band, appropriate regulatory conditions need to be agreed at WRC-19, and further-on established in national/regional authorisation processes for 5G networks.

Eurocontrol (November 2018)

To oppose any identification of a frequency band for IMT that could impact aviation systems, including enhanced flight vision systems (EFVS) operating in the 31.8-33.4 GHz band, within a new or existing allocation to the mobile service in the frequency range 24.25 to 86 GHz, unless agreed ITU-R studies demonstrate no adverse impact to those systems.

## OTHER INTERNATIONAL AND REGIONAL ORGANISATIONS

EBU (9th March 2017)

5G developments are still ongoing and there are many issues that will need to be addressed, including technical, market-related and regulatory. Nevertheless the large scale delivery of audio-visual content is considered to be one of the key 5G applications to be included in next IMT-2000 standards.

We believe that the performance targets proposed for IMT-2020, in particular the very high throughput, can only be achieved if the system has access to a large amount of radio spectrum and uses large contiguous bandwidth (e.g. 100 MHz or more per channel), which can only be found in the higher frequency ranges. The WRC-19 discussions point towards bands in the range 24.25-86 GHz. EBU supports that considerations of bands above 6 GHz for IMT-2020 shall be limited to the bands identified by WRC-15 in order to strengthen the opportunities for global harmonisation.

GSMA (12th September 2018)

WRC-19 Agenda Item 1.13 should be seen in the wider context of ‘5G spectrum’. The success of 5G will be dependent on availability of significant new widely harmonised mobile spectrum to ensure that 5G services can meet future expectations and deliver the full range of potential capabilities. Spectrum for 5G will be needed within three key frequency ranges in order to deliver widespread coverage and support all foreseen use cases, namely sub-1 GHz, 1-6 GHz and above 6 GHz. A successful outcome from WRC-19 will be vital to realise the 5G vision with low cost devices, higher reliability and very high capacity where there is high density of usage.

The GSMA supports the following frequency bands/ranges from within those listed in Resolution 238 to be identified for IMT on a global basis at WRC-19:

* 24.25-27.5 GHz – however unwanted emissions limits in the ECC Decision for this band will make the lower portion unusable for outdoor 5G networks and have significant negative impact on performance of 5G in other parts of the band, and other technical conditions that have been proposed to restrict emissions from IMT base stations will severely constrain the ability of licensees to build effective 5G networks.
* 37-43.5 GHz – Identifying the whole of this frequency range for IMT at WRC-19 will allow different countries/regions to select suitable portions to be used for 5G in their parts of the world, whilst enabling harmonisation and economies of scale.
* 66-71 GHz – and furthermore we believe that other bands above 45 GHz, in particular around 45/50 GHz, should also continue to be considered.

GSA (19th April 2017)

Some of the 5G/IMT-2020 requirements will be met by frequency bands below 6 GHz, whereas frequency bands considered under AI 1.13 would allow to meet some specific 5G requirements, such as provision of very high data rates in hot spot areas.

For AI 1.13, GSA supports the initial focus of the CEPT studies on the 24.25-27.5 GHz “pioneer band”. Identification of this band for IMT would give a significant amount of spectrum for meeting specific 5G requirements. This would also allow Europe to benefit from economies of scale due to the possibility for equipment to support a continuous “tuning range” covering the spectrum above 27.5 GHz that will be used for early 5G deployments including in the US, Korea and Japan.

In addition to the European pioneer band 24.25-27.5 GHz, GSA is of the view that the 40.5-43.5 GHz band is also an important band for CEPT studies under AI 1.13. GSA supports the position of RSPG that ”shift of use from other bands to this 40.5-43.5GHz band should be avoided as far as possible in order to keep the option open to make it available for 5G in the future”.

GSA further supports studies of the all other frequency bands listed under Agenda Item 1.13. Prioritization of those bands is for further discussion.

Finally, GSA emphasizes that spectrum harmonization remains important for the success of 5G, and even more important for higher frequencies in order to support the development of a new 5G ecosystem. It is also of paramount importance that in order to avoid undue limitations on the IMT usage, the sharing and compatibility studies should be based on realistic parameters, deployment scenarios and assumptions.

DIGITALEUROPE (19th April 2017)

Spectrum for 5G/IMT-2020 will require harmonized mobile spectrum in various frequency ranges below and above 6 GHz to ensure that 5G services will meet the full range of capabilities.

For AI 1.13 DIGITALEUROPE supports studies for all bands listed in Resolution 238 (WRC-15).

DIGITALEUROPE supports the initial priority of the CEPT studies on the 24.25-27.5 GHz “pioneer band”. Identification of this band for IMT would give a significant amount of spectrum for meeting early 5G requirements. This would also allow Europe to benefit from economies of scale due to the possibility for equipment to support a harmonized and continuous “tuning range” through association with the spectrum above 27.5 GHz that will be used for early 5G deployments including in the US, Korea and Japan.

DIGITALEUROPE sees also advantages for the band 40.5-43.5 GHz, such as availability of a broad spectrum range, potentially fewer constraints on the mobile use due to the lower degree of utilization by the current incumbent users and a potential for global harmonization by association with the band 37-40.5 GHz.

Finally, DIGITALEUROPE emphasizes that spectrum harmonization remains important for the success of 5G, and even more important for higher frequencies in order to support the development of a new 5G ecosystem. It is also of paramount importance that in order to avoid undue limitations on the IMT usage, the sharing and compatibility studies should be based on realistic parameters, deployment scenarios and assumptions. Digital Europe supports the content of the deliverables provided by ITU-R SG3 and WP5D to ITU-R TG5/1.

31st August 2017

DIGITALEUROPE is of the view that 26 GHz spectrum should be licensed and in particular, licence-exempt use in the 26 GHz could be ruled out in the ongoing ECC PT1 studies on sharing and compatibility.

CRAF (20th November 2018)

CRAF supports the protection of existing RAS frequency allocations at 23.6-24.0 GHz, 31.3-31.5 GHz, 42.5-43.5 GHz and 76-86 GHz from future IMT operations. Careful coordination by national administrations especially in case of in-band sharing and adjacent band compatibility scenarios is necessary for each individual RAS station. CRAF supports national regulations on 5G operations such as individual licensing and avoidance of deployment in rural areas in the vicinity of a RAS station. Since user equipment will not be subject to individual licensing, CRAF opposes these devices operating in a shared-band situation (42.5-43.5 GHz). CRAF also opposes the use of mesh networks connecting 5G devices in the vicinity of RAS stations. In order to assist the administrations with coordination between IMT 5G and the RAS, CRAF supports the development of ITU-R Recommendations or Reports, as appropriate.

Wi-Fi Alliance® (4th July 2018)

Wi-Fi Alliance® believes an IMT Identification associated with the 66-71 GHz band is completely unnecessary and potentially damaging to innovation, competition, and consumers.

It is vital to understand that the Wi-Fi Alliance® is not opposed to the 66-71 GHz band, or adjacent bands, being used for 5G deployments but in this context we believe that 5G is more than the technologies likely to be included under the IMT label.

Wi-Fi Alliance® notes the 66-71 GHz band already has a co-primary MOBILE allocation.

In Europe, the Radio Spectrum Policy Group of the European Union (RSPG), in their Second Opinion on 5G networks[[6]](#footnote-6) stated:

“10. The RSPG is of the opinion that general authorised frequency use can be an important breeding ground for innovation and contributes towards a dynamic market environment. The application of a general authorisation regime is foreseen in the 66-71 GHz band which could be an important band for 5G.“

Noting the above extract from Radio Spectrum Policy Group in their Second Opinion on 5G networks, the Wi-Fi Alliance® is aware that the RSPG are now recommending in their (DRAFT) RSPG Opinion on the ITU-R World Radiocommunication Conference 2019[[7]](#footnote-7) “that the European Commission propose an EU position to the Council, conditional to the results of studies, support further the identification of the band 40.5 - 43.5 GHz and 66 - 71 GHz for IMT on a global basis”. The Wi-Fi Alliance® will of course be submitting a response to the RSPG WRC-19 consultation but in this paper wanted to highlight the inconsistency with the RSPG stating the 66-71 “could be an important band for 5G” and then limiting it to “IMT on a global basis”; 5G is more than IMT.

Furthermore in support of a global IMT identification in the 66-71 GHz band the RSPG state “conditional to the results of studies”; there have been zero sharing studies submitted addressing IMT and Multiple Gigabit Wireless Systems (MGWS) either co-channel or for adjacent channel. This can be explained by the fact that many countries have already identified th2 66-71 GHz band and adjacent bands for implementation of licence-exempt 5G MGWS (e.g. WiGig). The importance of the 66-71 GHz band for MGWS is explained below.

ITU-R confirms implementation of Multiple Gigabit Wireless Systems (MGWS) systems in this frequency band as detailed in Recommendation ITU-R M.2003-2 (01/2018)[[8]](#footnote-8) “Multiple Gigabit Wireless Systems in frequencies around 60 GHz” and draft revision of Report ITU-R M.2227-1[[9]](#footnote-9) “Multiple Gigabit Wireless Systems in frequencies around 60 GHz”. Recommendation ITU-R M.2003-2 (01/2018) “recommends” states “that the MGWS standards and their system characteristics contained in Annex 1 should be used”; and extract from Annex 1 is provided highlighting the contiguous spectrum requirements.

A minimum of 7 GHz contiguous spectrum in the 57-71 GHz is needed to satisfy the requirements of the applications envisioned to be used in this spectrum, such as uncompressed video (e.g. high definition multimedia interface (HDMI) at 3 Gbit/s), wireless docking, wireless networking, and rapid download/upload. This would allow up to six channels for flexibility and improved connectivity. Furthermore, for single channels, a channel bandwidth of 2 160 MHz allows simpler modulation schemes to achieve multi-Gbit/s data rates, which is suitable for adoption by low power devices such as smartphones, tablets, netbook and notebook PCs. If single channels are bonded to achieve greater capacity, the bandwidth is defined as an integer multiple of 2 160 MHz to enable coexistence with 2 160 MHz systems.

Also, in the United States, the FCC[[10]](#footnote-10) has decided to maintain the unlicensed use of the 64-71 GHz band and even to expand these operations on to aircraft in flight.

It is important to recognize the nascent state of 5G ecosystem in the 60-70 GHz frequency range. Multi-gigabit devices are just beginning to be introduced into the market. Growing demand has been driving technological developments towards much higher throughputs (20 Gbps and higher) which can be attained only with corresponding spectrum capacity. It is difficult to predict, prior to WRC-19, how technologies, spectrum needs, market demands and other factors will evolve in this frequency range.

The Wi-Fi Alliance® believes that an international-treaty level regulatory action on the 66-71 GHz band at WRC-19 under agenda item 1.13 potentially limiting the band to IMT would be premature and counterproductive. The Wi-Fi Alliance® does not accept that additional caveats related to an IMT identification also allowing non-IMT technologies would be sufficient, acceptable in the spirit of technology neutrality, or indeed transparent and fair!

Identifying 66-71 GHz for IMT would do little to achieve international harmonization noting the 66-71 GHz band already has a co-primary MOBILE allocation. Instead, such action would create regulatory uncertainty which, in turn, would be highly disruptive to existing operations and discourage ongoing research and development of other types of 5G Multiple Gigabit Wireless Systems (e.g. WiGig).

1. Including studies with respect to services in adjacent bands, as appropriate. [↑](#footnote-ref-1)
2. When conducting studies in the band 24.5-27.5 GHz, to take into account the need to ensure the protection of existing earth stations and the deployment of future receiving earth stations under the EESS (space-to-Earth) and SRS (space-to-Earth) allocation in the frequency band 25.5-27 GHz. [↑](#footnote-ref-2)
3. i.e. excluding Annex B from Doc ITU-R TG5/1 Document 5-1/36 Attachment 1: Information on spectrum needs in some countries [↑](#footnote-ref-3)
4. These deployment environments are based on information available on how IMT-2020 is expected to be deployed in bands 24.25-86 GHz and should not be used to limit any IMT-2020 deployments in the future. [↑](#footnote-ref-4)
5. Doc 9718, AN/957, Volume I, ICAO spectrum strategy, policy statements and related information, First Edition, 2014 [↑](#footnote-ref-5)
6. [RSPG Second Opinion on 5G Networks](https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/RSPG18-005final-2nd_opinion_on_5G.pdf) [↑](#footnote-ref-6)
7. [RSPG Final Opinion WRC19 for public consultation](https://circabc.europa.eu/sd/a/7ab8a6bb-f59a-434f-9b66-606b5a8067ce/RSPG18-023final-Opinion_WRC19-for_public_consultation.pdf) [↑](#footnote-ref-7)
8. [ITU-R REC-M.2003-2](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2003-2-201801-I%21%21MSW-E.docx) [↑](#footnote-ref-8)
9. [Draft revision of Report ITU-R M.2227-1](https://www.itu.int/dms_ties/itu-r/md/15/sg05/c/R15-SG05-C-0066%21%21MSW-E.docx) [↑](#footnote-ref-9)
10. [FCC use-of-spectrum-bands-above-24-ghz-for-mobile-radio-services](https://www.federalregister.gov/documents/2018/01/02/2017-27437/use-of-spectrum-bands-above-24-ghz-for-mobile-radio-services) [↑](#footnote-ref-10)