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| **Radiocommunication Study Groups** |  |
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| **18 August 2020** |
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| Annex 11 to the Working Party 5B Chairman’s Report | |
| working document towards a preliminary draft new  reporT ITU-R M.[UA\_GRound\_DAA] | |
| Guidance on suitable frequency bands and services to be used by unmanned aircraft ground based detect-and-avoid non-cooperative systems | |

(201X)

Scope

Unmanned aircraft (UA) applications have been expanding throughout the world and will continue to increase the numbers of UA worldwide. With integration of UA into airspace, it is essential that spectrum to support UA ground based detect and avoid (DAA)[[1]](#footnote-1) systems be clearly identified. This Report provides guidance as to which frequency bands are suitable for UA ground based DAA systems.

Guidance for DAA installed onboard unmanned aircraft are not included in this ITU-R Report but can be found in ITU-R Report M.[UA-AIRBORNE-DAA][[2]](#footnote-2).

*[Editor’s note: The intent of establishing this new Reports is to replace the current Report ITU-R M.2204 in association with ITU-R Report M.[UA-AIRBORNE-DAA] on UA airborne detect and avoid.]*

Keywords

Unmanned Aircraft

List of Abbreviations/Glossary

ADS-B Automatic dependent surveillance-broadcast

ATC Air traffic control

CNPC Control and non-payload communications

DAA Detect and Avoid

ICAO International Civil Aviation Organization

NMAC Near mid-air collision

TCAS Traffic collision avoidance system

UA Unmanned aircraft

UACS Unmanned aircraft control station

UAS Unmanned aircraft system

Related ITU-R Recommendations and Reports

[ITU-R M.2204](http://www.itu.int/rec/R-REC-M.2007/en): Characteristics and spectrum considerations for sense and avoid systems use on unmanned aircraft systems

*[TBC]*

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# 1 Background

Unmanned aircraft are powered aircraft that do not carry a human pilot, use aerodynamic forces to provide vehicle lift, and employ a remote pilot, fly semi-autonomously, or autonomously. The current state-of-the-art in unmanned aircraft system (UAS) design and operation has led to the rapid development of UAS applications to fill many diverse requirements. UAS applications include agricultural applications, communications relays, aerial photography, mapping, emergency management, scientific research, environmental monitoring, hurricane tracking, cloud seeding, volcano monitoring, forest fire suppression, emergency management, search and rescue operations, and law enforcement applications. The safe operation of UAS in civil airspace requires addressing the same issues as manned aircraft, namely integration into the air traffic control (ATC) system. Because the pilot is no longer aboard, a method of replacing the pilot’s responsibility to “see and avoid” other aircraft is required (see International Civil Aviation Organization’s (ICAO’s) Annex 2 “Rules of the Air”). While existing aircraft systems have been adapted or modified to accommodate detect and avoid (DAA) requirements for cooperative targets, new electronic technologies are needed to address the DAA requirements for non-cooperative targets.

## 2 Terminology/Definitions

**Control and non-payload communications (CNPC)**: The radio links, used to exchange information between the UA and UACS, that ensure safe, reliable, and effective UA flight operation. The functions of CNPC can be related to different types of information such as: telecommand messages, non-payload telemetry data, support for navigation aids, air traffic control voice relay, air traffic services data relay, target track data, airborne weather radar downlink data, non-payload video downlink data.

**Detect and avoid (DAA)**: The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action

**Intruder**: An aircraft (manned or unmanned) that enters the DAA surveillance volume and tracked by the DAA system.

*[Chairman’s note: can we find a term other than “Intruder” that has little less military implication*

**Unmanned aircraft (UA)**: Designates all types of aircraft remotely controlled.

**Unmanned aircraft control station (UACS)**:Facilities from which a UA is controlled remotely.

**Unmanned aircraft systems (UAS)**: Consists of the following subsystems:

– UA (i.e. the aircraft itself);

– UACS;

– CNPC;

– ATC communications subsystem (not necessarily relayed through the UA);

– DAA;

– Payload subsystem (e.g. Video camera …).

[*Editor’s note: the following sections will need to be reviewed*

## 2.1 Airspace

For the purposes of this report, the airspace may be grouped into three categories, namely:

– ATC Separation Assurance Airspace – Air traffic control is responsible for safe separation of all aircraft. This comprises Classes A, B, and, if the UAS is operated in accordance with instrument flight rules, Class C airspace.

– Limited or no ATC Separation Assurance Airspace – Air traffic control is not responsible for safe separation of all airspace users. This comprises Classes D, E, F and G airspace.

– Segregated Airspace – A defined volume of airspace is reserved for exclusive use of a particular UAS. In such airspace there would be no air traffic control service and therefore ATC is not responsible for separation but there are one or more aircraft, under the control of the same operator, in this airspace at a given time.]

## 2.2 Categories

In this report, the operations of UAS are classified in three main categories:

• the '**open**’ category is a category of UAS operation that, considering the risks involved, does not require a prior authorisation by the competent authority nor a declaration by the UAS operator before the operation takes place;

• the ‘**specific**’ category is a category of UAS operation that, considering the risks involved, requires an authorisation by the competent authority before the operation takes place, taking into account the mitigation measures identified in an operational risk assessment, except for certain standard scenarios where a declaration by the operator is sufficient or when the operator holds a light UAS operator certificate with the appropriate privileges;

• the ‘**certified**’ category is a category of UA operation that, considering the risks involved, requires the certification of the UAS, a licensed remote pilot and an operator approved by the competent authority, in order to ensure an appropriate level of safety.

]

# 3 Scenarios

[TBD?

Non-cooperative

Categories from EASA]

# 4 Description of principles for ground based detect and avoid

[TBD]

# 5 Spectrum analysis on suitability for ground based detect and avoid system for unmanned aircraft

[TBD]

## 5.1 Criteria for suitability of spectrum for detect and avoid systems

[TBD]

## 5.2 Analysis of the suitability of frequency bands

[TBD]

*[Editor's note: The following sections contain applicable provisions from the Radio Regulations, including allocations and relevant footnotes, and are provided as a baseline to facilitate the determination of the suitability of spectrum for DAA operations. The suitability of frequency bands will take into account co-existence with other services/systems operating in that band.]*

### 5.2.1 Frequency band 960-1 215 MHz

#### 5.2.1.1 Allocations to operate detect and avoid and other services in the frequency band 960‑1 215 MHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 960-1 164 AERONAUTICAL MOBILE (R) 5.327A  AERONAUTICAL RADIONAVIGATION 5.328  5.328AA | | |
| 1 164-1 215 AERONAUTICAL RADIONAVIGATION 5.328  RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B  5.328A | | |

**5.327A** The use of the frequency band 960-1 164 MHz by the aeronautical mobile (R) service is limited to systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **417 (Rev.WRC-15)**. (WRC-15)

5.328 The use of the band 960-1 215 MHz by the aeronautical radionavigation service is reserved on a worldwide basis for the operation and development of airborne electronic aids to air navigation and any directly associated ground-based facilities.     (WRC 2000)

5.328AA The frequency band 1 087.7-1 092.3 MHz is also allocated to the aeronautical mobile-satellite (R) service (Earth‑to‑space) on a primary basis, limited to the space station reception of Automatic Dependent Surveillance-Broadcast (ADS‑B) emissions from aircraft transmitters that operate in accordance with recognized international aeronautical standards. Stations operating in the aeronautical mobile-satellite (R) service shall not claim protection from stations operating in the aeronautical radionavigation service. Resolution **425** **(WRC‑15)** shall apply.     (WRC‑15)

#### 5.2.1.2 Related ITU-R documents and aviation documents in the frequency band 960-1 215 MHz

Recommendations ITU-R M.1318, ITU-R M.1787, ITU-R M.1901, ITU-R M.1904, ITU-R M.1905, and ITU-R M.2030 apply to the radionavigation-satellite service (RNSS) in the band 1 164-1 215 MHz. Resolution 417 (Rev.WRC-15) also contains provisions for the protection of RNSS in the 1 164-1 215 MHz band from AM(R)S airborne and ground-based stations in the frequency band 960-1 164 MHz.

*[Editor’s Note: Additional work on this section is needed]*

#### 5.2.1.3 Suitability of the frequency band 960-1 215 MHz for ground based detect and avoid systems

No restriction in the RR.

The frequency band 960-1 215 MHz is operated by various aeronautical systems including DME, TACAN, TCAS, ADS-B, Multilateration, and non-ICAO (e.g. Recommendation ITU-R M.2013) systems. The 1 164-1 215 MHz portion of the band is also used for RNSS (space-to-Earth) and (space-to-space) services on a ubiquitous basis, including on aircraft, and this use presents additional co-existence issues.

This frequency band 960-1 215 MHz is not suitable for ground based DAA systems.

### 5.2.2. Frequency band 1 215-1 300 MHz

#### 5.2.2.1 Allocation to operate detect and avoid and other services in the frequency band 1 215-1 300 MHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 1 215-1 240 EARTH EXPLORATION-SATELLITE (active)  RADIOLOCATION  RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A  SPACE RESEARCH (active)  5.330 5.331 5.332 | | |
| 1 240-1 300 EARTH EXPLORATION-SATELLITE (active)  RADIOLOCATION  RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A  SPACE RESEARCH (active)  Amateur  5.282 5.330 5.331 5.332 5.335 5.335A | | |

**5.329** Use of the radionavigation-satellite service in the band 1 215-1 300 MHz shall be subject to the condition that no harmful interference is caused to, and no protection is claimed from, the radionavigation service authorized under No. **5.331**. Furthermore, the use of the radionavigation-satellite service in the band 1 215-1 300 MHz shall be subject to the condition that no harmful interference is caused to the radiolocation service. No. **5.43** shall not apply in respect of the radiolocation service. Resolution **608 (WRC-03)\*** shall apply.     (WRC‑03)

**5.329A** Use of systems in the radionavigation-satellite service (space-to-space) operating in the bands 1 215-1 300 MHz and 1 559-1 610 MHz is not intended to provide safety service applications, and shall not impose any additional constraints on radionavigation-satellite service (space-to-Earth) systems or on other services operating in accordance with the Table of Frequency Allocations.     (WRC‑07)

**5.330** *Additional allocation:* in Angola, Saudi Arabia, Bahrain, Bangladesh, Cameroon, China, Djibouti, Egypt, the United Arab Emirates, Eritrea, Ethiopia, Guyana, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Nepal, Oman, Pakistan, the Philippines, Qatar, the Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the band 1 215-1 300 MHz is also allocated to the fixed and mobile services on a primary basis.     (WRC‑12)

**5.331** *Additional allocation:* in Algeria, Germany, Saudi Arabia, Australia, Austria, Bahrain, Belarus, Belgium, Benin, Bosnia and Herzegovina, Brazil, Burkina Faso, Burundi, Cameroon, China, Korea (Rep. of), Croatia, Denmark, Egypt, the United Arab Emirates, Estonia, the Russian Federation, Finland, France, Ghana, Greece, Guinea, Equatorial Guinea, Hungary, India, Indonesia, Iran (Islamic Republic of), Iraq, Ireland, Israel, Jordan, Kenya, Kuwait, The Former Yugoslav Republic of Macedonia, Lesotho, Latvia, Lebanon, Liechtenstein, Lithuania, Luxembourg, Madagascar, Mali, Mauritania, Montenegro, Nigeria, Norway, Oman, Pakistan, the Netherlands, Poland, Portugal, Qatar, the Syrian Arab Republic, Dem. People’s Rep. of Korea, Slovakia, the United Kingdom, Serbia, Slovenia, Somalia, Sudan, South Sudan, Sri Lanka, South Africa, Sweden, Switzerland, Thailand, Togo, Turkey, Venezuela and Viet Nam, the band 1 215-1 300 MHz is also allocated to the radionavigation service on a primary basis. In Canada and the United States, the band 1 240-1 300 MHz is also allocated to the radionavigation service, and use of the radionavigation service shall be limited to the aeronautical radionavigation service.     (WRC‑12)

**5.332** In the band 1 215**-**1 260 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause harmful interference to, claim protection from, or otherwise impose constraints on operation or development of the radiolocation service, the radionavigation-satellite service and other services allocated on a primary basis.     (WRC‑2000)

**5.335** In Canada and the United States in the band 1 240-1 300 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause interference to, claim protection from, or otherwise impose constraints on operation or development of the aeronautical radionavigation service.     (WRC‑97)

**5.335A** In the band 1 260-1 300 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause harmful interference to, claim protection from, or otherwise impose constraints on operation or development of the radiolocation service and other services allocated by footnotes on a primary basis.     (WRC‑2000)

#### 5.2.2.2 Related ITU-R documents and aviation documents in the frequency band 1 215-1 300 MHz

Recommendation ITU-R M.1463 contains characteristics and protection criteria for radar systems operating in the aeronautical radionavigation and radiolocation services in the band 1 215-1 400 MHz.

Recommendations ITU-R M.1318, ITU-R M.1787, ITU-R M1901, ITU-R M.1902, ITU-R M.1904, and ITU-R M.2030 apply to the radionavigation-satellite services in the band 1 215-1 300 MHz.

Recommendations ITU-R RS.577, ITU-R RS.1166, and ITU-R RS.2105 apply to the Earth exploration-satellite (active) and space research (active) services in the band 1 215-1 300 MHz.

[Editor’s Note: Additional work on this section is needed]

#### 5.2.2.3 Suitability of the band 1 215-1 300 MHz for ground based detect & avoid systems

Many aviation and non-aviation radars already operate in the frequency band 1 215-1 300 MHz as do many RNSS (space-to-Earth) receivers, and RNSS (space-to-space) receivers. The frequency band 1 215-1 300 MHz may be suitable to support ground based DAA systems in administrations and in frequency bands where No. **5.331** applies if coordination with existing radar systems can be achieved. In addition, DAA systems should take all practicable measures to ensure compatibility to RNSS receivers operating in the frequency band 1 215-1 300 MHz and the adjacent 1 164-1 215 MHz and 1 300-1 350 MHz frequency bands. Since RNSS (space-to-Earth) receivers operate on a ubiquitous basis, including onboard aircraft, and are potentially co-located with ground based DAA systems, there could also be practical compatibility issues associated with the operation of DAA systems in the frequency band 1 215-1 300 MHz.

### 5.2.3 Frequency band 1 300-1 350 MHz

#### 5.2.3.1 Allocation to operate detect and avoid and other services in the frequency band 1 300-1 350 MHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 1 300-1 350 RADIOLOCATION  AERONAUTICAL RADIONAVIGATION 5.337  RADIONAVIGATION-SATELLITE (Earth-to-space)  5.149 5.337A | | |

5.337 The use of the bands 1 300-1 350 MHz, 2 700-2 900 MHz and 9 000-9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

5.337A The use of the band 1 300-1 350 MHz by earth stations in the radionavigation-satellite service and by stations in the radiolocation service shall not cause harmful interference to, nor constrain the operation and development of, the aeronautical-radionavigation service.     (WRC‑2000)

#### 5.2.3.2 Related ITU-R documents and aviation documents in the frequency band 1 300-1 350 MHz

Recommendation ITU-R M.1463 contains characteristics and protection criteria for radar systems operating in the aeronautical radionavigation and radiolocation services in the band 1 215-1 400 MHz.

Recommendation ITU-R M.1584 contains a methodology for computing separation distances between earth stations of the radionavigation-satellite service (Earth-to-space) and radars of the radiolocation service and the aeronautical radionavigation service in the frequency band 1 300-1 350 MHz.

#### 5.2.3.3 Suitability of the band 1 300-1 350 MHz for ground based detect & avoid systems

Operation of ground based DAA systems in the frequency band 1 300-1 350 MHz may be suitable, however many aviation and non-aviation radars already operate in this band. It may be possible that the frequency band 1 300-1 350 MHz could be used to support ground based DAA systems if coordination with existing aeronautical radionavigation radar systems can be achieved. In addition, DAA systems should take all practicable measures to minimize interference to radiolocation systems and to ensure compatibility with RNSS receivers operating in the frequency band 1 300-1 350 MHz and RNSS receivers operating in the adjacent 1 215-1 300 MHz frequency band especially given that RNSS receivers can be co-located with ground based DAA systems.

### 5.2.4 Frequency band 1 559-1 626.5 MHz

#### 5.2.4.1 Allocation to operate detect and avoid and other services in the frequency band 1 559-1 626.5 MHz

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **1 559-1 610** AERONAUTICAL RADIONAVIGATION  RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.208B 5.328B 5.329A  5.341 | | |
| **1 610-1 610.6**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION | **1 610-1 610.6**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION  RADIODETERMINATION- SATELLITE (Earth-to-space) | **1 610-1 610.6**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION  Radiodetermination-satellite (Earth-to-space) |
| 5.341 5.355 5.359 5.364  5.366 5.367 5.368 5.369  5.371 5.372 | 5.341 5.364 5.366 5.367  5.368 5.370 5.372 | 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372 |
| **1 610.6-1 613.8**  MOBILE-SATELLITE (Earth-to-space) 5.351A  RADIO ASTRONOMY  AERONAUTICAL RADIONAVIGATION | **1 610.6-1 613.8**  MOBILE-SATELLITE (Earth-to-space) 5.351A  RADIO ASTRONOMY  AERONAUTICAL RADIONAVIGATION  RADIODETERMINATION-SATELLITE (Earth-to-space) | **1 610.6-1 613.8**  MOBILE-SATELLITE (Earth-to-space) 5.351A  RADIO ASTRONOMY  AERONAUTICAL RADIONAVIGATION  Radiodetermination-satellite (Earth-to-space) |
| 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369  5.371 5.372 | 5.149 5.341 5.364 5.366  5.367 5.368 5.370 5.372 | 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369  5.372 |
| **1 613.8-1 626.5**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION  Mobile-satellite (space-to-Earth) 5.208B | **1 613.8-1 626.5**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION  RADIODETERMINATION- SATELLITE (Earth-to-space)  Mobile-satellite (space-to-Earth) 5.208B | **1 613.8-1 626.5**  MOBILE-SATELLITE (Earth-to-space) 5.351A  AERONAUTICAL RADIONAVIGATION  Mobile-satellite (space-to-Earth) 5.208B  Radiodetermination-satellite (Earth-to-space) |
| 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369  5.371 5.372 | 5.341 5.364 5.365 5.366  5.367 5.368 5.370 5.372 | 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369  5.372 |

**5.208B[[3]](#footnote-3)\*** In the frequency bands:

137-138 MHz,

387-390 MHz,

400.15-401 MHz,

1 452-1 492 MHz,

1 525-1 610 MHz,

1 613.8-1 626.5 MHz,

2 655-2 690 MHz,

21.4-22 GHz,

Resolution **739 (Rev.WRC-15)** applies. (WRC-15)

**5.328B** The use of the bands 1 164-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the application of the provisions of Nos. 9.12, 9.12A and 9.13. Resolution 610 (WRC-03) shall also apply; however, in the case of radionavigation-satellite service (space-to-space) networks and systems, Resolution 610 (WRC-03) shall only apply to transmitting space stations. In accordance with No. 5.329A, for systems and networks in the radionavigation-satellite service (space-to-space) in the bands 1 215-1 300 MHz and 1 559-1 610 MHz, the provisions of Nos. 9.7, 9.12, 9.12A and 9.13 shall only apply with respect to other systems and networks in the radionavigation-satellite service (space-to-space).     (WRC‑07)

**5.329A** Use of systems in the radionavigation-satellite service (space-to-space) operating in the bands 1 215-1 300 MHz and 1 559-1 610 MHz is not intended to provide safety service applications, and shall not impose any additional constraints on radionavigation-satellite service (space-to-Earth) systems or on other services operating in accordance with the Table of Frequency Allocations.     (WRC‑07)

**5.351A** For the use of the bands 1 518-1 544 MHz, 1 545-1 559 MHz, 1 610-1 645.5 MHz, 1 646.5-1 660.5 MHz, 1 668-1 675 MHz, 1 980-2 010 MHz, 2 170-2 200 MHz, 2 483.5-2 520 MHz and 2 670-2 690 MHz by the mobile-satellite service, see Resolutions **212 (Rev.WRC-07)[[4]](#footnote-4)\*** and **225 (Rev.WRC-07) [[5]](#footnote-5)\*\***. (WRC-07)

**5.355** *Additional allocation:* in Bahrain, Bangladesh, Congo (Rep. of the), Djibouti, Egypt, Eritrea, Iraq, Israel, Kuwait, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the bands 1 540-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz are also allocated to the fixed service on a secondary basis.    (WRC‑12)

**5.359** *Additional allocation:* in Germany, Saudi Arabia, Armenia, Azerbaijan, Belarus, Benin, Cameroon, the Russian Federation, France, Georgia, Guinea, Guinea-Bissau, Jordan, Kazakhstan, Kuwait, Lithuania, Mauritania, Uganda, Uzbekistan, Pakistan, Poland, the Syrian Arab Republic, Kyrgyzstan, the Dem. People’s Rep. of Korea, Romania, Tajikistan, Tunisia, Turkmenistan and Ukraine, the frequency bands 1 550-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz are also allocated to the fixed service on a primary basis. Administrations are urged to make all practicable efforts to avoid the implementation of new fixed-service stations in these frequency bands.     (WRC‑15)

**5.364** The use of the band 1 610-1 626.5 MHz by the mobile-satellite service (Earth-to-space) and by the radiodetermination-satellite service (Earth-to-space) is subject to coordination under No. **9.11A**. A mobile earth station operating in either of the services in this band shall not produce a peak e.i.r.p. density in excess of −15 dB(W/4 kHz) in the part of the band used by systems operating in accordance with the provisions of No. **5.366** (to which No. **4.10** applies), unless otherwise agreed by the affected administrations. In the part of the band where such systems are not operating, the mean e.i.r.p. density of a mobile earth station shall not exceed –3 dB (W/4 kHz). Stations of the mobile-satellite service shall not claim protection from stations in the aeronautical radionavigation service, stations operating in accordance with the provisions of No. **5.366** and stations in the fixed service operating in accordance with the provisions of No. **5.359**. Administrations responsible for the coordination of mobile-satellite networks shall make all practicable efforts to ensure protection of stations operating in accordance with the provisions of No. **5.366**.

**5.366** The band 1 610-1 626.5 MHz is reserved on a worldwide basis for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities. Such satellite use is subject to agreement obtained under No. **9.21**.

**5.367** *Additional allocation*:  The frequency band 1 610-1 626.5 MHz is also allocated to the aeronautical mobile-satellite (R) service on a primary basis, subject to agreement obtained under No. **9.21**.    (WRC‑12)

**5.368** With respect to the radiodetermination-satellite and mobile-satellite services the provisions of No. **4.10** do not apply in the band 1 610-1 626.5 MHz, with the exception of the aeronautical radionavigation-satellite service.

**5.369** *Different category of service:*in Angola, Australia, China, Eritrea, Ethiopia, India, Iran (Islamic Republic of), Israel, Lebanon, Liberia, Madagascar, Mali, Pakistan, Papua New Guinea, Syrian Arab Republic, the Dem. Rep. of the Congo, Sudan, South Sudan, Togo and Zambia, the allocation of the band 1 610-1 626.5 MHz to the radiodetermination-satellite service (Earth-to-space) is on a primary basis (see No. **5.33**), subject to agreement obtained under No. **9.21** from countries not listed in this provision.    (WRC‑12)

**5.371** *Additional allocation:* in Region 1, the band 1 610-1 626.5 MHz (Earth-to-space) is also allocated to the radiodetermination-satellite service on a secondary basis, subject to agreement obtained under No. **9.21**.     (WRC‑12)

#### 5.2.4.2 Related ITU-R documents and aviation documents in the frequency band 1 559-1 626.5 MHz

Recommendations ITU-R M.1318, ITU-R M.1787, ITU-R M.1901, ITU-R M.1903, ITU-R M.1904, and ITU-R M.2030 apply to the radionavigation-satellite services in the band 1 559-1 610 MHz.

*[Editor’s Note: Additional work on this section is needed]*

#### 5.2.4.3 Suitability of the band 1 559-1 626.5 MHz for ground based detect & avoid

**5.2.4.3.1 1 559-1 610 MHz**

No restriction in the RR.

Noting that the frequency band 1 559-1 610 MHz is used to provide radionavigation-satellite service (RNSS) in the space-to-Earth and space-to-space directions that provide critical position, navigation and timing (PNT) for multiple applications, the frequency band 1 559-1 610 MHz is not suitable for ground based DAA systems.

**5.2.4.3.2 1 610-1 626.5 MHz**

Operation of a ground based DAA systems is not suitable due to the airborne restriction in RR No. **5.366** in the frequency band 1 610-1 626.5 MHz.

### 5.2.5 Frequency band 2 700-3 100 MHz

#### 5.2.5.1 Allocation to operate detect and avoid and other services in the frequency band 2 700-3 100 MHz

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **2 700-2 900** AERONAUTICAL RADIONAVIGATION 5.337  Radiolocation  5.423 5.424 | | |
| **2 900-3 100** RADIOLOCATION 5.424A  RADIONAVIGATION 5.426  5.425 5.427 | | |

**5.337** The use of the bands 1 300-1 350 MHz, 2 700-2 900 MHz and 9 000-9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

**5.423** In the band 2 700-2 900 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the aeronautical radionavigation service.

**5.424** *Additional allocation:*in Canada, the band 2 850-2 900 MHz is also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars.

**5.424A** In the band 2 900-3 100 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the radionavigation service.      (WRC-03)**.**

**5.426** The use of the band 2 900-3 100 MHz by the aeronautical radionavigation service is limited to ground-based radars.

#### 5.2.5.2 Related ITU-R documents and aviation documents in the frequency band 2 700-3 100 MHz

Recommendation ITU-R M.1464 contains characteristics and protection criteria for radar systems operating in the aeronautical radionavigation and radiolocation services in the band 2 700-2 900 MHz. Recommendation ITU-R M.1849 contains the technical and operational aspects of ground based meteorological radars.

#### 5.2.5.3 Suitability of the band 2 700-3 100 MHz for ground based detect & avoid

**5.2.5.3.1 2 700-2 900 MHz**

Operation of ground based DAA systems in the 2 700-2 900 MHz is suitable however, many aviation radars already operate in this band and these radars are typically found at airports. In addition meteorological radars (5.423) are also operated in this band. The 2 700-2 900 MHz frequency band can be used to support ground based DAA systems located beyond major airports.

**5.2.5.3.2 2 900-3 100 MHz**

Operation of ground based DAA systems in the frequency band 2 900-3 100 MHz may be suitable however, compatibility with shipboard maritime radionavigation systems is a significant issue.

This frequency band 2 900-3 100 MHz can be used to support ground bases DAA systems provided operations are compatible with maritime radars that operate in this band.

### 5.2.6 Frequency band 4 200-4 400 MHz

#### 5.2.6.1 Allocations to operate detect and avoid and other services in the frequency band 4 200‑4 400 MHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 4 200-4 400 AERONAUTICAL MOBILE (R) 5.436  AERONAUTICAL RADIONAVIGATION 5.438  5.437 5.439 5.440 | | |

5.436 Use of the frequency band 4 200-4 400 MHz by stations in the aeronautical mobile (R) service is reserved exclusively for wireless avionics intra-communication systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution 424 (WRC-15).     (WRC-15)

5.437 Passive sensing in the Earth exploration-satellite and space research services may be authorized in the frequency band 4 200-4 400 MHz on a secondary basis.     (WRC-15)

5.438 Use of the frequency band 4 200-4 400 MHz by the aeronautical radionavigation service is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground.     (WRC-15)

**5.439** Additional allocation: in Iran (Islamic Republic of), the band 4 200-4 400 MHz is also allocated to the fixed service on a secondary basis.     (WRC-12)

**5.440** The standard frequency and time signal-satellite service may be authorized to use the frequency 4 202 MHz for space-to-Earth transmissions and the frequency 6 427 MHz for Earth-to-space transmissions. Such transmissions shall be confined within the limits of ± 2 MHz of these frequencies, subject to agreement obtained under No. **9.21**.

#### 5.2.6.2 Related ITU-R documents and aviation documents in the frequency band 4 200-4 400 MHz

Recommendation ITU-R M.2059 contains characteristics and protection criteria for radio altimeter systems operating in the aeronautical radionavigation service in the band 4 200-4 400 MHz and Recommendation M.2085 contains characteristics and protection criteria for wireless avionics intra-communication systems operating in the aeronautical mobile (R) service in the frequency band 4 200-4 400 MHz. Recommendation ITU-R RS-1624 contains information on sharing between the Earth exploration satellite (passive) service and airborne altimeters in the aeronautical radionavigation service in the band 4 200-4 400 MHz.

The aeronautical radionavigation service in the band 4 200-4 400 MHz is used for aircraft radio altimeter systems. Information on these weather detection systems can be found in and Technical Standard Orders C87a[[6]](#footnote-6) and C92c[[7]](#footnote-7).

#### 5.2.6.3 Suitability of the frequency band 4 200-4 400 MHz for ground based detect and avoid systems

Operation of ground based DAA systems is not suitable due to radio altimeter only restriction on the aeronautical radionavigation service in RR No. **5.438** in the band 4 200-4 400 MHz.

**5.2.7 Frequency band 5 000-5 250 MHz**

**5.2.7.1 Allocations to operate detect and avoid and other services in the frequency band 5 000‑5 250 MHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **5 000-5 010** AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA  AERONAUTICAL RADIONAVIGATION  RADIONAVIGATION-SATELLITE (Earth-to-space) | | |
| **5 010-5 030** AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA  AERONAUTICAL RADIONAVIGATION  RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space)  5.328B 5.443B | | |
| **5 030-5 091** AERONAUTICAL MOBILE (R) 5.443C  AERONAUTICAL MOBILE-SATELLITE (R) 5.443D  AERONAUTICAL RADIONAVIGATION  5.444 | | |
| **5 091-5 150** FIXED-SATELLITE (Earth-to-space) 5.444A  AERONAUTICAL MOBILE 5.444B  AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA  AERONAUTICAL RADIONAVIGATION  5.444 | | |
| **5 150-5 250** FIXED-SATELLITE (Earth-to-space) 5.447A  MOBILE except aeronautical mobile 5.446A 5.446B  AERONAUTICAL RADIONAVIGATION  5.446 5.446C 5.447 5.447B 5.447C | | |

**5.443C** The use of the frequency band 5 030-5 091 MHz by the aeronautical mobile (R) service is limited to internationally standardized aeronautical systems. Unwanted emissions from the aeronautical mobile (R) service in the frequency band 5 030-5 091 MHz shall be limited to protect RNSS system downlinks in the adjacent 5 010-5 030 MHz band. Until such time that an appropriate value is established in a relevant ITU-R Recommendation, the e.i.r.p. density limit of -75 dBW/MHz in the frequency band 5 010-5 030 MHz for any AM(R)S station unwanted emission should be used.     (WRC‑12)

**5.444** The frequency band 5 030-5 150 MHz is to be used for the operation of the international standard system (microwave landing system) for precision approach and landing. In the frequency band 5 030-5 091 MHz, the requirements of this system shall have priority over other uses of this frequency band. For the use of the frequency band 5 091-5 150 MHz, No. **5.444A** and Resolution **114 (Rev.WRC-15)** apply.     (WRC‑15)

**5.444B** The use of the frequency band 5 091-5 150 MHz by the aeronautical mobile service is limited to:

– systems operating in the aeronautical mobile (R) service and in accordance with international aeronautical standards, limited to surface applications at airports. Such use shall be in accordance with Resolution **748 (Rev.WRC-15)**;

– aeronautical telemetry transmissions from aircraft stations (see No. **1.83**) in accordance with Resolution **418 (Rev.WRC-15)**.     (WRC‑15)

**5.446** *Additional allocation:*in the countries listed in No. **5.369**, the frequency band 5 150‑5 216 MHz is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis, subject to agreement obtained under No. **9.21**. In Region 2 (except in Mexico), the frequency band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis. In Regions 1 and 3, except those countries listed in No. **5.369** and Bangladesh, the frequency band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a secondary basis. The use by the radiodetermination-satellite service is limited to feeder links in conjunction with the radiodetermination-satellite service operating in the frequency bands 1 610-1 626.5 MHz and/or 2 483.5-2 500 MHz. The total power flux-density at the Earth’s surface shall in no case exceed −159 dB(W/m2) in any 4 kHz band for all angles of arrival.     (WRC‑15)

**5.446C** *Additional allocation:* in Region 1 (except in Algeria, Saudi Arabia, Bahrain, Egypt, United Arab Emirates, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Syrian Arab Republic, Sudan, South Sudan and Tunisia) and in Brazil, the band 5 150-5 250 MHz is also allocated to the aeronautical mobile service on a primary basis, limited to aeronautical telemetry transmissions from aircraft stations (see No. **1.83**), in accordance with Resolution **418 (Rev.WRC‑12)[[8]](#footnote-8)\***. These stations shall not claim protection from other stations operating in accordance with Article **5**. No. **5.43A** does not apply.    (WRC‑12)

**5.447** *Additional allocation:* in Côte d'Ivoire, Egypt, Israel, Lebanon, the Syrian Arab Republic and Tunisia, the band 5 150-5 250 MHz is also allocated to the mobile service, on a primary basis, subject to agreement obtained under No. **9.21**.In this case, the provisions of Resolution **229** **(Rev.WRC‑12)** do not apply.    (WRC‑12)

**5.447B** *Additional allocation*:  the band 5 150-5 216 MHz is also allocated to the fixed-satellite service (space-to-Earth) on a primary basis. This allocation is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to provisions of No. **9.11A**. The power flux-density at the Earth’s surface produced by space stations of the fixed-satellite service operating in the space-to-Earth direction in the band 5 150-5 216 MHz shall in no case exceed –164 dB(W/m2) in any 4 kHz band for all angles of arrival.

**5.2.7.2 Related ITU-R documents and aviation documents in the frequency band 5 000-5 250 MHz**

Recommendations ITU-R M.1318, ITU-R M.1901, ITU-R M.1906, and ITU-R M.2031 apply to the radionavigation-satellite services in the bands 5 000-5 010 MHz and 5 010-5 250 MHz.

*[Editor’s Note: Additional work on this section is needed]*

**5.2.7.3 Suitability of the frequency band 5 000-5 250 MHz for ground based detect and avoid systems**

The frequency band 5 000-5 250 MHz is operated or planned by various aeronautical systems including the microwave landing system, the radionavigation-satellite service links, UAS terrestrial and satellite C2 Links, radio local area networks, aeronautical telemetry downlinks, the fixed-satellite service (Earth-to-space) (space-to-Earth), and the mobile service. Therefore, co-existence of DAA systems onboard unmanned aircraft is not ensured.

The frequency band 5 000-5 250 MHz is not suitable for ground based DAA systems.

**5.2.8 Frequency band 5 350-5 470 MHz**

**5.2.8.1 Allocations to operate detect and avoid and other services in the frequency band 5 350‑5 470 MHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **5 350-5 460** EARTH EXPLORATION-SATELLITE (active) 5.448B  RADIOLOCATION 5.448D  AERONAUTICAL RADIONAVIGATION 5.449  SPACE RESEARCH (active) 5.448C | | |
| **5 460-5 470** EARTH EXPLORATION-SATELLITE (active)  RADIOLOCATION 5.448D  RADIONAVIGATION 5.449  SPACE RESEARCH (active)  5.448B | | |

**5.448B** The Earth exploration-satellite service (active) operating in the band 5 350-5 570 MHz and space research service (active) operating in the band 5 460-5 570 MHz shall not cause harmful interference to the aeronautical radionavigation service in the band 5 350-5 460 MHz, the radionavigation service in the band 5 460-5 470 MHz and the maritime radionavigation service in the band 5 470-5 570 MHz.     (WRC-03)

**5.448C** The space research service (active) operating in the band 5 350-5 460 MHz shall not cause harmful interference to nor claim protection from other services to which this band is allocated.      (WRC-03)

**5.448D** In the frequency band 5 350-5 470 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the aeronautical radionavigation service operating in accordance with No. **5.449**.      (WRC-03)

**5.449** The use of the band 5 350-5 470 MHz by the aeronautical radionavigation service is limited to airborne radars and associated airborne beacons.

**5.2.8.2 Related ITU-R documents and aviation documents in the frequency band 5 350-5 470 MHz**

Recommendation ITU-R M.1638 contains characteristics and protection criteria for systems operating in the aeronautical radionavigation and radiolocations services in the band 5 350-5 470 MHz. Technical Standard Order C212[[9]](#footnote-9) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the band 5 350-5 470 MHz. The aeronautical radionavigation service in the band 5 350-5 470 MHz is also used for systems that provide weather information for pilots onboard aircraft. Information on these weather detection systems can be found in and Technical Standard Order (TSO) C63c[[10]](#footnote-10).

There are no ITU-R Recommendations that apply to the Earth exploration-satellite (active) and space research (active) services in the band 5 350-5 470 MHz.

There are no ITU-R Recommendations that apply to the maritime radionavigation service in the band 5 470-5 570 MHz.

**5.2.8.3 Suitability of the frequency band 5 350-5 470 MHz for ground based detect and avoid systems**

Operation of a ground based DAA systems is not suitable due to the airborne only restriction in RR No. **5.449** in the frequency band 5 470-5 570 MHz.

**5.2.9 Frequency band 8 750-8 850 MHz**

**5.2.9.1 Allocations to operate detect and avoid and other services in the frequency band 8 750‑8 850 MHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **8 750-8 850** RADIOLOCATION  AERONAUTICAL RADIONAVIGATION 5.470  5.471 | | |

**5.470** The use of the band 8 750-8 850 MHz by the aeronautical radionavigation service is limited to airborne Doppler navigation aids on a centre frequency of 8 800 MHz.

**5.471** *Additional allocation:*in Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands, Qatar and Sudan, the frequency bands 8 825-8 850 MHz and 9 000-9 200 MHz are also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars only.     (WRC‑15)

**5.2.9.2 Related ITU-R documents and aviation documents in the frequency band 8 750-8 850 MHz**

Recommendation ITU-R M.1796-2 contains characteristics and protection criteria for systems operating in the aeronautical radionavigation and radiolocations services in the band 8 500-10 680 MHz and includes characteristics for a DAA radar that operates in the band 8 750-8 850 MHz. Technical Standard Order C212[[11]](#footnote-11) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the band 8 750-8 850 MHz. The aeronautical radionavigation service in the band 8 750-8 850 MHz is also used for systems that provide weather information for pilots onboard aircraft. Information on these weather detection systems can be found in and Technical Standard Order C65a[[12]](#footnote-12).

**5.2.9.3 Suitability of the frequency band 8 750-8 850 MHz for ground based detect and avoid systems**

Operation of a ground based DAA systems is not suitable due to the airborne only restriction in RR No. **5.470** in the frequency band 8 750-8 850 MHz.

### 5.2.10 Frequency band 9 000-9 200 MHz

#### 5.2.10.1 Allocation to operate detect and avoid and other services in the frequency band 9 000-9 200 MHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 9 000-9 200 RADIOLOCATION  AERONAUTICAL RADIONAVIGATION 5.337  5.471 5.473A | | |

**5.337** The use of the bands 1 300-1 350 MHz, 2 700-2 900 MHz and 9 000-9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

5.471 *Additional allocation:*in Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands, Qatar and Sudan, the frequency bands 8 825-8 850 MHz and 9 000-9 200 MHz are also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars only.     (WRC‑15)

5.473A In the band 9 000-9 200 MHz, stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from, systems identified in No. **5.337** operating in the aeronautical radionavigation service, or radar systems in the maritime radionavigation service operating in this band on a primary basis in the countries listed in No. **5.471**.     (WRC-07)

#### 5.2.10.2 Related ITU-R documents and aviation documents in the frequency band 9 000-9 200 MHz

Recommendation ITU-R M.1796-2 contains characteristics and protection criteria for systems operating in the aeronautical radionavigation and radiolocations services in the band 8 500-10 680 MHz and includes characteristics for precision approach and landing radar, Airport surveillance radar, and Airport surface detection equipment (ASDE) radars.

#### 5.2.10.3 Suitability of the frequency band 9 000-9 200 MHz for ground based detect & avoid systems

No restriction in the RR.

Noting that the use of the radiolocation service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service, the band 9 000-9 200 MHz is suitable for operation of ground based DAA systems.

DAA systems need to be compatible with existing aviation surveillance radar system that operate in the frequency band 9 000-9 200 MHz and colocation of a DAA system with existing aviation surveillance radars that operates in this band may be difficult.

In some administrations maritime radionavigation radar systems for use by shore-based radars are also allocated and coordination of DAA operations with these maritime radars is required.

### 5.2.11 Frequency band 9 300-9 800 MHz

**5.2.11.1 Allocations to operate detect and avoid and other services in the frequency band 9 300‑9 800 MHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **9 300-9 500** EARTH EXPLORATION-SATELLITE (active)  RADIOLOCATION  RADIONAVIGATION  SPACE RESEARCH (active)  5.427 5.474 5.475 5.475A 5.475B 5.476A | | |
| **9 500-9 800** EARTH EXPLORATION-SATELLITE (active)  RADIOLOCATION  RADIONAVIGATION  SPACE RESEARCH (active)  5.476A | | |

**5.427** In the bands 2 900-3 100 MHz and 9 300-9 500 MHz, the response from radar transponders shall not be capable of being confused with the response from radar beacons (racons) and shall not cause interference to ship or aeronautical radars in the radionavigation service, having regard, however, to No. **4.9**.

**5.474** In the band 9 200-9 500 MHz, search and rescue transponders (SART) may be used, having due regard to the appropriate ITU-R Recommendation (see also Article **31**).

**5.475** The use of the band 9 300-9 500 MHz by the aeronautical radionavigation service is limited to airborne weather radars and ground-based radars. In addition, ground-based radar beacons in the aeronautical radionavigation service are permitted in the band 9 300-9 320 MHz on condition that harmful interference is not caused to the maritime radionavigation service.     (WRC-07)

**5.475A** The use of the band 9 300-9 500 MHz by the Earth exploration-satellite service (active) and the space research service (active) is limited to systems requiring necessary bandwidth greater than 300 MHz that cannot be fully accommodated within the 9 500-9 800 MHz band.      (WRC‑07)

**5.475B** In the band 9 300-9 500 MHz, stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from, radars operating in the radionavigation service in conformity with the Radio Regulations. Ground-based radars used for meteorological purposes have priority over other radiolocation uses.      (WRC‑07)

**5.476A** In the band 9 300-9 800 MHz, stations in the Earth exploration-satellite service (active) and space research service (active) shall not cause harmful interference to, nor claim protection from, stations of the radionavigation and radiolocation services.     (WRC‑07)

**5.2.11.2 Related ITU-R documents and aviation documents in the frequency band 9 300-9 800 MHz**

Recommendation ITU-R M.1796-2 contains characteristics and protection criteria for systems operating in the aeronautical radionavigation and radiolocations services in the band 8 500-10 680 MHz and includes characteristics for a DAA radar that operates in the band 9 300-9 500 MHz. Technical Standard Order C212[[13]](#footnote-13) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the band 9 300-9 500 MHz. The aeronautical radionavigation service in the band 9 300-9 500 MHz is also used for systems that provide weather information for pilots onboard aircraft. Information on these weather detection systems can be found in and Technical Standard Order C63c[[14]](#footnote-14).

Recommendations ITU-R RS.577, ITU-R RS.1166, and ITU-R RS.2105 apply to the Earth exploration-satellite (active) and space research (active) services in the bands 9 300-9 500 MHz and 9 500-9 800 MHz.

**5.2.11.3 Suitability of the frequency band 9 300-9 800 MHz for ground based detect and avoid systems**

**5.2.11.3.1 9 300-9 500 MHz**

Operation of ground based DAA systems in the band 9 300-9 500 MHz is not suitable due to restriction in RR No. **5.475** limiting the aeronautical radionavigation service to airborne weather radars.

**5.2.11.3.2 9 500-9 800 MHz**

No restriction in the RR.

Noting that the use of the Space research service (active) shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service, the band 9 500-9 800 MHz is suitable for operation of ground based DAA systems provided compatibility with radiolocation systems in the band are ensured.

The use of the Earth exploration satellite (active) service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service. However there are operational EESS (active) missions for which compatibility with DAA systems has not been ensured. Therefore DAA systems should take all practicable measures to minimize the chance of interference causing the premature obsolescence of in-orbit EESS (active) assets.

### 5.2.12 Frequency band 13.25-13.4 GHz

#### 5.2.12.1 Allocations to operate detect and avoid and other services in the frequency band 13.25‑13.4 GHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 13.25-13.4 EARTH EXPLORATION-SATELLITE (active)  AERONAUTICAL RADIONAVIGATION 5.497  SPACE RESEARCH (active)  5.498A 5.499 | | |

**5.497** The use of the band 13.25-13.4 GHz by the aeronautical radionavigation service is limited to Doppler navigation aids

5.498A The Earth exploration-satellite (active) and space research (active) services operating in the band 13.25‑13.4 GHz shall not cause harmful interference to, or constrain the use and development of, the aeronautical radionavigation service.     (WRC-97)

5.499 *Additional allocation:*in Bangladesh and India, the band 13.25-14 GHz is also allocated to the fixed service on a primary basis. In Pakistan, the band 13.25-13.75 GHz is allocated to the fixed service on a primary basis.    (WRC‑12)

#### 5.2.12.2 Related ITU-R documents and aviation documents in the frequency band 13.25‑13.4 GHz

Recommendation ITU-R M.2008-1 contains characteristics and protection criteria for radar operating in the aeronautical radionavigation service. Technical Standard Order C212[[15]](#footnote-15) contains the aviation standards for airborne DAA radars operating in the aeronautical radonavigation service in the frequency band 13.25-13.40 GHz.

The aeronautical radionavigation service in the band 13.25-13.40 GHz is also used for systems that determine the ground speed and drift angle of an aircraft. ITU-R Recommendation M.2008-1 contains characteristics and protection criteria for these systems. Technical Standard Order C65a[[16]](#footnote-16) contains the aviation standards for these systems.

There are no ITU-R Recommendations that apply to the Earth exploration-satellite (active) and space research (active) services in the band 13.25-13.40 GHz however Report ITU-R RS.2068-1 describes the use of this band by spaceborne active sensors.

There are no ITU-R Recommendations that apply to the fixed service in the band 13.25-13.40 GHz band.

#### 5.2.12.3 Suitability of the frequency band 13.25‑13.4 GHz for ground based detect & avoid systems

No restriction in the RR.

Noting that the use of the space research services shall not constraint the use and development of aeronautical radionavigation service, operation of ground based DAA systems is suitable provided the DAA system employs Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. 5.470.

The use of the Earth exploration satellite (active) service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service. However there are operational EESS (active) missions for which compatibility with DAA systems has not been ensured. Therefore DAA systems should take all practicable measures to minimize the chance of interference causing the premature obsolescence of in-orbit EESS (active) assets.

DAA systems need to be compatible with existing aviation radar system that operate in the band 13.25-13.4 GHz.

Since the frequency band 13.25-13.4 GHz is also allocated to the fixed service in Bangladesh, India, and Pakistan the suitability of this band needs to be further studied in those locations where fixed service is allocated on a primary basis.

### 5.2.13 Frequency band 14-14.3 GHz

**5.2.13.1 Allocations to operate detect and avoid and other services in the frequency band 14-14.3 GHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **14-14.25** FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.484B 5.506  5.506B  RADIONAVIGATION 5.504  Mobile-satellite (Earth-to-space) 5.504B 5.504C 5.506A  Space research  5.504A 5.505 | | |
| **14.25-14.3** FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.484B 5.506  5.506B  RADIONAVIGATION 5.504  Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.508A  Space research  5.504A 5.505 5.508 | | |

**5.504** The use of the band 14-14.3 GHz by the radionavigation service shall be such as to provide sufficient protection to space stations of the fixed-satellite service.

**5.504A** In the band 14-14.5 GHz, aircraft earth stations in the secondary aeronautical mobile-satellite service may also communicate with space stations in the fixed-satellite service. The provisions of Nos. **5.29**, **5.30** and **5.31** apply.     (WRC-03)

**5.505** *Additional allocation:* in Algeria, Saudi Arabia, Bahrain, Botswana, Brunei Darussalam, Cameroon, China, Congo (Rep. of the), Korea (Rep. of), Djibouti, Egypt, the United Arab Emirates, Gabon, Guinea, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Lebanon, Malaysia, Mali, Morocco, Mauritania, Oman, the Philippines, Qatar, the Syrian Arab Republic, the Dem. People’s Rep. of Korea, Singapore, Somalia, Sudan, South Sudan, Swaziland, Chad, Viet Nam and Yemen, the frequency band 14-14.3 GHz is also allocated to the fixed service on a primary basis.     (WRC‑15)

**5.508** *Additional allocation:* in Germany, France, Italy, Libya, The Former Yugoslav Rep. of Macedonia and the United Kingdom, the band 14.25-14.3 GHz is also allocated to the fixed service on a primary basis.    (WRC‑12)

**5.2.13.2 Related ITU-R documents and aviation documents in the frequency band 14‑14.3 GHz**

Recommendation ITU-R M.946-3 contains power flux density limits for radionavigation transmitters to protect space station received in the fixed-satellite service in the 14 GHz band.

*[Editor’s Note: Additional work on this section is needed]*

**5.2.13.3 Suitability of the frequency band 14-14.3 GHz for ground based detect and avoid systems**

The frequency band 14-14.3 GHz is used for satellite uplinks and No. 5.504 requires the radionavigation service to protect the satellite receivers. The power flux density limits to achieve this protection are found in Recommendation ITU-R M.946-3. In addition, the fixed service systems is allocated in various countries and coexistence between ground based DAA systems aircraft and the fixed service is not ensured.

The frequency band 14-14.3 GHz is not suitable for ground based detect and avoid systems.

### 5.2.14 Frequency band 15.4-15.7 GHz

#### 5.2.14.1 Allocation to operate detect and avoid and other services in the frequency band 15.4-15.7 GHz

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **15.4-15.43** RADIOLOCATION 5.511E 5.511F  AERONAUTICAL RADIONAVIGATION | | |
| **15.43-15.63** FIXED-SATELLITE (Earth-to-space) 5.511A  RADIOLOCATION 5.511E 5.511F  AERONAUTICAL RADIONAVIGATION  5.511C | | |
| **15.63-15.7** RADIOLOCATION 5.511E 5.511F  AERONAUTICAL RADIONAVIGATION | | |

**5.511A** Use of the frequency band 15.43-15.63 GHz by the fixed-satellite service (Earth-to-space) is limited to feeder links of non-geostationary systems in the mobile-satellite service, subject to coordination under No. **9.11A**.     (WRC‑15)

**5.511C** Stations operating in the aeronautical radionavigation service shall limit the effective e.i.r.p. in accordance with Recommendation ITU‑R S.1340‑0. The minimum coordination distance required to protect the aeronautical radionavigation stations (No. **4.10** applies) from harmful interference from feeder-link earth stations and the maximum e.i.r.p. transmitted towards the local horizontal plane by a feeder-link earth station shall be in accordance with Recommendation ITU‑R S.1340‑0.     (WRC‑15)

**5.511E** In the frequency band 15.4-15.7 GHz, stations operating in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the aeronautical radionavigation service.    (WRC‑12)

**5.511F** In order to protect the radio astronomy service in the frequency band 15.35-15.4 GHz, radiolocation stations operating in the frequency band 15.4-15.7 GHz shall not exceed the power flux-density level of −156 dB(W/m2) in a 50 MHz bandwidth in the frequency band 15.35-15.4 GHz, at any radio astronomy observatory site for more than 2 per cent of the time.    (WRC‑12)

#### 5.2.14.2 Related ITU-R documents and aviation documents in the frequency band 15.4‑15.7 GHz

Recommendation ITU-R M.1730-1 contains characteristics and protection criteria for systems operating in the radiolocations services in the band 15.4-17.3 GHz. There are no characteristics for any aeronautical radionavigation systems that operates in the band 15.4-15.7 GHz. Technical Standard Order C212[[17]](#footnote-17) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the band 15.4-15.7 GHz. The aeronautical radionavigation service in the band 15.4-15.7 GHz is also used for systems that provide weather information for pilots onboard aircraft. Information on these weather detection systems can be found in and Technical Standard Order C65a[[18]](#footnote-18).

Recommendation ITU-R S.1340 addresses sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the Earth-to-space direction in the band 15.4-15.7 GHz.

Recommendation ITU-R S.1341 sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the space-to-Earth direction in the band 15.4-15.7 GHz and the protection of the radio astronomy service in the band 15.35-15.4 GHz.

#### 5.2.14.3 Suitability of the band 15.4-15.7 GHz for ground based detect & avoid systems

Noting that radiolocation service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service operating in the band 15.4-15.7 GHz and that procedures for sharing with MSS feeder links in the 15.43-15.63 GHz can be found in Recommendations ITU-R S.1340 and S.1341, the band 15.4-15.7 GHz is suitable for operation of ground based DAA systems. Further, compatibility with DAA systems onboard UA will also be required.

### 5.2.15 Frequency band 24.45-24.65 GHz

#### 5.2.15.1 Allocation to operate detect and avoid and other services in the frequency band 24.45-24.65 GHz

|  |  |  |
| --- | --- | --- |
| Allocation to services | | |
| Region 1 | Region 2 | Region 3 |
| 24.45-24.65  FIXED  INTER-SATELLITE  MOBILE except aeronautical mobile 5.338A 5.532AB | 24.45-24.65  FIXED 5.532AA  INTER-SATELLITE  MOBILE except aeronautical mobile 5.338A 5.532AB  RADIONAVIGATION  5.533 | 24.45-24.65  FIXED  INTER-SATELLITE  MOBILE 5.338A 5.532AB  RADIONAVIGATION  5.533 |

**5.338A** In the frequency bands 1 350-1 400 MHz, 1 427-1 452 MHz, 22.55-23.55 GHz, 24.25-27.5 GHz, 30-31.3 GHz, 49.7-50.2 GHz, 50.4-50.9 GHz, 51.4-52.4 GHz, 52.4-52.6 GHz, 81-86 GHz and 92-94 GHz, Resolution **750 (Rev.WRC-19)** applies.     (WRC‑19)

**5.532AA** The allocation to the fixed service in the frequency band 24.25-25.25 GHz is identified for use in Region 2 by high-altitude platform stations (HAPS). This identification does not preclude the use of this frequency band by other fixed-service applications or by other services to which this frequency band is allocated on a co-primary basis, and does not establish priority in the Radio Regulations. Such use of the fixed-service allocation by HAPS is limited to the HAPS-to-ground direction and shall be in accordance with the provisions of Resolution **166 (WRC-19)**.     (WRC‑19)

**5.532AB** The frequency band 24.25-27.5 GHz is identified for use by administrations wishing to implement the terrestrial component of International Mobile Telecommunications (IMT). This identification does not preclude the use of this frequency band by any application of the services to which it is allocated and does not establish priority in the Radio Regulations. Resolution **242 (WRC-19)** applies.     (WRC‑19)

5.533 The inter-satellite service shall not claim protection from harmful interference from airport surface detection equipment stations of the radionavigation service.

#### 5.2.15.2 Related ITU-R documents and aviation documents in the frequency band 24.45‑24.65 GHz

There are no ITU-R Recommendations that apply to the radionavigation service in the frequency band 24.45-24.65 GHz band. Technical Standard Order C212[[19]](#footnote-19) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the frequency band 24.45-24.65 GHz.

Recommendations ITU-R X.XXXX and ITU-R X.XXXX apply to the inter-satellite service in the frequency band 24.45-24.65 GHz band.

Recommendations ITU-R X.XXXX and ITU-R X.XXXX apply to the fixed service in the frequency band 24.45-24.65 GHz band.

There are no ITU-R Recommendations that apply to the mobile service in the frequency band 24.45-24.65 GHz band.

#### 5.2.15.3 Suitability of the band 24.45-24.65 GHz for ground based detect & avoid systems

There is no worldwide allocation to the radionavigation service in this band however, regional allocations do allow for operations of ground based DAA systems in many parts of the world.

### 5.2.15.3.1 Region 1

Operation of ground based DAA systems in Region 1 is not suitable since there is no radionavigation allocation in the frequency band 24.45-24.65 GHz in Region 1.

### 5.2.15.3.2 Region 2

Operation of ground bases DAA systems in the frequency band 24.45-24.65 GHz may be suitable in Region 2 provided users take into account fixed and mobile systems that operate on a coequal basis in this band in accordance with the provisions of Resolution **166 (WRC-19)**    (WRC‑19) and Resolution **242 (WRC-19)**    (WRC‑19).

### 5.2.15.3.3 Region 3

Operation of ground based DAA systems in the frequency band 24.45-24.65 GHz may be suitable in Region 3 provided users take into account the fixed and mobile systems that operate on a coequal basis in this band in accordance with the provisions of Resolution **242 (WRC-19)**    (WRC‑19).

### 5.2.16 Frequency band 31.8-33.4 GHz

#### 5.2.16.1 Allocation to operate detect and avoid and other services in the frequency band 31.8-33.4 GHz

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **31.8-32** FIXED 5.547A  RADIONAVIGATION  SPACE RESEARCH (deep space) (space-to-Earth)  5.547 5.547B 5.548 | | |
| **32-32.3** FIXED 5.547A  RADIONAVIGATION  SPACE RESEARCH (deep space) (space-to-Earth)  5.547 5.547C 5.548 | | |
| **32.3-33** FIXED 5.547A  INTER-SATELLITE  RADIONAVIGATION  5.547 5.547D 5.548 | | |
| **33-33.4** FIXED 5.547A  RADIONAVIGATION  5.547 5.547E | | |

**5.547** The bands 31.8-33.4 GHz, 37-40 GHz, 40.5-43.5 GHz, 51.4-52.6 GHz, 55.78-59 GHz and 64-66 GHz are available for high-density applications in the fixed service (see Resolution **75** **(WRC-2000)**[[20]](#footnote-20)\*). Administrations should take this into account when considering regulatory provisions in relation to these bands. Because of the potential deployment of high-density applications in the fixed-satellite service in the bands 39.5-40 GHz and 40.5-42 GHz (see No. **5.516B**), administrations should further take into account potential constraints to high-density applications in the fixed service, as appropriate.     (WRC‑07)

#### 5.2.16.2 Related ITU-R documents and aviation documents in the frequency band 31.8‑33.4 GHz

Recommendation ITU-R M.1466-1 contains characteristics and protection criteria for aeronautical radionavigation systems in the band 31.8-33.4 GHz. Technical Standard Order C212[[21]](#footnote-21) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation service in various bands including the frequency band 31.8-33.4 GHz.

*[Editor’s Note: Additional work on this section is needed]*

#### 5.2.16.3 Suitability of the band 31.8-33.4 GHz for ground based detect & avoid

[TBD]

**5.2.17 Frequency band 43.5-47.0 GHz**

[TBD]

**5.2.18 Frequency band 66.0-71.0 GHz**

[TBD]

**5.2.19 Frequency band 95.0-100.0 GHz**

[TBD]

**5.2.20 Frequency band 123.0-130.0 GHz**

[TBD]

**5.2.21 Frequency band 191.8-200.0 GHz**

[TBD]

**5.2.22 Frequency band 235.0-238.0 GHz**

[TBD]

# 6 Summary

*TBD*

*[Editor's note: The Summary section will identify the suitability of each band for DAA operations based on a review of the applicable provisions of the Radio Regulations as well as taking into account co-existence with other services/systems operating in each band.]*

| Radionavigation  Frequency Band | Suitability for Airborne DAA | Reason |
| --- | --- | --- |
| 960-1 215 MHz | [TBD] | [TBD] |
| 1 215-1 300 MHz | [TBD] | [TBD] |
| 1 300-1 350 MHz | [TBD] | [TBD] |
| 1 559-1 610 MHz | [TBD] | [TBD] |
| 1 610-1 626.5 MHz | [TBD] | [TBD] |
| 2 700-2 900 MHz | [TBD] | [TBD] |
| 2 900-3 100 MHz | [TBD] | [TBD] |
| 4 200-4 400 MHz | [TBD] | [TBD] |
| 5 000-5 250 MHz | [TBD] | [TBD] |
| 5 350-5 470 MHz | [TBD] | [TBD] |
| 8 750-8 850 MHz | [TBD] | [TBD] |
| 9 000-9 200 MHz | [TBD] | [TBD] |
| 9 300-9 500 MHz | [TBD] | [TBD] |
| 9 500-9 800 MHz | [TBD] | [TBD] |
| 13.25-13.4 GHz | [TBD] | [TBD] |
| 14-14.3 GHz | [TBD] | [TBD] |
| 15.4-15.7 GHz | [TBD] | [TBD] |
| 24.45-24.65 GHz | [TBD]  in Region 1 | [TBD] |
| [TBD]  in Region 2 | [TBD] |
| [TBD]  in Region 3 | [TBD] |
| 31.8-33.4 GHz | [TBD] | [TBD] |
| 43.5-47.0 GHz | [TBD] | [TBD] |
| 66.0-71.0 GHz | [TBD] | [TBD] |
| 95.0-100.0 GHz | [TBD] | [TBD] |
| 123.0-130.0 GHz | [TBD] | [TBD] |
| 191.8-200.0 GHz | [TBD] | [TBD] |
| 235.0-238.0 GHz | [TBD] | [TBD] |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Previous ITU-R documents on unmanned aircraft systems, including Report ITU-R M.2204, have used the term sense-and-avoid (S&A) instead of DAA. The reason for the change is that the the International Civil Aviation Organization (ICAO) uses DAA instead of S&A (see ICAO Document 10019 (issued) and manual from RPAS panel). [↑](#footnote-ref-1)
2. Report ITU-R M.[UA-AIRBORNE-DAA], “Guidance on suitable frequency bands and services to be used by airborne unmanned aircraft detect-and-avoid non-cooperative systems”. [↑](#footnote-ref-2)
3. \* This provision was previously numbered as No. 5.347A. It was renumbered to preserve the sequential order. [↑](#footnote-ref-3)
4. \* *Note by the Secretariat:* This Resolution was revised by WRC-15. [↑](#footnote-ref-4)
5. \*\* *Note by the Secretariat:* This Resolution was revised by WRC-12. [↑](#footnote-ref-5)
6. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order [TSO-C687a](http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgTSO.nsf/0/3e13da064e29a5f586257a1b005889a8/$FILE/TSO-C87a.pdf), Airborne Low Range Radar Altimeter, 31 May 2012. [↑](#footnote-ref-6)
7. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C92c, Airborne Ground Proximity Warning Equipment, 19 March 1996. [↑](#footnote-ref-7)
8. \* *Note by the Secretariat:*  This Resolution was revised by WRC-15. [↑](#footnote-ref-8)
9. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-9)
10. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C63c, Airborne Weather and Ground Mapping Pulsed Radars, 18 August 1983. [↑](#footnote-ref-10)
11. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-11)
12. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C65a, Airborne Doppler Radar Ground Speed and/or Drift Angle Measuring Equipment (for Air Carrier Aircraft), 18 August 1983. [↑](#footnote-ref-12)
13. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-13)
14. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C63c, Airborne Weather and Ground Mapping Pulsed Radars, 18 August 1983. [↑](#footnote-ref-14)
15. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-15)
16. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C65aTSO-C65a, Airborne Doppler Radar Ground Speed and/or Drift Angle Measuring Equipment (for Air Carrier Aircraft), 18 August 1983. Note: This TSO has been cancelled. Equipment that has been previously approved under this TSO may continue to be produced and installed on aircraft. [↑](#footnote-ref-16)
17. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-17)
18. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C65a, Airborne Doppler Radar Ground Speed and/or Drift Angle Measuring Equipment (for Air Carrier Aircraft), 18 August 1983. [↑](#footnote-ref-18)
19. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-19)
20. \* *Note by the Secretariat:*  This Resolution was revised by WRC-12. [↑](#footnote-ref-20)
21. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 22, September 2017. [↑](#footnote-ref-21)