|  |  |
| --- | --- |
| **U.S. Radiocommunications Sector**  **Fact Sheet** | |
| **Working Party:** ITU-R WP-5B | **Document No:** USWP5B26-02-First Draft |
| **Ref:** Annex 32 to Document 5B/225-E | **Date:** 3 March 2021 |
| **Document Title:** WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW 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 | |
| **Author(s)/Contributors(s):**  Don Nellis  Federal Aviation Administration  800 Independence Ave., S.W.  Washington, DC 20591  Mohammed Rahman  Federal Aviation Administration  800 Independence Ave., S.W.  Washington, DC 20591  Michael Neale  ACES Corporation for the FAA | Phone: (202) 267-9779  e-mail: Donald.Nellis@faa.gov  Phone: (202) 267-6573  e-mail: Mohammed.Rahman@faa.gov  Phone: (858) 705-8978  e-mail: Michael.Neale@ACES-INC.COM |
| **Purpose/Objective:** The purpose of this contribution is to continue to update a new report to identify and provide information on appropriate frequency bands for Detect and Avoid radar systems installed on unmanned aircraft. This report, along with a companion report for ground based radars to support unmanned aircraft operations, will ultimately replace ITU-R Report M.2204-0. | |
| **Abstract:** This contribution will continue the process of drafting a new report for Detect and Avoid radar systems installed on unmanned aircraft based on the update to the draft new report found in Annex 32 of the Chairman’s Report of the November 2020 WP-5B meeting. This new report will update the list of frequency bands allocated to the Aeronautical Radionavigation and Radionavigation Services, which could be used for Detect and Avoid radar systems installed on unmanned aircraft. The report will also provide information on other systems and services in these bands, coexistence issues, and an evaluation of the suitability of the band for UAS Detect and Avoid radar systems. | |

|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Source: Document 5B/TEMP/87  Subject: New Report ITU-R M.[UA-AIRBORNE-DAA] | **Annex 32 to Document 5B/225-E** |
| **November 2020** |
| **English only** |
| Annex 32 to the Working Party 5B Chairman’s Report | |
| working document towards a preliminary draft new  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 | |

(202X)

[Editor’s note: this editor’s note summarize the discussion on the scope of this new ITU-R Report

Introductory questions:

*– Scope of this document: airborne and ground:*

*• 2 different reports: this one focused on airborne, the second one on ground systems: to be reconsider when materials will be available;*

*‣ Ground for small UA’s that don’t have the capability to carry radar: primary radar may be used to locate other aircraft/UA and communicate to the UA their location;*

*‣ Ground based radar around airport to complement the system onboard aircraft due to ground clutter that may affect efficiency of detection*

*– To identify the existing allocations to ARNS and/or RNS. The possible use of AMRS has not been agreed noting that:*

*• On one hand, it is not the aim to seek AMRS allocation for detect and avoid;*

*• On the other hand, some systems operating into AMRS may provide detect and avoid functions.*

*– To define the lower limit in the frequency*

*– To define the upper limit in the frequency*

*– To define the framework for each band*

*– Discussion took place on the 2 following options:*

*• To continue to use the term Sense and Avoid that is not recognized by ICAO for RPAS*

*• or to use Detect and Avoid: to align definitions but the impact need to be further considered*

*– question was raised if the scope should cover all UA not under ICAO?:*

*• categories defined at EASA: open, specific, certified)*

*• certified UA have to be under ICAO regulation and possibly the specific ones*

*• Asia may have different approaches*

*– Non-cooperative scenarios]*

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 detect and avoid (DAA)[[1]](#footnote-1) operations be clearly identified. This Report provides guidance as to which frequency bands are suitable for UA DAA operations for systems fitted onboard aircraft for non-cooperative scenarios.

The ground based stations used for UA DAA operations are not included in this ITU-R Report but can be found in Report ITU-R M.[UA\_GROUND\_DAA][[2]](#footnote-2).

[Editor’s note: The intent of establishing this new Report is to replace the current Report ITU‑R M.2204 in association with Report ITU-R M.[UA\_GROUND\_DAA] on UA ground based 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

*Recommendations*

[TBC]

Reports

[ITU-R M.2204](https://www.itu.int/pub/R-REP-M.2204-2010): Characteristics and spectrum considerations for sense and avoid systems use on Unmanned Aircraft Systems (UAS)

TABLE OF CONTENTS

Page

[1 Background 6](#_Toc51922582)

[2 Terminology/definitions 6](#_Toc51922583)

[2.1 Airspace 7](#_Toc51922585)

[2.2 Categories 7](#_Toc51922586)

[3 Scenarios 7](#_Toc51922587)

[4 Description of principle for detect and avoid onboard unmanned aircraft 7](#_Toc51922588)

[4.1 Applicability of detect and avoid to overall collision avoidance approach 8](#_Toc51922589)

[4.2 Aircraft-based detect and avoid 9](#_Toc51922590)

[5 Spectrum analysis on suitability for detect and avoid system onboard unmanned aircraft 14](#_Toc51922591)

[5.1 Criteria for suitability of spectrum for detect and avoid systems 14](#_Toc51922592)

[5.2 Analysis of suitability of frequency bands 15](#_Toc51922593)

[6 Summary 39](#_Toc51922594)

# 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 onboard, 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:** 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:** 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: Is there a term that is less military in implication that could be used instead of Intruder]

**Unmanned aircraft:** Designates all types of aircraft remotely controlled.

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

**Unmanned aircraft systems**: 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: These 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 principle for detect and avoid onboard unmanned aircraft

*[Editor’s note: the section relative to the description of detect and avoid onboard unmanned aircraft will need to be updated including relevant information that could be received from ICAO but not only.]*

The principle of a detect and avoid system is that it fits into the total systems approach to collision avoidance. As shown in Figure 1, the approach to collision avoidance uses a layered approach. Current technologies that may accommodate these layers include ATC procedures, ground and surface ATC surveillance systems, automatic dependent surveillance-broadcast (ADS-B), airborne collision avoidance system also called traffic collision avoidance system (TCAS), and DAA. [DAA has to be operative for the self-separation and collision avoidance layers.

Figure 1

Layered collision avoidance approach



## 4.1 Applicability of detect and avoid to overall collision avoidance approach

An important point to consider in the design of a detect and avoid system is how it fits into the total systems approach to collision avoidance. ICAO Document 9854[[3]](#footnote-3) describes conflict management as consisting of three layers: strategic conflict management, remain well clear, and collision avoidance as shown in Figure 1. The DAA system provides the remain well clear and collision avoidance layers.

Figure 1

Three layers of conflict management according to ICAO Doc 9854



### 4.1.1 Strategic conflict management

Strategic conflict management includes pre-flight actions performed to minimize potential flight path conflicts with, and maximize separation from, intruders. Strategic conflict management also includes risk mitigation that is achieved through airspace organization and management, demand and capacity balancing, and traffic synchronization.

### 4.1.2 Remain well clear/separation provision

At the remain well clear level of DAA, the system identifies the pilot to a potential violation of the DAA Well Clear volume. Based on the information provided by the DAA system, the pilot identifies whether, and if so, what type of a manoeuvre is necessary to avoid the intruder, and then executes that manoeuvre. If operating under an ATC clearance, the UA Pilot coordinates with ATC to obtain an amended clearance before executing the manoeuvre.

### 4.1.3 Collision avoidance

Collision avoidance is the last layer to of conflict management and aims to prevent an intruder from penetrating the near mid-air collision (NMAC) volume. The airborne collision avoidance system is a system that is currently used to this effect on manned aircraft.

## 4.2 Aircraft-based detect and avoid

There are factors that drive the performance requirements needed from an RF-based airborne DAA sensor as shown in Figure 2. The number of factors that drive the performance requirements for an airborne DAA sensor is large resulting in a very difficult multidimensional trade space containing both dependent variables and independent variables. These factors include characteristics of the encounter including NMAC volume, the latencies in the actual airborne DAA system implementation, and the performance parameters of the radar used as the airborne DAA sensor.

Figure 2

Detect and avoid sensor performance requirement factors



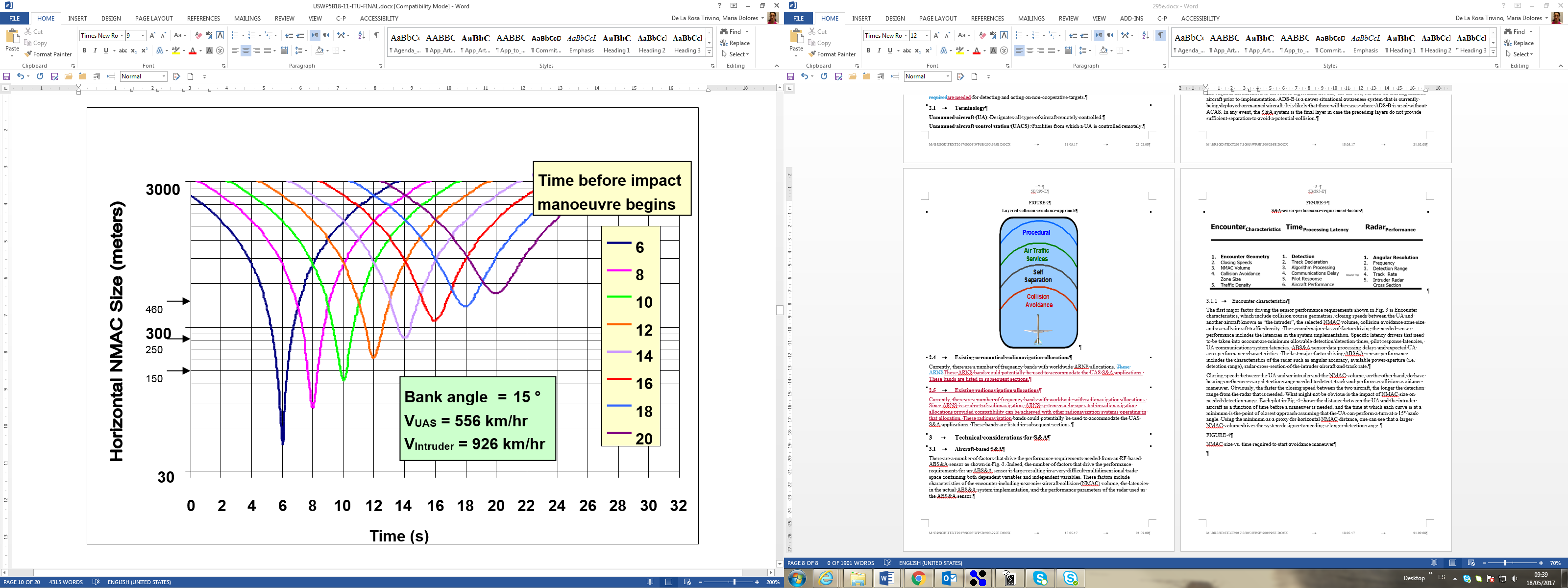
### 4.2.1 Encounter characteristics for aircraft-based detect and avoid

The first major factor driving the sensor performance requirements shown in Figure 3 is Encounter characteristics, which include collision course geometries, closing speeds between the UA and another aircraft known as “the intruder”, the selected NMAC or well clear volume, collision avoidance zone size and overall aircraft traffic density. The second major class of factor driving the needed sensor performance includes the latencies in the system implementation. Specific latency drivers that need to be taken into account are minimum allowable detection/detection times, pilot response latencies, UA communications system latencies, airborne DAA sensor data processing delays and expected UA aero-performance characteristics. The last major factor driving airborne DAA sensor performance includes the characteristics of the radar such as angular accuracy, available power-aperture (i.e. detection range), radar cross-section of the intruder aircraft and track rate.

Closing speeds between the UA and an intruder and the NMAC or well clear volume, on the other hand, do have bearing on the necessary detection range needed to detect, track and perform a collision avoidance manoeuvre. Obviously, the faster the closing speed between the two aircraft, the longer the detection range from the radar that is needed. Additionally, larger NMAC or well clear volumes also increase detection range. Each plot in Figure 3 shows the distance between the UA and the intruder aircraft as a function of time before a manoeuvre is needed, and the time at which each curve is at a minimum is the point of closest approach assuming that the UA can perform a turn at a 15° bank angle. Using the minimum as a proxy for horizontal NMAC distance, one can see that a larger NMAC volume drives the system designer to needing a longer detection range.

Figure 3

Near mid-air collision size vs. time required to start avoidance manoeuvre



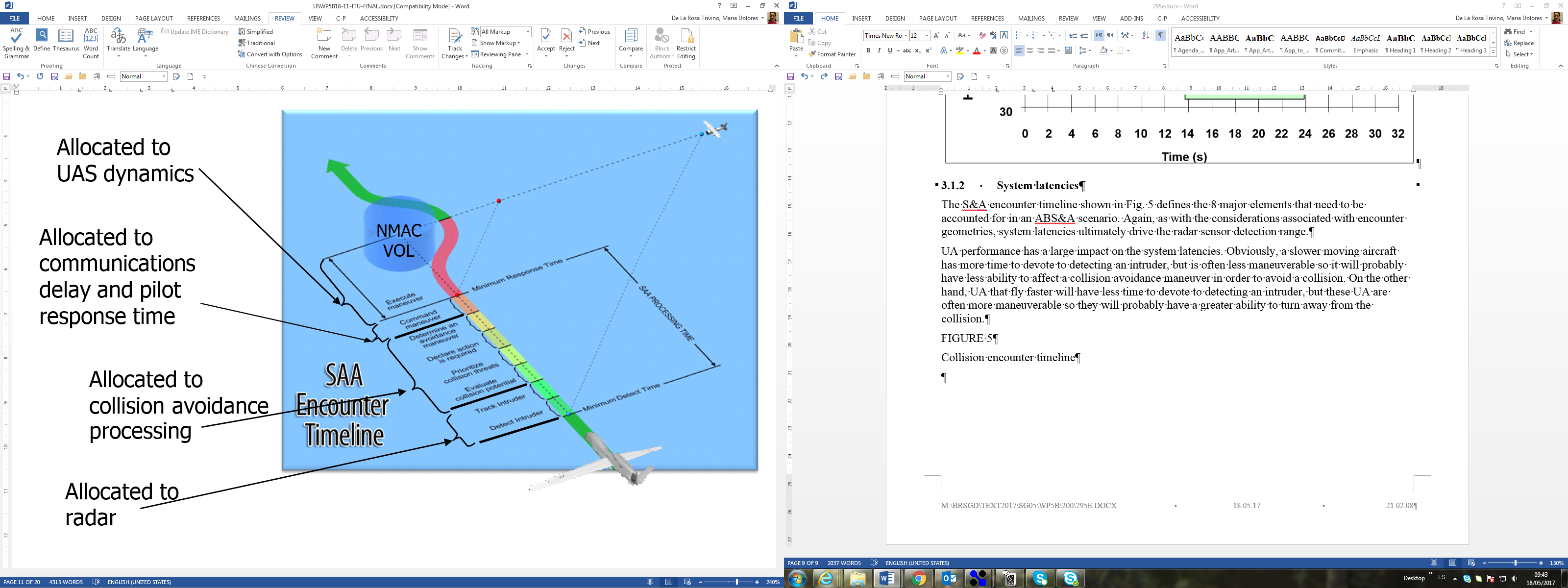
### 4.2.2 System latencies for aircraft-based detect and avoid

The DAA encounter timeline shown in Figure 4 defines the 8 major elements that need to be accounted for in an airborne DAA scenario. Again, as with the considerations associated with encounter geometries, system latencies ultimately drive the radar sensor detection range.

UA performance has a large impact on the system latencies. Obviously, a slower moving aircraft has more time to devote to detecting an intruder, but is often less maneuverable so it will probably have less ability to affect a collision avoidance manoeuvre in order to avoid a collision. On the other hand, UA that fly faster will have less time to devote to detecting an intruder, but these UA are often more manoeuvrable so they will probably have a greater ability to turn away from the collision.

FIGURE 4

Collision encounter timeline



### 4.2.3 Radar performance considerations for aircraft-based detect and avoid

Lastly, specific requirements on the performance of the radar component of the DAA system will affect the radar design and performance and be a main driver in frequency band selection. In particular, SWAP and the required accuracy of intruder position (as measured by angular and range resolution) will affect:

*[Chairman’s note: What is SWAP?]*

1) The detection range of an intruder

The detection range of an intruder is highly dependent on the transmit power-gain product of the radar. Transmit power is usually the highest power consuming element in the radar, which will affect power consumption directly and other SWAP elements indirectly. In order to constrain the radar transmit power and power consumption, lower frequencies are preferred for two factors:

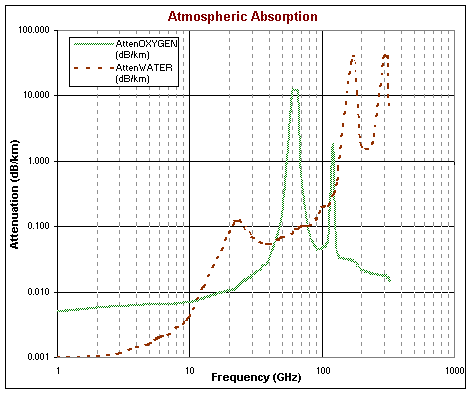
– in general, lower frequencies have lower rain attenuation and atmospheric absorption factors as shown in Figure 5 below;

– higher efficiency amplifiers are more readily available at lower frequencies and hence same output power can be obtained at lower power consumption.

For antenna gain evaluation, higher frequencies will have higher antenna gain for same antenna size.

Figure 5

Plot of atmospheric absorption at microwave frequencies



2) The accuracy of the intruder position

In order to estimate the intruder position, the radar measures the range, azimuth (bearing) and elevation angle of the intruder relative to the ownership UA.

The range resolution and accuracy is mainly dependent on the frequency bandwidth of the waveform and is usually sufficient to achieve required accuracy.

The radar usually relies on monopulse processing to improve angle accuracy. Typical accuracies are in the 1:10-1:20 of the 3 dB beamwidth of the antenna. For same antenna size, the beamwidth is reduced as the frequency is increased, and hence the accuracy is improved as the frequency is increased. Note that reducing the beamwidth may have the adverse effect of needing a longer frame time to cover all the required field of regard, hence these parameters are usually traded in a system optimization.

Thus, the proper selection of frequency is critical to the success of the airborne DAA radar. There is no optimum solution that fits all UAS classes, the solution will depend on the UAS class, and operational environment. As shown in Figure 6, the X band gives a compromise for trading all parameters. A lower band would have lower power consumption for same range requirement but may need a larger size antenna to achieve the required antenna gain and intruder position accuracy. Frequencies below C band are not expected to achieve required angle accuracy.

On the high frequency side, Ku band and higher can achieve required gain and position accuracy with smaller size but may need higher power to achieve required detection range.

Figure 6

Qualitative evaluation of parameters that affect choice of frequency band



### 4.2.4 Other technical considerations for aircraft-based detect and avoid

Another factor that must be taken into account in the determination of a suitable frequency for an airborne radar sensor is electromagnetic interference compatibility, both local compatibility on the UA, as well as compatibility with co-primary users of the spectrum. For example, if a UA is carrying another radar as part of its mission payload, one would prefer that the DAA sensor frequency be out-of-band from the mission payload radar in order to minimize interference between the two radars. In addition, the prevalence of other radars (e.g. weather radars) in a certain frequency band may impact the use of that frequency band for airborne DAA.

]

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

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

1) The spectrum analysis on suitability is limited to frequency band for which an allocation to radionavigation service or to aeronautical radionavigation service on a primary allocation.

[Editor’s note: Administrations are invited to provide rationale on the previous sentence.]

Worldwide allocation would be needed for certified UA but for open or some specific unmanned, regional allocation may be appropriate. The impact of regional harmonization compared to a global one will need to be addressed.

[Editor’s note: The consideration of regional allocation may be different is we dealing with airborne DAA or ground based DAA.]

2) Frequencies below 500 MHz are considered not suitable for DAA onboard aircraft equipment neither those above [40] GHz considering the technology not mature enough at this stage.

[Editor’s note: Administrations are invited to provide rationale on the previous sentence. For high frequency band that 40 GHz, there are RNS and ARNS allocations that might be also studied depending also of the conclusion of WRC-19.]

3) Coexistence with other incumbent services/existing applications

Some of the frequency bands currently allocated to the radionavigation service and/or the aeronautical radionavigation service may also be allocated to other services and used by other applications that would make difficult to use for DAA.

When a frequency band is allocated in the same band to one or more other services, co-existence has to be ensured taking into account priories identified in allocation footnotes and that RR No. **4.10** applies for the radionavigation service.

Where no priority between co-primary users exists, RR No. **4.10** also does not provide priority, so deployment of detect and avoid systems requires further analyses to determine compatibility with other services prior to its operational deployment.

4) Performance

[To be developed]

## 5.2 Analysis of suitability of frequency bands

[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 detect and avoid systems onboard unmanned aircraft

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 and co-existence with DAA systems onboard aircraft is not ensured. 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 DAA systems onboard UA.

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

#### 5.2.2.1 Allocations 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 service in the band 1 215-1 300 MHz.

Recommendations ITU-R M.1318, ITU-R M.1787, ITU-R M.1901, 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 bands 1 215-1 300 MHz.

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

#### 5.2.2.3 Suitability of the frequency band 1 215-1 300 MHz for detect and avoid systems onboard unmanned aircraft

While operation of DAA radars on UA is allowed in administrations and in frequency bands where No. **5.331** applies, there are many high powered ground based aviation and non-aviation radars that already operate in this band making coordination with DAA systems onboard UA difficult or impossible. The frequency band 1 215-1 300 MHz is also used for many aviation and non-aviation RNSS (space-to-Earth) receivers, and by RNSS (space-to-space) receivers. The frequency band 1 215-1 300 MHz is not suitable for DAA onboard UA due to the difficulty in coordinating with existing high powered ground based radars and the limited number of administrations where this band may be used. There could also be onboard compatibility issues since RNSS receivers can also be installed onboard aircraft.

### 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 frequency band 1 300-1 350 MHz for detect and avoid systems onboard unmanned aircraft

Operation of DAA systems onboard UA is not suitable due to ground based only restriction in RR No. **5.337** in the frequency band 1 300-1 350 MHz.

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

#### 5.2.4.1 Allocations 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[[4]](#footnote-4)\*** 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 1215‑1 300 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)[[5]](#footnote-5)\*** and **225 (Rev.WRC-07) [[6]](#footnote-6)\*\***. (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.1091, 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 frequency band 1 559-1 626.5 MHz for detect and avoid systems onboard unmanned aircraft

##### 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 DAA systems onboard unmanned aircraft.

##### 5.2.4.3.2 1 610-1 626.5 MHz

No restriction in the RR.

1 610-1 626.5 MHz is operated by various satellite systems and co-existence with DAA systems is not ensured.

This frequency band 1 610-1 626.5 MHz may be suitable for DAA systems onboard UA if compatibility with the various satellite systems that operate in this band is ensured and compatibility with RNSS (space-to-Earth) receivers operating in the adjacent 1 559-1 610 MHz frequency band is also ensured. There could also be onboard compatibility issues since these satellite systems can also be installed onboard aircraft.

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

#### 5.2.5.1 Allocations 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 frequency band 2 700-3 100 MHz for detect and avoid systems onboard unmanned aircraft

##### 5.2.5.3.1 2 700-2 900 MHz

Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.337** in the frequency band 2 700-2 900 MHz. Additionally, many radars are operated including for meteorological radars (RR No. **5.423**) making the 2 700-2 900 MHz frequency band not suitable for DAA systems onboard UA.

##### 5.2.5.3.2 2 900-3 100 MHz

Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.426** in the frequency band 2 900-3 100 MHz. Additionally, various radar systems operate in this band and co-existence with DAA systems onboard aircraft is not ensured.

The frequency band 2 900-3 100 MHz is considered not suitable for DAA systems onboard UA.

### 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 ITU-R 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[[7]](#footnote-7) and C92c[[8]](#footnote-8).

#### 5.2.6.3 Suitability of the frequency band 4 200-4 400 MHz for detect and avoid systems onboard unmanned aircraft

Operation of DAA systems onboard unmanned aircraft 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)[[9]](#footnote-9)\***. 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 5 010-5 030 MHz.

Recommendation ITU-R M.1827 contains technical and operational requirements for stations of the aeronautical mobile (R) service limited to surface application at airports in the frequency band 5 091-5 150 MHz.

Recommendation ITU-R M.1828 contains technical and operational requirements for aircraft stations of aeronautical mobile service limited to transmissions of telemetry for flight testing in the band 5 091-5 150 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 detect and avoid systems onboard unmanned aircraft

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 DAA systems onboard UA.

### 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[[10]](#footnote-10) 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[[11]](#footnote-11).

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 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 detect and avoid systems onboard unmanned aircraft

No restriction in the RR.

Noting that the use of the space research service (active) and radiolocation service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service, the band 5 350-5 470 MHz may be suitable for operation of DAA systems onboard UA. However, DAA systems should take all practicable measures to ensure the compatibility of the DAA system with the incumbent services in the band.

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 weather radar system that operate in the band 5 350-5 470 MHz and colocation of a DAA system on an aircraft that is also equipped with a weather radar that operates in this band may be difficult.

Operators need to be aware that the maritime radionavigation service also operates in the band 5 350-5 470 MHz and coordination between the two services may be required is some locations.

It is recommended that DAA system employ interference monitoring and channel switching techniques to minimize interference from aviation weather radars and other radars operating in this band. For more information see Technical Standard Order C212.

### 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[[12]](#footnote-12) 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[[13]](#footnote-13).

#### 5.2.9.3 Suitability of the frequency band 8 750-8 850 MHz for detect and avoid systems onboard unmanned aircraft

No restriction in the RR.

The band 8 750-8 850 MHz is suitable for operation of DAA systems onboard UA provided the DAA system employs Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. **5.470**.

DAA systems need to be compatible with existing aviation weather radar system that operate in the frequency band 8 750-8 850 MHz and colocation of a DAA system on an aircraft that is also equipped with a weather radar that operates in this band may be difficult.

It is recommended that DAA system employ interference monitoring and channel switching techniques to minimize interference from aviation weather radars and other radars operating in this band. For more information see Technical Standard Order C212.

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

#### 5.2.10.1 Allocations 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 detect and avoid systems onboard unmanned aircraft

Operation of DAA systems onboard UA is not suitable due to ground based only restriction in RR No. **5.337** in the frequency band 9 000-9 200 MHz.

### 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[[14]](#footnote-14) 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[[15]](#footnote-15).

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 detect and avoid systems onboard unmanned aircraft

##### 5.2.11.3.1 9 300-9 500 MHz

Operation of DAA systems onboard UA 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 DAA systems onboard UA.

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.

It is recommended that DAA system employ interference monitoring and channel switching techniques to minimize interference from other radars operating in this band. For more information see Technical Standard Order C212.

### 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[[16]](#footnote-16) contains the aviation standards for airborne DAA radars operating in the aeronautical radionavigation 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. Recommendation ITU-R M.2008-1 contains characteristics and protection criteria for these systems. Technical Standard Order C65a[[17]](#footnote-17) contains the aviation standards for these systems.

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 13.25-13.40 GHz. In addition, 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 detect and avoid systems onboard unmanned aircraft

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 DAA systems onboard UA is suitable provided the DAA system employs Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. **5.497**.

The use of the Earth exploration satellite (active) service shall not cause harmful interference to or, or constrain the use and development of, 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 and colocation of a DAA system on an aircraft that is also equipped with an aviation radar that operates in this band may be difficult. Further, compatibility with ground based DAA systems will also be required.

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 | | |
| 14.25-14.3FIXED-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 detect and avoid systems onboard unmanned aircraft

The frequency band 14-14.3 GHz is used for satellite uplinks and RR 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 the DAA systems onboard aircraft and the fixed service is not ensured.

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

### 5.2.14 Frequency band 15.4-15.7 GHz

#### 5.2.14.1 Allocations 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[[18]](#footnote-18) 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[[19]](#footnote-19).

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 Compatibility studies with systems operating within the band and in adjacent bands

##### 5.2.14.3.1 In-band compatibility study with systems of the radiolocation service

Characteristics of systems operating in the radiolocation service in the band 15.4-15.7 GHz can be found in:

• Rec. ITU-R 1730-1 “Characteristics of and protection criteria for the radiolocation service in the frequency band 15.4-17.3 GHz”.

##### 5.2.14.3.2 In-band compatibility study with systems of the fixed-satellite service

Technical and operational characteristics, as well as sharing and compatibility issues involving systems of the fixed-satellite service in the band 15.4 – 15.7 GHz are covered by:

• Rec. ITU-R S.1340-0 “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”;

• Rec. ITU-R S.1341-0 “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”.

##### 5.2.14.3.3 Compatibility study with systems of the radioastronomy service in adjacent band

Technical and operational characteristics, as well as sharing and compatibility issues involving systems of the fixed-satellite service in the band 15.35-15.4GHz are covered by:

• Rec. ITU-R S.1341-0 “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”;

• Rec. ITU-R RA.769-2 “Protection criteria used for radio astronomical measurements”.

##### 5.2.14.3.4 Compatibility study with systems of the radiolocation service in adjacent band

Characteristics of systems operating in the radiolocation service in the band 15.7-16.7 GHz can be found in:

* Rec. ITU-R 1730-1 “Characteristics of and protection criteria for the radiolocation service in the frequency band 15.4-17.3 GHz”.

#### 5.2.14.4 Suitability of the frequency band 15.4-15.7 GHz for detect and avoid systems onboard unmanned aircraft

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 ITU-R S.1341, the band 15.4-15.7 GHz is suitable for operation of DAA systems onboard UA. Further, compatibility with ground based DAA systems will also be required.

It is recommended that DAA system employ interference monitoring and channel switching techniques to minimize interference from other radars operating in this band. For more information see Technical Standard Order C212.

### 5.2.15 Frequency band 24.45-24.65 GHz

#### 5.2.15.1 Allocations 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[[20]](#footnote-20) 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.

There are no ITU-R Recommendations that 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.

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

#### 5.2.15.3 Suitability of the frequency band 24.45-24.65 GHz for detect and avoid systems onboard unmanned aircraft

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

##### 5.2.15.3.1 Region 1

Operation of DAA systems onboard UA 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 DAA systems onboard UA 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 DAA systems onboard UA 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)**.

### 5.2.16 Frequency band 31.8-33.4 GHz

#### 5.2.16.1 Allocations 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 |
| 31.8-32FIXED 5.547A  RADIONAVIGATION  SPACE RESEARCH (deep space) (space-to-Earth)  5.547 5.547B 5.548 | | |
| 32-32.3FIXED 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)**[[21]](#footnote-21)\*). 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)

**5.547A** Administrations should take practical measures to minimize the potential interference between stations in the fixed service and airborne stations in the radionavigation service in the 31.8-33.4 GHz band, taking into account the operational needs of the airborne radar systems.      (WRC‑2000)

**5.547B** Alternative allocation: in the United States, the band 31.8-32 GHz is allocated to the radionavigation and space research (deep space) (space-to-Earth) services on a primary basis.      (WRC‑97)

**5.547C** Alternative allocation: in the United States, the band 32-32.3 GHz is allocated to the radionavigation and space research (deep space) (space-to-Earth) services on a primary basis.      (WRC‑03)

**5.547D** Alternative allocation: in the United States, the band 32.3-33 GHz is allocated to the inter-satellite and radionavigation services on a primary basis.      (WRC‑97)

**5.547E** Alternative allocation: in the United States, the band 33-33.4 GHz is allocated to the radionavigation service on a primary basis.      (WRC‑97)

**5.548** In designing systems for the inter-satellite service in the band 32.3-33 GHz, for the radionavigation service in the band 32-33 GHz, and for the space research service (deep space) in the band 31.8-32.3 GHz, administrations shall take all necessary measures to prevent harmful interference between these services, bearing in mind the safety aspects of the radionavigation service (see Recommendation 707).      (WRC‑03)

#### 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[[22]](#footnote-22) 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 frequency band 31.8-33.4 GHz for detect and avoid systems onboard unmanned aircraft

[The frequency band 31.8-33.4 GHz is operated by various fixed systems and co-existence with DAA systems onboard aircraft is not ensured. Then, this frequency band 31.8-33.4 GHz is considered not suitable for DAA systems onboard UA, noting also that this frequency band is allocated to the space research service with receivers on the ground.]

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

### 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\_GROUND\_DAA], “Guidance on suitable frequency bands and services to be used by unmanned aircraft ground bases detect-and-avoid non-cooperative systems”. [↑](#footnote-ref-2)
3. *Global Air Traffic Management Operational Concept,* International Civil Aviation Organization Document 9854, First Edition, 2005. [↑](#footnote-ref-3)
4. \* This provision was previously numbered as No. **5.347A**. It was renumbered to preserve the sequential order. [↑](#footnote-ref-4)
5. \* *Note by the Secretariat:* This Resolution was revised by WRC-15. [↑](#footnote-ref-5)
6. \*\* *Note by the Secretariat:* This Resolution was revised by WRC-12. [↑](#footnote-ref-6)
7. Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-687a Airborne Low Range Radar Altimeter, 31 May 2012. [↑](#footnote-ref-7)
8. 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-8)
9. \* *Note by the Secretariat:*  This Resolution was revised by WRC-15. [↑](#footnote-ref-9)
10. 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-10)
11. 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-11)
12. 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-12)
13. 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-13)
14. 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-14)
15. 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-15)
16. 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-16)
17. 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-17)
18. 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-18)
19. 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-19)
20. 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-20)
21. \* *Note by the Secretariat:*  This Resolution was revised by WRC-12. [↑](#footnote-ref-21)
22. 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-22)