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| **U.S. Radiocommunications Sector**  **Fact Sheet** | |
| **Working Party:** ITU-R WP-5B | **Document No:** USWP5B35-15 |
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| **Document Title:** **WORKING DOCUMENT TOWARDS A HANDBOOK ITU-R M. [HDBK\_STATUS.SPECTRUM.RPAS\_DAA]** - Handbook on status of availability of spectrum for detect-and-avoid radars [onboard] remotely piloted aircraft. | |
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| **Purpose/Objective:** This Handbook is intended as a replacement for Report ITU-R M.2204-0 (11/2010) “Characteristics and spectrum considerations for sense and avoid systems used on unmanned aircraft systems”. Earlier efforts were made to update to Report ITU-R M.2204-0 however, it was decided that a Handbook would be a more appropriate location to catalog the information currently found in the report. This new ITU-R Handbook will provide information on appropriate frequency bands for Detect and Avoid (DAA) radar systems onboard unmanned aircraft or for ground based DAA radar systems to support unmanned aircraft operations. | |
| **Abstract:** This contribution continues the process of developing a new ITU-R Handbook for unmanned aircraft DAA system by addressing comments received from other administrations during previous ITU-R WP 5B meetings. This new Handbook will explore 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 or on the ground in support of unmanned aircraft operations. | |

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| WORKING DOCUMENT TOWARDS A HANDBOOK ITU-R M. [HDBK\_STATUS.SPECTRUM.RPAS\_DAA] | |
| Handbook on status of availability of spectrum for  detect-and-avoid radars [onboard] remotely piloted aircraft | |

**Introduction**

This Handbook is intended as a replacement for Report ITU-R M.2204-0 (11/2010) “Characteristics and spectrum considerations for sense and avoid systems used on unmanned aircraft systems”. Earlier efforts were made to update to Report ITU-R M.2204-0 however, it was decided that a Handbook would be a more appropriate location to catalog the information currently found in the report. This new ITU-R Handbook will provide information on appropriate frequency bands for Detect and Avoid (DAA) radar systems onboard unmanned aircraft or for ground based DAA radar systems to support unmanned aircraft operations.

**Proposal**

This contribution continues the process of developing a new ITU-R Handbook for unmanned aircraft DAA system by addressing comments received from other administrations during previous ITU-R WP 5B meetings. This new Handbook will explore 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 or on the ground in support of unmanned aircraft operations.

**Attachment:** 1

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| **ATTACHMENT** |
| WORKING DOCUMENT TOWARDS A HANDBOOK ITU-R M. [HDBK\_STATUS.SPECTRUM.RPAS\_DAA] |
| **Handbook on status of availability of spectrum for  detect-and-avoid radars [onboard] remotely piloted aircraft** |

(202X)

[Editor’s note: The text below has not been discussed nor agreed. Some parts of the text are extracted from existing documents from ITU-R and aviation standardization. There is no intention to have any action in link with any agenda item.]

Preface

[TBD]

Foreword

[TBD]

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# 1 Introduction

## 1.1 Detect and avoid radars for remotely piloted aircraft systems

Remotely piloted aircraft (RPA) 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 safe operation of Remotely piloted aircraft systems (RPAS) 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 systems like ACAS (Airborne Collision Avoidance System) already used for manned aircraft can be used also for RPAS to avoid cooperative aircraft specific systems are expected to avoid collision with non-cooperative aircraft: detect and avoid (DAA) radars.

## 1.2 Objective

The present ITU-R Report provides a status of the availability of spectrum for detect and avoid radars for non-cooperative aircraft onboard remotely piloted aircraft.

The intent is to study spectrum allocated to radionavigation or aeronautical radionavigation services in which onboard DAA radars could operate on a worldwide basis. The R.R. No. **4.10** stipulates that “Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies”.

Consequently, if a frequency band allocated to radionavigation or aeronautical services is used or planned to be used for another application in the same service or in another service by a spectrum regulator on its territory, then it would not be possible to operate worldwide onboard DAA radars unless compatibility could be ensured with these applications.

For example, the case of radio-altimeters onboard aircraft in the frequency band 4200-4400 MHz is a typical safety of life system operated worldwide under the radionavigation service.

[Among the different type of applications for DAA and the complexity to find appropriate spectrum, it should be noted that priority should be given to detect and avoid onboard aircraft aiming to be operated worldwide. Indeed, these types of DAA require an agreement from overall countries. For ground DAA covering a delimited area, the selection of relevant spectrum would be much more flexible.]

## 1.3 Terminology

**Control and non-payload communications:** The radio links, used to exchange information between the RPA and RPA control station (CS), that ensure safe, reliable, and effective RPA flight operation. The functions of command and non-payload communication (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 (to define the origin of this description)

**Intruder:** An aircraft that enters the DAA surveillance volume and tracked by the DAA system.

**Remotely piloted aircraft:** Designates types of aircraft remotely controlled for category certified.

**Remotely piloted aircraft control station:** Facilities from which a RPA is controlled remotely.

**Remotely piloted aircraft systems**: Consists of the following subsystems:

– Remotely piloted aircraft;

– Aircraft control station;

– Control non payload communication;

– Air traffic control (ATC) communications subsystem

– DAA radars;

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

**Separation provision:** The tactical process of keeping aircraft away from hazards by at least the appropriate separation minima.

**Separation minima:** The minimum displacements between an aircraft and a hazard which maintain the risk of collision at an acceptable level of safety.

**Strategic conflict management:** Airspace organization and management, demand and capacity balancing and traffic synchronization components.

## 1.4 Related ITU recommendations and reports

Recommendations

[ITU-R M.1372-1](https://www.itu.int/rec/R-REC-M.1372/en) *Efficient use of the radio spectrum by radar stations in the radiodetermination service*

[ITU-R M.1638-1](https://www.itu.int/rec/R-REC-M.1638/en) *Characteristics of and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 MHz*

[ITU-R M.1796-2](https://www.itu.int/rec/R-REC-M.1796/en) *Characteristics of and protection criteria for terrestrial radars operating in the radiodetermination service in the frequency band 8 500-10 680 MHz*

[ITU-R M.2007](https://www.itu.int/rec/R-REC-M.2007/en) *Characteristics of and protection criteria for radars operating in the aeronautical radionavigation service in the frequency band 5 150-5 250 MHz*

[ITU-R M.2008-1](https://www.itu.int/rec/R-REC-M.2008/en) *Characteristics and protection criteria for radars operating in the aeronautical radionavigation service in the frequency band 13.25-13.40 GHz*

*TBD*

Report

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

# 2 Principles of detect and avoid

[Editor’s note: this section is copied from [ITU-R M.2204](https://www.itu.int/pub/R-REP-M.2204) released in 11/2010 and needs to be updated with the last up to date information that may be asked to ICAO.]

## [2.1 Detect and avoid systems

The principle of a DAA 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.

Figure 1

Layered collision avoidance approach

Diagram

Description automatically generated

## 2.2 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. Using the three layer approach described in ICAO Document 9854 (strategic conflict management, separation provision, and collision avoidance) for conflict management will limit, to an acceptable level, the risk of collision between aircraft and hazards. ICAO Doc 10019 specifically defines conflict management approach towards DAA. As shown in Figure 1, The DAA system provides the “remain well clear” function as the separation provision and “collision avoidance” function as the collision avoidance.

Figure 2

Three layers of conflict management approach towards detect and avoid

Diagram

Description automatically generated

### 2.2.1 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.

### 2.2.2 Remain well clear/separation provision

In this phase, actions are undertaken by all participants to ensure the safe execution of the flight depending on the airspace classification. Separation provisions by ATC and “remain-well-clear (RWC)” by pilots/remote pilots are utilized in this phase. At the remain well clear level of DAA, the system identifies the pilot to a potential violation of the DAA Remain 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.

### 2.2.3 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. As indicated in the figure above, DAA systems are expected to perform the collision avoidance function in addition to the “remain well clear function”.

## 2.3 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 3

Detect and avoid sensor performance requirement factors

A close-up of a sign

Description automatically generated

### 2.3.1 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 the intruder, the selected NMAC or remain 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 4

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

Graphical user interface, application

Description automatically generated

### 2.3.2 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 manoeuvrable 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 5

Collision encounter timeline

Graphical user interface, chart

Description automatically generated

### 2.3.3 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, size weight and power (SWAP) and the required accuracy of intruder position (as measured by angular and range resolution) will affect determination of a suitable frequency for an airborne radar sensor.

### 2.3.4 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 6

Plot of atmospheric absorption at microwave frequencies



### 2.3.5 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 7

Qualitative evaluation of parameters that affect choice of frequency band



### 2.3.6 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.

## 2.4 Ground-based detect and avoid

The radiofrequency part of a ground-based detect and avoid (GBDAA) for unmanned aircraft could use already existing air traffic control systems to locate and provide information on the location of the various aircraft in the considered by UAS for DAA purposes. However, air traffic control systems are not optimized to meet the needs of small low flying UAs. Therefore, additional GBDAA is needed to augment existing air traffic control surveillance.

GBDAA systems detect and generate tracks within its Declaration Volume (DV) of airborne traffics. Unlike air traffic control radars, DAA radars detect aircraft that fly at relatively low altitudes with smaller radar cross-sections.

As with the ABDAA, GBDAA compliments other surveillance sensors by providing detection of non-cooperative traffic (i.e., those without operating transponders or ADS-B Out capabilities). Aircraft tracks are established at sufficient range and accuracy to enable an UA flying within GBDAA Operational Volume (OV) to remain well clear of other aircraft.

FIGURE 8

Ground-based detect and avoid

Diagram, map

Description automatically generated

In some cases, there are no significant differences between the GBDAA and ABDAA systems. The requirements are simply to support the safety case, whether that’s achieved with airborne sensors, ground-based sensors, or both. However, it should be noted that the capability of ground-based vs airborne radar is different. A GBDAA radar looking up can see both in front and behind and aircraft of interest, whereas an ABDAA radar onboard the aircraft is generally pointed in the direction of flight and can only detect objects across a field of view in the direction it is flying. Additionally, smaller UAS are limited in the size and power of radar they can carry, whereas ground-based radar has less limitation with regards to size or weight of the DAA radars. There are also different technical challenges; for example, with GBDAA where line-of-sight over hills and buildings will need to be considered during implementation whereas with ABDAA implementation may require careful consideration of ground clutter (and returns from objects on the ground more generally) at low altitudes.

GBDAA systems use ground-based sensor as the surveillance sensor and may have multiple GBDAA sensors to cover the necessary Surveillance Volume. The GBDAA can be utilized to enable transit operations, or operations at lower altitudes in area near airports as well as to enable extended operations.]

## 3 Status of the uses of the frequency bands allocated to frequency bands allocated to radionavigation or aeronautical radionavigation services

## 3.1 Extract from Report ITU-R M.2204

Relevant extracts from the Report ITU-R M.2204 (2010) are reflected below:

“There are currently five frequency bands allocated to ARNS that are used to support airborne aeronautical radionavigation radar systems worldwide. These bands are listed in Table 3. There are currently existing standards for these airborne radars in all of these bands.

TABLE 3

ARNS allocations for airborne radars

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Band | Status | Applicable RR  (Edition of 2008) footnotes | Example of Aviation Standards | ITU-R Recommendations |
| 4 200-4 400 MHz | primary | 5.438, 5.439, 5.440 | C67(1), C92c(2) |  |
| 5 350-5 470 MHz | primary | 5.449, 5.448B, 5.448C, 5.448D | C63c(3) | M.1638 |
| 8 750-8 850 MHz | primary | 5.470, 5.471 | C65a(4) | M.1796 |
| 9 300-9 500 MHz | primary | 5.474, 5.475, 5.475A, 5.475B, 5.476 | C65c(3) | M.1796 |
| 13.250-13.400 GHz | primary | 5.497, 5.498A, 5.499 | C65a(4) |  |
| (1) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C67, Airborne Radar Altimeter Equipment (For Air Carrier Aircraft), 15 November 1960.  (2) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C67, Airborne Ground Proximity Warning Equipment, 19 March 1996.  (3) 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.  (4) 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 | | | | |

There are currently twelve other frequency bands allocated to ARNS that are used to support a variety of ARNS applications. These bands are listed in Table 5. There are existing standards for the ARNS systems in many of these bands. It should be noted that some of these bands may be appropriate for ABS&A or GBS&A radars.

TABLE 5

Frequency band allocated to ARNS allocations

| Band | Status | Applicable RR (Edition of 2008) footnotes | Example of Aviation Standards | ITU-R Recommendations |
| --- | --- | --- | --- | --- |
| 190-285 kHz | primary | 5.68, 5.69, 5.70, 5.71 | C41d(1) |  |
| 325-405kHz | primary | 5.72 | C41d(1) |  |
| 415-435 kHz | primary | 5.72 | C41d(1) |  |
| 510-535 kHz | primary | 5.72 | C41d(1) |  |
| 74.8-75.2 MHz | primary | 5.180, 5.181 | C35d(2) |  |
| 108-117.975MHz | primary | 5.197, 5.197A, | C36e(3), C40c(4) |  |
| 328.6-335.4 MHz | primary | 5.258, 5.259 | C34e(5) |  |
| 960-1 215 MHz | primary | 5.328, 5.328A | C66c(6) |  |
| 5 000-5 030 MHz | primary | 5.367 |  |  |
| 5 030-5 150 MHz | primary | 5.367, 5.444, 5.444A, 5.446, 5.447, 5.447B, 5.447C | C104(7) |  |
| 5 150-5 250 MHz | primary | 5.367, 5.444, 5.444A, 5.446, 5.447, 5.447B, 5.447C |  | M.1454, S.1426,  S.1427 |
| 15.400-15.700 GHz | primary | 5.511A, 5.511C, 5.511D | C63c(8) | S.1340, S.1341 |
| (1) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C41d, Airborne Automatic Direction Finding (ADF) Equipment, 6 May 1985.  (2) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C35d, Airborne Radio Marker Receiving Equipment, 5 May 1971.  (3) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C36e, Airborne ILS Localizer Receiving Equipment Operating within the Radio Frequency Range of 108-112 Megahertz (MHz), 25 January 1988.  (4) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C40c, VOR Receiving Equipment Operating within the Radio Frequency Range of 108-117.95 Megahertz (MHz), 25 January 1988.  (5) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C34e, Airborne ILS Glide Slope Receiving Equipment Operating within the Radio Frequency Range of 328.6-335.4 Megahertz (MHz), 15 January 1988.  (6) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C66c, Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz (MHz), 18 January 1991.  (7) Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington DC, Technical Standard Order TSO-C93, Microwave Landing System (MLS) Airborne Receiving Equipment, 22 June 1982.  (8) 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. | | | | |

Many of the existing ARNS are already in use and the existing users of these bands will need to be considered when selecting ARNS bands for S&A applications.

## 3.2 Existing DAA systems

**4.1.1 Existing DAA systems in the 2 700-2 900 MHz band**

**4.1.1.1 Description DAA system in the 2 700-2 900 MHz band**

The frequency band 2 700-2 900 MHz is allocated to the Aeronautical Radionavigation and the radionavigation services on primary basis and the following footnotes are applicable:

**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.

**4.1.1.2 Compatibility of DAA system in the 2 700-2 900 MHz band with other services and systems**

Operation of ground based DAA systems in the 2 700-2 900 MHz is possible however, many aviation radars already operate in this band and these radars are typically found at airports. In addition meteorological radars (RR No. **5.423**) are also operated in this band. The 2 700-2 900 MHz frequency band can be used to support ground based DAA systems located beyond major airports and away from meteorological radars.

Operation of DAA systems on-board unmanned aircraft is not compatible in the 2 700-2 900 MHz band due to ground based only restriction in RR No. **5.337** and the potential for interference with existing aviation and meteorological radars in the band. Due to the operation of existing ground based aviation and meteorological radars in this band, it is unlikely that DAA systems on-board UA could operate compatibly with the existing systems.

**4.1.2 Existing DAA systems in the 9 000-9 200 MHz band**

**4.1.2.1 Description of DAA system in the 9 000-9 200 MHz band**

The frequency band 9 000-9 200 MHz is allocated to the Aeronautical Radionavigation and the Radiolocation Services on a primary basis and the following footnotes are applicable:

**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)

**4.1.2.2 Compatibility of DAA system in the 9 000-9 200 MHz bandwith other services and systems**

Operation of ground based DAA systems in the 9 000-9 200 MHz is possible however, ground based DAA systems will need to be compatible with existing aviation surveillance radar system which are typically found at airports. As a result, location of a DAA system on some airports may be difficult in this band. The 9 000-9 200 MHz frequency band can be used to support ground based DAA systems located beyond major airports.

In some administrations maritime radionavigation radar systems are employed for shore-based applications and coordination of ground based DAA systems with these maritime radars will be necessary.

Operation of DAA systems on-board unmanned aircraft is not compatible in the 9 000-9 200 MHz band due to ground based only restriction in RR No. **5.337** and the potential for interference with existing aviation radars in the band. Due to the operation of existing ground based aviation radars in this band, it is unlikely that DAA systems on-board UA could operate compatibly with the existing aviation systems.

**4.1.3 Existing DAA systems in the 13.25-13.4 GHz band**

**4.1.3.1 Description of DAA system in the 13.25-13.4 GHz band**

The frequency band 13.25-13.4 GHz is allocated to the Aeronautical Radionavigation, the Earth exploration-satellite (active), and the space research (active) services on a primary basis and the following footnotes are applicable:

**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)

**4.1.3.2 Compatibility of DAA system in the 13.25-13.4 GHz bandwith other services and systems**

Operation of ground based or airborne DAA systems in the band 13.25-14 GHz will need to be compatible with existing aviation radar system that operate in the band 13.25-13.4 GHz. An example of an existing aeronautical radionavigation system can be found in ITU-R Recommendation M.2008-1. Colocation of a DAA system on an aircraft that is also equipped with an aviation radar that operates in this band may be difficult to achieve. Further, DAA systems in the band 13.25-14 GHz must employ Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. **5.470**.

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.

**4.2 New systems DAA under consideration**

**4.2.1 Description DAA system X**

5.0 Conclusions

5.1 Summary A

*[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** | **Suitability for Ground DAA** | **Reason/Recommendation** |
| --- | --- | --- | --- |
| **960-1 215 MHz** | This frequency band is not suitable for DAA systems onboard UA | This frequency band 960-1 215 MHz is not suitable for ground DAA systems | Co-existence with DAA systems onboard aircraft is not ensured due to the presence of various aeronautical systems. The use of RNSS (space-to-Earth) and (space-to-space) services in 1 164-1 215 MHz on a ubiquitous basis, presents additional co-existence issues |
| **1 215-1 300 MHz** | 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. | The frequency band 1 215-1 300 MHz may be suitable for Ground DAA. | *[TBD]* |
| **2 700-2 900 MHz** | This frequency band is not suitable for DAA systems onboard UA | This frequency band is suitable for ground DAA systems | Operation of ground based DAA systems located beyond major airports are suitable. Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.337** |
| **2 900-3 100 MHz** | This frequency band is not suitable for DAA systems onboard UA | This frequency band is suitable for ground DAA systems | Operation of the ground based DAA systems shall be compatible with maritime radars that operate in this band. Compatibility with shipboard maritime radionavigation systems is a significant issue.  Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.337** |
| **9 000-9 200 MHz** | This frequency band is not suitable for DAA systems onboard UA | This frequency band is suitable for ground DAA systems | Noting that the use of the radiolocation service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service, the band is suitable for operation of ground based DAA systems. Operation of DAA systems onboard UA is for ground based as per restriction in RR No. **5.337** |
| **13.25-13.4 GHz** | This frequency band is suitable for DAA systems onboard UA | This frequency band is not suitable for ground DAA systems | Operation of ground based DAA systems is suitable provided the DAA system employs Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. **5.470**.  DAA systems shall avoid chance of interference causing the premature obsolescence of in-orbit EESS (active) assets.  Compatibility between existing aviation radar system and ground DAA system may be difficult. Further, compatibility with ground based DAA systems will also be required. |
| **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] |  |

5.2 Summary B

| Frequency bands allocated to Radionavigation or Aeronautical radionavigation | Current or planned uses | Suitability for airborne DAA | Reason/Recommendation |
| --- | --- | --- | --- |
| 190-285 kHz | Non Directional Beacons and Locators | [Not suitable due to the characteristics of HF bands] |  |
| 325-405kHz | Non Directional Beacons and Locators | [Not suitable due to the characteristics of HF bands] |  |
| 415-435 kHz | Non Directional Beacons and Locators | [Not suitable due to the characteristics of HF bands] |  |
| 510-535 kHz | Non Directional Beacons and Locators | [Not suitable due to the characteristics of HF bands] |  |
| 74.8-75.2 MHz | Markers | [Not suitable] |  |
| 108-117.975MHz | VHF voice communication  VHF omnidirectional range (VOR)  Instrument landing system (ILS) (Localiser)  Ground based augmentation system (GBAS)VHF data link Mod 2 | [Not suitable] | [This band is already significantly used by other civil aviation systems] |
| 328.6-335.4 MHz | Instrument landing system (ILS) | [Not suitable] | [No 5.258 states “the use of the band 328.6-335.4 MHz by the aeronautical radionavigation service is limited to Instrument Landing Systems (glide path)”] |
| 960-1 215 MHz | Distance measuring equipment (DME)  Universal Access Transceiver (UAT)  Automatic dependant surveillance-broadcasting (ADS-B)  L-Band datalink communication system (LDACs)  Secondary Surveillance RADAR (SSR)  Airborne Collision Avoidance System (ACAS)  Radio navigation satellite service | This frequency band is not suitable for DAA systems onboard RPA | Co-existence with DAA systems onboard aircraft is not ensured due to the presence of various aeronautical systems. The use of RNSS (space-to-Earth) and (space-to-space) services in 1 164-1 215 MHz on a ubiquitous basis, presents additional co-existence issues |
| 2 700-2 900 MHz | Surveillance radars  Meteorological radars | This frequency band is not suitable for DAA systems onboard RPA | Operation of ground based DAA systems located beyond major airports are suitable. Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.337** |
| 2 900-3 100 MHz | Maritime radars  Surveillance radars | This frequency band is not suitable for DAA systems onboard RPA | Operation of the ground based DAA systems shall be compatible with maritime radars that operate in this band. Compatibility with shipboard maritime radionavigation systems is a significant issue.  Operation of DAA systems onboard unmanned aircraft is not suitable due to ground based only restriction in RR No. **5.337** |
| 4 200-4 400 MHz | Radio-altimeters  Wireless aviation intra-communication | This frequency band is not suitable for DAA systems onboard RPA | [No 5.438 indicates “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)”] |
| 5 350-5 470 MHz | Ground meteorological radars  Governmental radars  Earth exploration satellite service (active) | This frequency band is not suitable for DAA systems onboard RPA | This frequency band is identified for on-board weather radars. Ground meteorological and governmental radars are widely or planned to be deployed in that frequency band. Furthermore Earth exploration satellite service (active) operates in this frequency band. Due to the heavily usage, significant sharing and compatibility challenges already occurs between these systems. Coexistence between these systems and DAA would then not be possible. |
| 8 750-8 850 MHz | Airborne radars | This frequency band is not suitable for DAA systems onboard RPA |  |
| 9 000-9 200 MHz | Ground meteorological radars  Primary surveillance radars | This frequency band is not suitable for DAA systems onboard RPA | Noting that the use of the radiolocation service shall not cause harmful interference to nor claim protection from the aeronautical radionavigation service, the band is suitable for operation of ground-based DAA systems. Operation of DAA systems onboard RPA is for ground based as per restriction in RR No. **5.337** |
| 9 300-9 500 MHz | Ground meteorological radars  On-board weather radars | This frequency band is not suitable for DAA systems onboard RPA | Most of on-board weather radars are deployed in this frequency band. This frequency band is also heavily used by governmental, aviation, maritime and weather applications. There are already significant compatibility challenges faced between the systems operated in incumbent services allocated in the frequency band. Additionally, the deployment of two air-to-air radars on the same aircraft would be hardly achievable. [No 5.475 indicates “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.”] |
| 13.25-13.4 GHz | Airborne radars  Satellite altimeter | [TBD] | Operation of ground based DAA systems is suitable provided the DAA system employs Doppler frequency shift processing to comply with the Doppler aids requirement in RR No. **5.470**.  Coexistence of DAA with EESS (active) would be difficult if Doppler radar are not limited to antenna pointing towards the ground.  Compatibility between existing aviation radar system and ground DAA system may be difficult. Further, compatibility with ground based DAA systems will also be required. |
| 14-14.3 GHz | Earth station transmission | This frequency band is not suitable for DAA systems onboard RPA |  |
| 15.4-15.7 GHz | Airborne radars | This frequency band is promising to be suitable for DAA systems onboard RPA for worldwide applications |  |
| 24.45-24.65 GHz | IMT | This frequency band is not suitable for DAA systems onboard RPA |  |
|  | [TBD]  in Region 2 |  |
|  | [TBD]  in Region 3 |  |
| 31.8-33.4 GHz | Fixed service (High density)  Enhanced flight vision system | This frequency band is not suitable for DAA systems onboard RPA |  |
| 43.5-47.0 GHz |  | [TBD] |  |
| 66.0-71.0 GHz |  | [TBD] |  |
| 95.0-100.0 GHz | Enhanced flight vision system | This frequency band is not suitable for DAA systems onboard RPA |  |
| 123.0-130.0 GHz |  | [TBD] |  |
| 191.8-200.0 GHz |  | [TBD] |  |
| 235.0-238.0 GHz |  | [TBD] |  |