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| **U.S. Radiocommunications Sector**  **Fact Sheet** | |
| **Working Party:** ITU-R WP-5B | **Document No:** USWP5B28-13-Final |
| **Ref:** Annex 18 to Document 5B/481-E | **Date:** 20 January 2022 |
| **Document Title:** WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R M.[15.4-15.7\_GHz\_ARNS] - Characteristics of and protection criteria for radars operating in the aeronautical radionavigation service in the frequency band 15.4-15.7 GHz. | |
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| **Purpose/Objective:** The purpose of this contribution is to continue to develop a new recommendation for aeronautical radionavigation systems, including unmanned aircraft systems (UAS) Detect and Avoid (DAA) radar systems, in the 15.4-15.7 GHz band. | |
| **Abstract:** This contribution will continue the process of developing a new recommendation containing characteristics of and protection criteria for systems that operate in the 15.4-15.7 GHz aeronautical radionavigation service allocation including UAS DAA systems. This contribution will be an update to the new report found in Annex 18 of the Chairman’s Report of the 21 December 2021 Document 5B/481-E meeting. | |

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| **Radiocommunication Study Groups** |  |
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| Received: 19 November 2021  Source: Document 5B/TEMP/123  Subject: New Recommendation ITU-R M.[15.4-15.7\_GHZ\_ARNS] | **Document 5B/xx** |
| **Xx March 2022** |
| **English only** |
| **United States of America** | |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW  RECOMMENDATION ITU-R M.[15.4-15.7\_GHz\_ARNS][[1]](#footnote-1)\* | |
| **Characteristics of and protection criteria for radars operating in the  aeronautical radionavigation service in the frequency  band 15.4-15.7 GHz** | |

**Introduction**

This document proposed new Recommendation is intended to provide characteristics and protection criteria for aeronautical radionavigation systems, including unmanned aircraft (UA) Detect and Avoid (DAA) radar system operating in the aeronautical radionavigation service (ARNS) in the frequency band 15.4-15.7 GHz. The revision of this Recommendation updates Table 1 for the representative technical parameters of radionavigation radar and Table 2 with technical parameters of landing systems. Updates were also made to *recommends* section, in Section 2 for the Ground DAA radar and in Section 4 for protection criteria. These technical and operational characteristics are to be used as a guideline in analyzing compatibility between radars operating in the aeronautical radionavigation service and systems in other services within this band.

**Proposal**

To provide the necessary characteristics for sharing studies with other systems in this band.

**Attachment**: 1

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| **Radiocommunication Study Groups** |  |
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| Source: Document 5B/TEMP/174  Subject: New Recommendation ITU-R  M.[15.4-15.7\_GHZ\_ARNS] | **Annex 18 to Document 5B/481-E** |
| **17 February 2022** |
| **English only** |
| Annex 18 to Working Party 5B Chairman’s Report | |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW  RECOMMENDATION ITU-R M.[15.4-15.7\_GHZ\_ARNS] | |
| Characteristics of and protection criteria for radars operating in the  aeronautical radionavigation service in the frequency  band 15.4-15.7 GHz | |

(202X)

Scope

This Recommendation specifies the characteristics and protection criteria of radars operating in the aeronautical radionavigation service (ARNS) in the frequency band 15.4-15.7 GHz. The technical and operational characteristics should be used in analysing compatibility between radars operating in the aeronautical radionavigation service and systems in other services.

Keywords

15.4-15.7 GHz, radar, characteristics, protection.

Abbreviations/Glossary

ATC Air traffic control

ARNS: Aeronautical radionavigation service

ABDAA Airborne detect and avoid

DAA: Detect and avoid

e.i.r.p: Effective isotropically radiated power

ESA: Electronically scanned array

FMCW: Frequency-modulated continuous wave

GBDAA Ground based detect and avoid

LFM: Linear frequency modulation

PSD: Power spectral density

RR: Radio Regulation

UA: Unmanned aircraft

UAS: Unmanned aircraft system

Related ITU Recommendations, Reports

*Recommendation*

[ITU-R S.1340](https://www.itu.int/rec/R-REC-S.1340-0-199710-I/en) 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

[ITU-R M.1372](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.1730](https://www.itu.int/rec/R-REC-M.1730/en) Characteristics of and protection criteria for the radiolocation service in the frequency band 15.4-17.3 GHz

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)

The ITU Radiocommunication Assembly,

considering

*a)* that antenna, signal propagation, target detection, and wide necessary bandwidth of radar required to achieve their functions are optimum in certain frequency bands;

*b)* that the technical characteristics of radars operating in the aeronautical radionavigation service (ARNS) are determined by the mission of the system and vary widely even within a frequency band,

recognizing

*a)* that the frequency band 15.4-15.7 GHz is allocated on a primary basis to aeronautical radionavigation, and radiolocation services, and that the fixed-satellite service (Earth-to-space) is also allocated on a primary basis in the frequency band 15.43-15.63 GHz;

*b)* that the radiolocation services operating in the frequency band 15.4-15.7 GHz shall not cause harmful interference to, or claim protection from the aeronautical radionavigation service;

*c)* that numerous features of radiodetermination radars can be expected to help suppress low-duty cycle (less than 5%) pulsed interference, especially from a few isolated sources. Techniques for suppression of low-duty cycle pulsed interference between two or more pulsed system are contained in Recommendation ITU-R M.1372 – Efficient use of the radio spectrum by radar stations in the radiodetermination service;

*d)* that the fixed-satellite service (Earth-to-space) operating in the frequency band 15.43‑15.63 GHz is limited to feeder links of non-geostationary systems in the mobile-satellite service and is subject to coordination under Radio Regulation (RR) No. **9.11A**;

*e)* that the limit of effective isotropically radiated power (e.i.r.p) of stations operating in the aeronautical radionavigation service is provided in Recommendation ITU-R S.1340;

*f)* that for stations operating in the fixed-satellite service (Earth-to-space), the minimum coordination distance required to protect the aeronautical radionavigation stations (RR 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 are provided in Recommendation ITU-R S.1340;

*g)* that for some specific systems performance requirements may be available,

recommends

1 that the technical and operational characteristics of the radars operating in the ARNS described in the Annex should be considered representative of those operating in the frequency band 15.4-15.7 GHz and used in studies of compatibility with systems in other services;  
2 that the criterion of interfering signal power to radar receiver noise power level (*I*/*N)* of [−6 dB/−10 dB], should be used as the required protection level for the aeronautical radionavigation radars, and that this represents the aggregate protection level if multiple interferers are present;

[Editor’s Note: The essence of deleted text and footnote in recommends 2 has been addressed in Section 4, Protection criteria by referencing elements from ITU-R M.1372 and ITU-R M.1730.]

[Editor’s Note: The essence of recommends 3 has been incorporated into recognizing c).]

Annex  
  
Technical and operational characteristics of radars operating in the  
aeronautical radionavigation service in the  
frequency band 15.4-15.7 GHz

# 1 Introduction

ARNS system operates on a primary basis in the frequency band 15.4-15.7 GHz. This Annex presents the technical and operational characteristics of representative ARNS radars operating in this frequency band.

Some ARNS systems are installed in unmanned aircraft (UA) or on the ground to detect non-cooperative aircraft as a surveillance system contributing to the UA detect and avoid (DAA) system. These radars are used for collision avoidance on-board UA and can be used as a part of the integration of unmanned aircraft system (UAS) [in non-segregated airspace.]

Some ARNS systems are used for landing.

# 2 Characteristics of aeronautical radionavigation detect and avoid radar

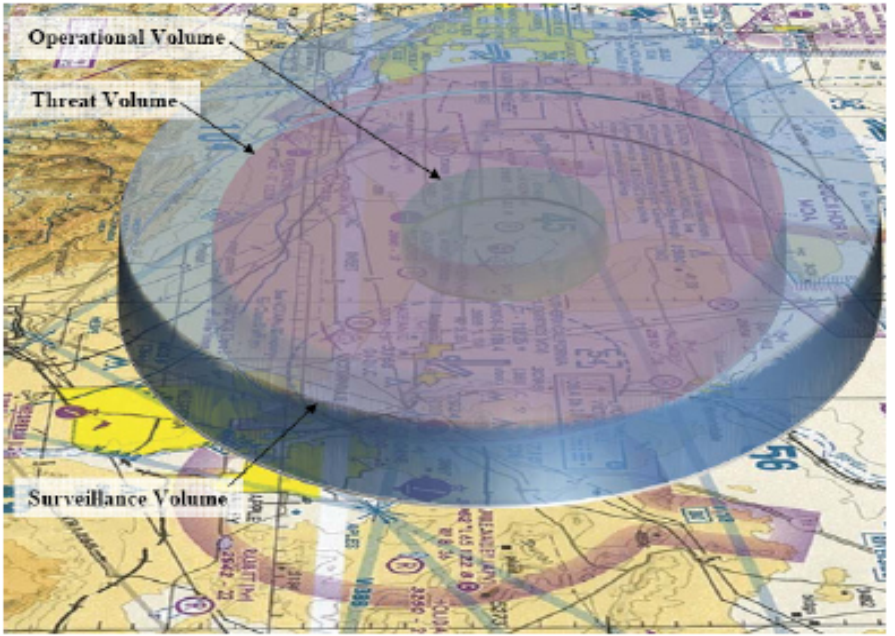
Unmanned aircraft are powered, aircraft that do not carry a human pilot, use aerodynamic forces to provide vehicle lift, and may fly semi-autonomously or autonomously, or be piloted remotely. The safe flight operation of UA in non-segregated airspace necessitates advanced techniques to detect and track nearby aircraft, terrain, remain well clear of obstacles, and properly act and respond to certain weather conditions. UA must avoid these objects in the same manner as manned aircraft. Two primary sensor systems are operational to allow a UAS to meet this requirement. The first class comprises sensor(s) or electronic system(s) on the air vehicle and is called airborne detect and avoid (ABDAA). The second class involves sensor(s) or electronic system(s) monitoring the air space from the ground and is refer to as ground based DAA (GBDAA).

The goal of airspace access for appropriately equipped UA systems is to achieve a level of safety equal to that of an aircraft with a pilot in the cockpit. The remote pilot will need to be aware of the environment within which the aircraft is operating, be able to identify the potential threats to the continued safe operation of the aircraft and take the appropriate action. In order for UAS to operate in non-segregated civil airspace, they must be integrated safely and adhere to current operational rules that provide an acceptable level of safety similar to that of a conventional manned aircraft. The DAA radar is part of an unmanned aircraft collision avoidance system whose primary function is to provide the capability to detect, track and report non-cooperative air traffic information to the remote pilot in order to maintain adequate separation from intruders. The system utilizes a “Pilot-in-the-Loop” approach in which the ground-based UA pilot will have final authority regarding UAS manoeuvres to avoid other aircraft (manned or unmanned).

The safe operation of UAS outside segregated airspace requires addressing the same issues as manned aircraft, namely integration into the air traffic control (ATC) system. There are scenarios that occur when traditional existing ground-based surveillance radars are unable to detect the UA when they are flying at low altitude. These scenarios are caused by terrain, man-made structures, flight below normal radar coverage and lack of a transponder. Implementation of GBDAA radar is necessitated to fill this gap by incorporating self-separation that requires the UAS operate in airspace inside a fixed threat detection airspace with no other air vehicles. If an aircraft enters the threat detection airspace, a ground-based surveillance system warns the operator. The operator will then execute the second phase and fly the UAS to a safe state. A safe state exists when the UAS lands, exits from its operating area into a safe area, or controlled or restricted airspace.

FIGURE 1

Ground-based DAA



GBDAA is a critical component to the overall DAA solution and predominant solution to support all classes of UAS to operate in non-segregated airspace because many operations are conducted with relatively much small classes of UAS that do not have the power, cooling and physical space to accommodate the currently projected size and weight of current onboard ABDAA systems.

The technical parameters are provided in Table 1.

TABLE 1

Representative Technical parameters of radionavigation radar

| Parameter | Units | Radar 1 | Radar 2 | Radar 3 |
| --- | --- | --- | --- | --- |
| Platform |  | Aircraft / Ground (on and off airports) | Aircraft / Ground (on and off airports) | Airborne / Ground |
| Platform height | km | Up to 20 (Air)  0 (Ground) | Up to 20 (Air)  0 (Ground) | Up to 20(Air) 0 (Ground) |
| Spectral usage |  | Air-to-air and Ground-to-Air aeronautical radionavigation DAA radar | Air-to-air and Ground-to-Air aeronautical radionavigation DAA radar | Air-to-air and Ground-to-Air aeronautical radionavigation DAA radar |
| Radar type |  | FMCW | FMCW | Pulse-Doppler |
| Range class |  | Short range | Short range | Medium range |
| Operating range | km | 0.8 (small UAS)  2.0 (small General Aviation aircraft) | 1.8 (small UAS)  4.5 (small General Aviation aircraft) | 9 |
| Maximum number of drones within the same operating area |  | [10 to 20 (Air)  32 (Ground) | 10 to 20 (Air) 32 (Ground) | 3 (Air)  12 (Ground) |
| Ground speed | km/h | 200 (Air) 0 (Ground) | 200 (Air) 0 (Ground) | < 700(Air) 0 (Ground) |
| Frequency tuning range | GHz | 15.4-15.7  (Note 1) | 15.4-15.7  (Note 1) | 15.4-15.7  (Note 2) |
| Channel selection method between radars |  | (Note 1) | (Note 1) | SW selectable  (Note 3) |
| Emission type |  | QXN | QXN | FXN |
| Modulation |  | FMCW | FMCW | LFM |
| Pulse width  (1 meter range resolution) | μs | 220 | 197 | 0.25 to 20 |
| Pulse rise and  fall times | μs | 5/5 | 0.5/0.5 | < 0.1 |
| RF emission bandwidth   −3 dB  −20 dB  −40 dB | MHz | 176  184  201 | 152  164  269 | (Band 1-MHz)  2580155 |
| Pulse repetition frequency | ps | 4000 | 4000 | 1-200 |
| Average transmitter power  (conducted) | W | 2 | 10 | 30 |
| Out-of-band emission characteristics | dBc | < 50 | < 40 | <-75 (through 3rd harmonic) |
| Spurious emission characteristics  (conducted) | dBc | -72 | -87 | -60 |
| Receiver IF bandwidth  −3 dB  −20 dB  −60 dB | MHz | 15  32  58 | 15  32  58 | <200  <300  <400 |
| Sensitivity | dBm | -147 | -141 | -121 |
| Receiver noise figure | dB | 1.5 | 1.5 | 4 |
| Calculated Rx noise power | dBW | -130.7 | -130.7 | -133  (Note 5) |
| Saturation level | dBW/m2 | -35 | -30 | -40 |
| Effective Incident RX Thermal Noise power | dBW/m2 | -176.6 | -176.6 | 107.5 |
| Antenna type |  | Bi-Static  Phased Array | Bi-Static Phased Array | ESA (Note 6) |
| Antenna placement |  | Aircraft (manned or unmanned)  Tower (<20m) | Aircraft (manned   or unmanned) Tower (<20m) | Aircraft (manned   or unmanned)  Tower (<20m)  (internally sealed package) |
| RX Element gain | dBi | 2 | 2 | 27 |
| Antenna gain | dBi | 12 | 15 | 27 |
| First TX antenna side lobe | dBi | -3 at 50° | -1 at 52° | <-20 |
| Horizontal beamwidth | degrees | 40 | 32 | 4 |
| Vertical beamwidth | degrees | 40 | 28 | 2 |
| Polarization |  | Vertical | Horizontal | Horizontal |
| Horizontal Antenna scan | degrees | ±60 | ±60 | ± 65 |
| Vertical Antenna scan | degrees | ±20 | ±60 | -40, +50 |

Notes:

1 Radar is pre-programmed at the factory to any centre frequency inside this band. The set range resolution directly affects BW. Therefore, the range resolution will be a factor when programming the centre frequency, to ensure that the spectral power is within the 15.4 to 15.7 GHz band. For radars set with larger RR (i.e smaller BW’s), multiple radars can be programmed and operated inside the 15.4 to 15.7 GHz band, allowing for coverage of larger areas.

2 Utilized bandwidth - Inclusive of frequency-channel guard-bands.

3 Channel selection is purely SW-defined and can be on-the-fly dynamic. Some settings may allow radar to self-configure based on detected spectrum-conflict.

4 Waveform is software-defined on a CPI-by-CPI basis, and optimized for targets, and spectral environments.

5 Compressed bandwidth before processing gain.

6 High T/R ESA RF beamforming on both transmit and receive.

# 3 Characteristics of aeronautical radionavigation landing system

This system is an electronic landing aid that provides flight path data to an approaching aircraft as the aircraft flies into range of the landing system. There are two separate surface transmitters, one for azimuth and one for elevation, as well as a receiver installed on the aircraft. The system utilizes a one-way transmission where the angular information is displayed on a cross-point indicator allowing the aircraft to align itself with the runway.

The technical parameters are provided in Table 2.

TABLE 2

Technical parameters of landing system

| Parameter | Units | Transmitter | Receiver |
| --- | --- | --- | --- |
| Platform |  | Land/Ship | Aircraft |
| Platform height | km | Land: 0.01 Ship: 0.015-0.024 | Maximum: 2 |
| Ground speed | km/h | Land: 0 Ship: < 50 | < 350 |
| Number of aircraft per landing system |  | 1 | 1 |
| Frequency tuning range | GHz | 15.4-15.7 | 15.4-15.7 |
| Emission type |  | Pulse | Not applicable |
| Pulse width | μs | 0.3 | Not applicable |
| Pulse rise and fall times | ns | Rise Time: 25-50;  Fall Time: 25-200 | Not applicable |
| RF emission bandwidth at   −3 dB  −20 dB  −40 dB | MHz | 4.8  18.5  65 | Not applicable |
| Pulse repetition frequency | pps | 15000 | Not applicable |
| Out-of-band emission characteristics | dBc | <43 | Not applicable |
| Spurious emission characteristics | dBc | 65 | Not applicable |
| Average transmitter power | W | Peak: 2500;  Average: 7 | Not applicable |
| Receiver IF bandwidth at  −3 dB  −20 dB  −60 dB | MHz | Not applicable | 12 17 24 |
| Sensitivity | dBm | Not applicable | −72 |
| Receiver noise figure | dB | Not applicable | 11.5 |
| Calculated Rx noise power | dBW | Not applicable | −121.7 |
| Image rejection | dB | Not applicable | 60 |
| Spurious rejection | dB | Not applicable | 50 |
| Antenna type |  | Parabolic Reflector | Horn |
| Antenna placement |  | Ground/Surface | Bottom of aircraft |
| Antenna gain | dBi | Horizontal: 32;  Vertical: 26 | 6 |
| First antenna side lobe | dBi | At least 17 dB below peak | At least 17 dB below peak |
| Horizontal beamwidth | degrees | Horizontal: 40;  Vertical: 2 | 70 |
| Vertical beamwidth | degrees | Horizontal: 1.3; Vertical: 6 | 36 |
| Polarization |  | Vertical | Vertical |
| Antenna scan | degrees | Sector Scan | Fixed |

# 4 Protection criteria

The desensitizing effect on radars from other services of a continuous-wave or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density (PSD) can, to within a reasonable approximation, simply be added to the PSD of the radar receiver thermal noise. If PSD of radar‑receiver noise in the absence of interference is denoted by *N*0 and that of noise-like interference by *I*0, the resultant effective noise PSD becomes simply *I*0 + *N*0.

The effect of pulsed interference is more difficult to quantify and is strongly dependent on receiver/processor design and mode of operation. In particular, the differential processing gains for valid-target return, which is synchronously pulsed, and interference pulses, which are usually asynchronous, often have important effects on the impact of given levels of pulsed interference. Several different forms of performance degradation can be inflicted by such desensitization. Assessing it will be an objective for analyses of interactions between specific radar types. Assessing it will be an objective for analysis of interactions between specific pulsed radar types.

In general, numerous features of radiodetermination radars can be expected to help suppress low-duty cycle pulsed interference, especially from a few isolated sources. Techniques for suppression of low-duty cycle pulsed interference are contained in Recommendation ITU-R M.1372 – Efficient use of the radio spectrum by radar stations in the radiodetermination service. When multiple interferers are present, the recommended I/N protection criteria remains unchanged. The total interference level actually arriving at the radar receiver depends on the number of interferers, their spatial distribution and their signal structure and needs to be assessed in the course of an aggregation analysis of a given scenario. If interference were received from several azimuth directions, an aggregation analysis has to cumulate simultaneous contributions from all these directions, being received via the radar antenna’s main beam and/or side-lobes, in order to assess compatibility.

[*Editor’s note: More information on the appropriate protection criteria will be provided once the technical and operational characteristics of radars in section 2 have been finalized.*

*– For typical radars an increase of about 1 dB would constitute significant degradation, equivalent to a detection-range reduction of about 6%. Such an increase corresponds to an I/N ratio of 1.26, or an I/N ratio of about −6 dB.*

*– For the radionavigation service considering the safety-of-life function, an increase of about 0.5 dB would constitute significant degradation. Such an increase corresponds to an (I/N) ratio of −10 dB.]*

These protection criteria represent the aggregate effects of multiple interferers, when present; the allowable *I*/*N* ratio for an individual interferer depends on the number of interferers and their geometry, and needs to be assessed in the course of analysis of a given scenario. The aggregation factor can be very substantial in the case of certain communication systems in which a great number of stations can be deployed.

1. \* This Recommendation should be brought to the attention of the International Civil Aviation Organization (ICAO). [↑](#footnote-ref-1)