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| U.S. Radiocommunications Sector  Fact Sheet | |
| **Working Party:** ITU-R WP-5B | **Document No:** USWP5B33-07 |
| **Ref:** Annex 8 to Document 5B/96-E | **Date:** 14 August 2024 |
| **Document Title:** 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. Due to the stability of the technical characteristics data for the airborne and ground based DAA system as well as the technical characteristics data for the landing system, this contribution proposes to upgrade the Working Document into Preliminary Draft New Recommendation. This contribution will be an update to the new report found in Annex 8 of the Chairman’s Report of the 27 May 2024 Document 5B/96-E meeting. | |

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| **Radiocommunication Study Groups** |  |
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**United States of America**

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 proposes new Recommendation with 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. 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

The United States proposes that ITU-R Working Party (WP) 5B consider the updates to the working document towards a preliminary draft New Recommendation [ITU-R M.[15.4-15.7\_GHz\_ARNS]](https://www.itu.int/dms_ties/itu-r/md/23/wp5b/c/R23-WP5B-C-0096!N08!MSW-E.docx) attached to the Chairman’s Report. The proposed updates seek to address the editor’s notes and square brackets in this document.

The United States proposals are highlighted in yellow. It is also proposed to elevate the status of this document to Preliminary Draft New Recommendation. It should be noted that in certain instances the United States has provided USA notes in response to the editor’s notes for clarification. These notes are not intended to be retained for the final output of this document.

**Attachment:** 1

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| **ATTACHMENT** |
| PRELIMINARY DRAFT NEW  RECOMMENDATION ITU-R M.[15.4-15.7\_GHz\_ARNS] |
| Characteristics of and protection criteria for Aeronautical Radionavigation System operating in the frequency band 15.4-15.7 GHz |

(202X)

[USA Note: The details on both the ground based and airborne DAA radars has been expanded several meetings ago. The sections A-2.1 and A-2.2 contains information on Airborne detect-and-avoid radar and Ground based detect-and-avoid radar. Unless there are any specific information requested there is not much to be added.]

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

ABDAA Airborne detect and avoid

ARNS Aeronautical radionavigation service

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

RCS Radar cross-section

RR Radio Regulations

SNR Signal-to-noise power ratio

UA Unmanned aircraft

UAS Unmanned aircraft system

Related ITU Recommendations and Reports

Recommendations

[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*

[ITU-R S.1340](https://www.itu.int/rec/R-REC-S.1340/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*

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 the technical characteristics of detect and avoid radars operating in the aeronautical radionavigation service (ARNS) are driven by the mission of the system, required performance and vary widely even within a frequency band;

*b)* that the performance characteristics of receivers should be adequate to ensure that they do not suffer from interference due to transmitters situated at a reasonable distance and which operate in accordance with the Radio Regulations,

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 the aeronautical radionavigation service is a safety service as specified by No. **4.10** of the Radio Regulations (RR) and harmful interference to it cannot be accepted;

*d)* 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;

[USA note: Details on Pulsed interference is located in section A-5.2 as well as captured in recognizing d) above]

*e)* 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 RR No. **9.11A**;

*f)* 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;

*g)* 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.1340-0;

*h)* that the frequency band 15.4-15.7 GHz is allocated worldwide on a primary basis to the aeronautical radionavigation service;

*i)* that the frequency band 15.4-15.7 GHz is also allocated worldwide on a primary basis to the radiolocation service and RR No. **5.511E** states that stations operating in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the aeronautical radionavigation service;

*j)* that the frequency range 15.4-15.7 GHz is also allocated on a secondary basis to the aeronautical mobile (OR) service by RR Nos. **5.511G** and **5.511H**;

recommends

1 that the technical and operational characteristics of the detect and avoid radars operating in the ARNS described in the annex should be considered in studies of sharing and compatibility with systems in other services;

2 that, in the absence of performance requirements, the criterion of interfering signal power to radar receiver noise power level (*I*/*N)* of −6 dB, should be used as the required protection level for the aeronautical radionavigation systems, and that this represents the aggregate protection level if multiple interferers are present.

[Editor’s note: Some administrations note that safety margin language is not needed in the presence of recognizing c) referencing RR No. **4.10**.]

Annex  
  
Technical and operational characteristics of Aeronautical Radionavigation System operating in the  
frequency band 15.4-15.7 GHz

# A-1 Introduction

ARNS system operates 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.

Some ARNS systems are used for collision avoidance between aircraft notably for unmanned aircraft and other .systems are used for landing purposes.

# A-2 Description of the detect and avoid radar *characteristics*

[USA Note: Many of the comments in Editor’s note above has been addressed in the description below as well as in section A 2.1 and A 2.2 and the rest are not applicable for this document.]

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).

## A-2.1 Airborne detect-and-avoid radar

ABDAA radars are being developed for the purpose of enhancing flight safety by providing warnings of potential collisions or conflicts with non-cooperative aircraft[[1]](#footnote-2). The mission of this class of airborne radars encompasses several partially-overlapping functions referred to as collision avoidance, conflict avoidance, self-separation, safe separation, sense-and-avoid and due regard. This class of radars is of particular interest in unmanned aircraft (UA) applications where there is no onboard pilot to provide the safety-of-flight function visually. 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.

Detect-and-avoid radars must track all potentially threatening aircraft (called ‘intruders’) in their field of regard while simultaneously searching for new threats. Since more than one intruder will frequently be in the radar’s field of regard, a multi-target tracker is required. This requires either fairly rapid track-while-scan operation, or alternatively, interleaved search and track functions in a mode called ‘search while track’ in which the track updates are scheduled as they are required. This type of operation requires beam agility beyond the capability of a mechanically scanned antenna. For this reason, airborne DAA radars typically use either electronically scanned antennas or beamforming techniques to provide the required search and track functions.

The range required for detection and tracking depends on the amount of warning time required. This in turn depends on the speed of the host platform (called the ‘ownship’), the speed of intruder aircraft, the ownship’s manoeuvring capability, the type of avoidance manoeuvre (e.g. lateral vs vertical) and delays in initiating and executing the avoidance manoeuvre. A relatively fast UA with limited manoeuvrability would require a sensor with a greater range than a slower, more manoeuvrable UA.

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 intruder aircraft. 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).

## A-2.2 Ground based detect-and-avoid radar

GBDAA is used for air traffic surveillance in support of DAA operations for unmanned aircraft. GBDAA detects and generate tracks within its declaration volume of airborne traffics. Unlike primary radars, DAA radars detect aircraft that flies 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 to remain well clear of other aircraft.

FIGURE A-1

Ground-based detect and avoid

Diagram, map

Description automatically generated

Presently, in the frequency band 15.4-15.7 GHz, 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, 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’s pointed. 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. 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.

# A-3 Characteristics of aeronautical radionavigation detect and avoid radar

The technical parameters are provided in Table 1.

TABLE A-1

[USA Note: Technical characteristics of Radar 1 -3 has been validated and accurately reflect in Table 1 below. As these parameters represent the true data of respective radar; a comparison among these three radars is not necessary. The radars are being built and went to through developmental phases; therefore, the data for these three radars are permanent and actual representative of the DAA radars.]

[USA Note: Antenna characteristics of the radars would suffice to be used for any interference analysis against these radars.]

Representative technical parameters of radionavigation radar

| Parameter | Units | Radar/DAA 1 (Note 1) | Radar/DAA 2 (Note 1) | Radar/DAA 3 (Note 1) | [Radar/DAA] 4 | [Radar/DAA] 5 | [Radar/DAA] 5 (Note 1) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Platform  (Note 1) |  | Airborne | Airborne | Airborne | Airborne | Airborne |  |
| Platform height (Note 1) | km | Up to 12 | Up to 12 | Up to 12 | Up to 5 | Up to 10 |  |
| Radar type |  | FMCW | FMCW | Pulse-Doppler | Air to Air  Pulse Modulation | Air to Air  Pulse Modulation |  |
| Operating range (Note 2) | km | 0.8 (small UAS) 2.0 (small General Aviation aircraft (GA)) | 1.8 (small UAS) 4.5 (small General Aviation aircraft) | 9 | 5 | 10 |  |
| Maximum number of drones / Number of platforms within the same operating area |  | 10 | 10 | 3 to 12 | Up to 10 | Up to 20 |  |
| Relativeto Air speed  (Note 2) | m/s | 14-28 (small UAS)  200 (small GA) | 14-28 (small UAS)  200 (small GA) | < 195 | Up to 150 | Up to 150 |  |
| **Transmitter** | | | | | | |  |
| Frequency tuning range | GHz | 15.4-15.7 (Note 3) | 15.4-15.7 (Note 3) | 15.4-15.7 (Note 4) | 15.4-15.7 | 15.4-15.7 |  |
| Channel selection method between radars |  | (Note 3) | (Note 3) | SW selectable (Note 5) | - | - |  |
| Pulse width (1 meter range resolution) | μs | 220 | 197 | 0.25 to 20  (Note 6) | 1 to 20 | 1 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)  25  80  155 | TBD | TBD |  |
| Pulse repetition frequency | ps | 4 000 | 4 000 | 1-200 | - | - |  |
| Pulse repetition interval | μs | - | - | - | 30 to 80 | 30 to 80 |  |
| Average transmitter power (conducted) | W | 2 | 10 | 30 | 70 | 100 |  |
| Out-of-band emission characteristics | dBc | < 50 | < 40 | <-75 (through 3rd harmonic) | - | - |  |
| Spurious emission characteristics (conducted) | dBc | −72 | −87 | −60 | - | - |  |
| **Receiver** | | | | | | |  |
| Receiver IF bandwidth  −3 dB  −20 dB  −60 dB | MHz | 15  32  58 | 15  32  58 | <200  <300  <400 | TBD | TBD |  |
| Sensitivity | dBm | −147 | −141 | −121 | TBD  (Note 7) | TBD (Note 7) |  |
| Receiver noise figure | dB | 1.5 | 1.5 | 4 | 6 | 3 |  |
| Calculated Rx noise power | dBW | −130.7 | −130.7 | −133  (Note 8) | - | - |  |
| Saturation level | dBW/m2 | −35 | −30 | −40 | - | - |  |
| Effective Incident RX Thermal Noise power | dBW/m2 | −176.6 | −176.6 | −107.5 | - | - |  |
| **Antenna** | | | | | | |  |
| Antenna type |  | Bi-Static Phased Array | Bi-Static Phased Array | ESA (Note 9) | MIMO | MIMO |  |
| Antenna placement (Note 1) |  | Aircraft (manned or unmanned) | Aircraft (manned  or unmanned) | Aircraft (manned or unmanned) | Fixed | Fixed |  |
| RX Element gain | dBi | 2 | 2 | 27 | - | - |  |
| Antenna gain | dBi | 12 | 15 | 27 | 9 | 9 |  |
| First TX antenna side lobe | dBi | −3 at 50° | −1 at 52° | < −20 | TBD | TBD |  |
| Horizontal beamwidth | degrees | 40 | 32 | 4 | 80  (Note 10) | 80  (Note 10) |  |
| Vertical beamwidth | degrees | 40 | 28 | 2 | 80  (Note 10) | 80  (Note 10) |  |
| Polarization |  | Vertical | Horizontal | Horizontal | Vertical | Vertical |  |
| Field of Regard | degrees | - | - | - | +/-110° to +/-180° | +/-110° to +/-180° |  |
| Horizontal Antenna scan | degrees | ±60 | ±60 | ±65 | - | - |  |
| Vertical Antenna scan | degrees | ±20 | ±60 | −40, +50 | - | - |  |
| Protection criteria (aggregate) *I/N* | dB | −6 | −6 | −6 | −6 | −6 |  |
| Notes:  1 In some cases a UAS is unable to equip with airborne DAA. These radars can also be deployed on the ground in order to provide the intended DAA functions.  2 These radars have similar detection range on the same aircraft even if it flies at a different speed as long as the radar tracking software is expecting and designed for the correct aircraft speeds. What matters is radar cross section (RCS, i.e. “size”) of the target.  3 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.  4 Utilized bandwidth - Inclusive of frequency-channel guard-bands.  5 Channel selection is purely SW-defined and can be changed on-the-fly. Some settings may allow radar to self-configure based on detected spectrum-conflict.  6 Waveform is software-defined on a CPI-by-CPI basis, and optimized for targets, and spectral environments.  7 MDS at RX input SNR = 12 dB.  8 Compressed bandwidth before processing gain.  9 High T/R ESA RF beamforming on both transmit and receive.  10 For one panel at -3dB. | | | | | | |  |

# [A-3.1 Antenna characteristics

[DAA](#ABBR_DAA) radars antennas could use MIMO (Multiple Input Multiple Output) fix panel, and therefore these characteristics must be complemented to obtain the complete radiation pattern for one panel. One panel does not allow to obtain the Field of Regard (FoR) requested for DAA function. The FoR of the radar refers to the area that has to be covered by the radar and is defined by the azimuth and elevation angles in regard to the platform coordinates. To obtain the requested FoR, it is necessary to use several panels. Typical FoR for DAA is ±110°, and is obtained by the use of 3 panels.

Typical FoR for DAA application

A pie chart with a circle and a circle with a circle and a circle with a circle with a circle and a circle with a circle with a circle with a circle with a circle with a circle

Description automatically generated with medium confidence

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[USA Note: MIMO antennas are fixed beam antennas used in mobile communication systems where two or more orthogonally polarized antennas are used to transmit two or more different data user streams and two or more receiving antennas are used to receive the orthogonally polarized data streams. It is not clear how the MIMO terminology is applied to radars.]

# A-4 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 A-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 | 15 000 | Not applicable |
| Out-of-band emission characteristics | dBc | < 43 | Not applicable |
| Spurious emission characteristics | dBc | 65 | Not applicable |
| Average transmitter power | W | Peak: 2 500;  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 |

[\**Editor’s note: There was a request to clarify and/or confirm the following inputs regarding antenna characteristics. There was also a request to provide the antenna patterns.]*

[USA Note: Antenna characteristics of the radars would suffice to be used for any interference analysis against these radars.]

# A-5 Protection criteria

## A-5.1 Continuous noise-like interference

Radars are affected in fundamentally different ways by unwanted signals of different forms, and an especially sharp difference prevails between the effects of continuous noise-like energy and those of pulses. Continuous-wave interference of a noise-like type inflicts a desensitizing effect on radiodetermination radars, and that effect is predictably related to its intensity.

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.

Given that, the radar protection criteria traditionally established within ITU-R are based on the penalties incurred to maintain the target-return signal-to-noise ratio in the presence of the interference, requiring that the target-return power be raised in proportion to the increase of noise power from *N*0 to *I*0 + *N*0. That can only be done by accepting shorter maximum ranges on given targets, sacrificing observation of small targets, or modifying the radar to give it a higher transmitter power or power-aperture product.

These penalties vary depending on the radar’s function and the nature of its targets. For most radars, an increase in the effective noise level of about 1 dB would inflict the maximum tolerable degradation on performance. In the case of a discrete target having a given average or median Radar cross-section (RCS), that increase would reduce the detection range by about 6% regardless of any RCS fluctuation characteristics that target might have. This effect results from the fact that the achievable free-space range is proportional to the 4th root of the resultant signal-to-noise power ratio (SNR), from the most familiar form of the radar range equation. A 1 dB increase of effective noise power is a factor of 1.26 in power, so it would, if uncompensated, require the free-space range from a given discrete target to be reduced by a factor of 1/(1.261/4), or 1/1.06; i.e. a range capability reduction of about 6%. In the range equation, the SNR is also directly proportional to transmitter power, to power-aperture product (for a surveillance radar), and to target radar cross section. Alternatively, therefore, the 1 dB increase of effective noise power could be compensated by forgoing detection of targets except those having an average radar cross section 1.26 times as large as the minimum-size target that could be detected in the interference-free regime or by increasing the radar transmitter power or its power-aperture product by 26%. Any of these alternatives is at the limit of acceptability in most radar missions, and the system modifications would be costly, impractical, or impossible, especially in mobile radars. For discrete targets, those performance penalties hold for any given probability of detection and false-alarm rate and any target fluctuation characteristics.

### A-5.1.1 Aggregation of interference contributions

The 1 dB increase in the effective noise level referred to throughout the above discussions corresponds to an *(I + N)/N* ratio of 1.26, or an *I/N* of about −6 dB.

More precisely, a 1 dB increase in effective noise power would result in a range capacity reduction of 6%, which corresponds to an *(I + N)/N* ratio of 1.26, or an *I/N* of about −6 dB.

This represents the tolerable aggregate effect of all interferers. It applies for reception via the radar’s main beam as well as for simultaneous reception via side lobes. The tolerable *I/N* for an individual noise-like interferer therefore depends on the number of interferers and their geometry and should be assessed in the analysis of a given scenario. This is a consequence of the fact that almost all the radars in this band serve event-driven missions, observe non-cooperative targets, and do not have the benefit of redundancy, including the re-transmission of packets that is becoming used more and more in communications technologies. Basically, sensing, including radar, is a fundamentally different use of the RF spectrum than is communications, and the same interference-protection rules are not appropriate for both.

## A-5.2 Pulsed interference

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. 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.

For typical radars an increase of about 1 dB would constitute significant degradation, equivalent to a detection-range reduction of about 6%. Therefore, the criterion of interfering signal power to radar receiver noise power level (*I*/*N)* of −6 dB should be used as the required protection level for the aeronautical radionavigation radars provided that this represents the aggregate protection level if multiple interferers are present.

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.

[USA note: Protection criteria of I/N -6 dB represent the required protection needed in the presence of multiple interferers.]

1. Aircraft that are not equipped with an air traffic control radar beacon system transponder, automatic dependent surveillance-broadcast system, traffic alert and collision avoidance system or airborne collision avoidance system. [↑](#footnote-ref-2)