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| U.S. Radiocommunications Sector  Fact Sheet | |
| **Working Party:** ITU-R WP-5B | **Document No:** USWP5B33-15 |
| **Ref:** 5B/96 Annex 18 | **Date:** 13 August 2024 |
| **Document Title:** Preliminary Draft Revision of Recommendation ITU-R M.1638-1, “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” | |
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| **Purpose/Objective:** The purpose of this document is to continue the revision to Recommendation ITU-R M.1638-1. | |
| **Abstract:** Recommendation ITU-R M.1638-1 contains characteristics for the radiolocation and aeronautical radionavigation systems operating within the 5250-5850 MHz frequency band. This contribution seeks to address comments and editor’s notes provided at the previous meeting. | |

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| **Radiocommunication Study Groups** | A blue logo with a black background  Description automatically generated |
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| DRAFT revision of RECOMMENDATION ITU-R M.1638-1 | |
| **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** | |

The United States proposes that ITU-R Working Party (WP) 5B consider the updates to the preliminary draft revision to Recommendation [ITU-R M.1638-1](https://www.itu.int/rec/R-REC-M.1638/en) 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 turquoise.

**Attachment:** 1

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| ATTACHMENT |
| PRELIMINARY DRAFT REVISION OF RECOMMENDATION ITU-R M.1638-1 |
| 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 |

Summary of revision

The summary of revisions to this Recommendation is as follows:

1) Add terms to Abbreviations/Glossary section

2) Add related ITU Recommendations and Reports

3) Update *considering* *b)* and *f)*

4) Move *considering* *c)* to *recognizing* *c)*

5) Add *recognizing* *a)* and *b)*

6) Provide updates to section 1 for clarification and additional information regarding aeronautical radionavigation. Moved footnote in table 1 to appropriate frequency band

7) Add three new radars to Table 2 (24, 25, and 26)

8) Update section 3.1 to provide additional information regarding aeronautical radionavigation radars.

**Attachment:** 1

Attachment

Preliminary DRAFT revision of RECOMMENDATION ITU-R M.1638-2

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

(2003-2015-202X)

Scope

This Recommendation describes the technical and operational characteristics of, and protection criteria for, radars operating in the frequency band 5 250-5 850 MHz, except ground based meteorological radars which are contained in Recommendation ITU-R M.1849. These characteristics are intended for use when assessing the compatibility of these systems with other services.

Keywords

Radar, shipborne, land-based, aeronautical, protection, multi-function

Abbreviations/Glossary

ARNS: Aeronautical radionavigation service

CW: Continuous wave

ECCM: Electronic countermeasures

*I/N*: Interference to noise ratio (dB)

RR: Radio Regulations

UAS: Unmanned aircraft system

Related ITU Recommendations, 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.1461](https://www.itu.int/rec/R-REC-M.1461/en) *Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services*

[ITU-R M.1849](https://www.itu.int/rec/R-REC-M.1849/en) *Technical and operational aspects of ground-based meteorological radars*

Report

[ITU-R M.2204](https://www.itu.int/rec/R-REC-M.2204/en) *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 large necessary bandwidth characteristics of radar to achieve their functions are optimum in certain frequency bands;

*b)* that the technical characteristics of radiolocation (except ground based meteorological radars) and radionavigation radars are determined by the mission of the system and vary widely even within a frequency band;

[*c)* that representative technical and operational characteristics of radiolocation (except ground based meteorological radars) and radionavigation radars are required to address sharing and compatibility with these systems as necessary;]

*d)* that procedures and methodologies to analyse compatibility between radars and systems in other services are provided in Recommendation ITU-R M.1461;

*e)* that radiolocation, radionavigation and meteorological radars operate in the frequency bands between 5 250-5 850 MHz;

*f)* that ground-based radars used for meteorological purposes are authorized to operate in the frequency band 5 600-5 650 MHz on a basis of equality with stations in the maritime radionavigation service (see Radio Regulations (RR) No. **5.452**);

*g)* that Recommendation ITU-R M.1849 contains technical and operational aspects of ground based meteorological radars and can be used as a guideline in analysing sharing and compatibility between ground based meteorological radars with systems in other services,

recognizing

*a)* that Report ITU-R [M.2204](https://www.itu.int/rec/R-REC-M.2204/en) contains characteristics and spectrum considerations for sense and avoid systems use on unmanned aircraft systems;

[USA note: The U.S. is of the view that this editor’s note can be deleted. WP 5B needs more discussion regarding work on M.2204 and the UAS DAA Handbook but for now *recognizing a)* remains factual.]

*b)* that mobile, except aeronautical mobile, service also is allocated on a primary basis in the frequency bands 5 250-5 350 MHz and 5 470-5 725 MHz and is used in accordance with RR Nos. **5.446A**, **5.447F** and **5.450A**;

*c)* that earth exploration satellite (active) service also is allocated on a primary basis in the frequency band 5 250-5 570 MHz and is used in accordance with RR Nos. **5.448A** and **5.448B**;

*d)* that space research (active) service also is allocated on a primary basis in the frequency band 5 255-5 570 MHz and is used in accordance with RR Nos. **5.448A**, **5.448B**, and **5.448C**;

*e)* that radiolocation systems are widely deployed for various purposes and are planned to continue their operations;

*f)* that radiolocation systems operating in the frequency band 5 350-5 470 MHz should operate in accordance with RR No. **5.448D**;

*g)* that the radionavigation service is a safety service as specified by RR No. **4.10** and requires special measures to ensure its freedom from harmful interference;

*h)* that the application of the RR No. **4.10** may require mitigation techniques and/or operational provisions taking into account *recognizing e)*;

*i)* 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 and 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*,

recommends

1 that the technical and operational characteristics of the radiolocation (except ground based meteorological radars) and radionavigation radars described in Annex 1 should be considered representative of those operating in the frequency bands between 5 250 and 5 850 MHz;

*2*that Recommendation ITU-R M.1461 should be used as a guideline in analysing sharing and compatibility between radiolocation (except ground based meteorological radars) and radionavigation radars described in Annex 1 with systems in other services;

3 that the criterion of interfering signal power to radar (except to ground based meteorological radars) receiver noise power level *I*/*N*, of −6 dB should be used as the required protection level for the radiodetermination sharing studies with other services and this protection criterion represents the net protection level if multiple interferers are present;

[4 that in the case of pulsed interference, the criteria should be based on a case-by-case analysis taking into account *recommends* 3 above and the undesired pulse train characteristics and, to the extent possible, the signal processing in the radar receiver;]

[5 that coexistence between systems operating in the frequency band 5 350-5 470 MHz is important for both meteorological radars and radionavigation systems, that the undesired pulse train characteristics and the receiver signal processing in Recommendation ITU-R M.1372 should be taken into account to the extent possible, and that the use of suitable technical mitigation means should be used to ensure compatibility, while taking into account RR No. **5.448D**.]

[Editor’s Note: One Administration notes that Recommendation ITU-R M.1372 is referenced in recognizing j) and pulsed interference as well as mitigation techniques are discussed in sections 4 and 5, respectively, so these proposed recommends 4 and 5 are not necessary.]

Annex 1  
  
Characteristics of radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars

# 1 Introduction

The frequency bands between 5 250 and 5 850 MHz that are allocated to the radionavigation and radiolocation services on a primary basis as shown in Table 1.

TABLE 1

|  |  |
| --- | --- |
| Frequency band (MHz) | Allocation |
| 5 250-5 255 | Radiolocation |
| 5 255-5 350 | Radiolocation |
| 5 350-5 460 | Aeronautical radionavigation Radiolocation |
| 5 460-5 470 | Radiolocation Radionavigation |
| 5 470-5 570 | Maritime radionavigation Radiolocation |
| 5 570-5 650 | Maritime radionavigation Radiolocation(1) |
| 5 650-5 725 | Radiolocation |
| 5 725-5 850 | Radiolocation |
| (1) In accordance with RR No. **5.452**, between 5 600 and 5 650 MHz, ground-based radars for meteorological purposes are authorized to operate on a basis of equality with stations in the maritime radionavigation service. Recommendation ITU-R M.1849 contains characteristics of ground based meteorological radars. | |

The radiolocation radars perform a variety of functions, such as:

– tracking space launch vehicles and aeronautical vehicles undergoing developmental and operational testing;

– sea and air surveillance;

– environmental measurements (e.g. study of ocean water cycles and weather phenomena such as hurricanes);

– Earth imaging; and

– national defense and multinational peacekeeping.

The aeronautical radionavigation radars are used primarily for airborne weather avoidance and windshear detection, and perform a safety service (see RR No. **4.10**). Airborne doppler navigation systems are installed in aircraft (helicopters, as well as fixed-wing aircraft) and used for specialized applications such as continuous determination of ground speed and drift angle information of an aircraft with respect to the ground. In addition, detect and avoid radars may be used for collision avoidance on-board unmanned aircraft.

In Table 2, there are multifunction radars.

Multifunction radarcan perform search, tracking, radionavigation including weather detection, functions with the same antenna in a single frequency band. For example, in airborne applications, mechanically steered antennas or phase array antennas are commonly used, and the functions typically include search and tracking of aerial and surface target search, and terrain and weather avoidance.

In shipborne applications mechanically steered antennas or phase array antennas are commonly used, and the functions typically include search and tracking of aerial and surface target search and weather avoidance. These multifunction radars provide space and weight (essential in the airborne applications) saving, and adaptable operating modes base on changing requirements.

# 2 Technical characteristics

The frequency bands between 5 250 and 5 850 MHz are used by many different types of radars on land-based fixed, shipborne, airborne, and transportable platforms. Table 2 contains technical characteristics of representative systems deployed in these frequency bands. This information is generally sufficient for general calculations to assess the compatibility between these radars and other systems. These radars are conventionally operated as monostatic radar with transmitter and receiver at the same location (Fig. 1a). However, Radars 10A and 14A of Table 2 are additionally operated as bistatic radar where the transmitter and receiver are spatially separated (Fig. 1b).

The advantage of the separation of transmitter and receiver is the possible enhancement of the radar cross-section of an object. The effect is exemplarily shown in Fig. 1c for a square plane. This is especially important if the object to be detected does not reflect much energy in the direction of the incident radar signal.

The distance between the transmitter and receiver (baseline) is typically in the range of 30-50 km. Synchronization of the transmitter and receiver can be achieved by a radio link or global navigation satellite service or by time standards. This operation mode with passive receiver at a different location than the transmitter should be taken into account in compatibility studies. Since the receivers are not changed, the protection criteria of the mono-static and bi-static radar receiver are equal.

Figure 1

1a: Monostatic radar; 1b: Bi-static radar; 1c: Diffracted power of a simple square plane



This Table contains characteristics of some frequency-hopping radars which are operating in this frequency range.Frequency hopping is one of the most common electronic‑counter-counter-measures (ECCM). Radar systems that are designed to operate in hostile electronic attack environments use frequency hopping as one of its ECCM techniques. This type of radar typically divides its allocated frequency band into channels. The radar then randomly selects a channel from all available channels for transmission. This random occupation of a channel can occur on a per beam position basis where many pulses on the same channel are transmitted, or on a per pulse basis. This important aspect of radar systems should be considered, and the potential impact of frequency hopping radars should be taken into account in sharing studies.

TABLE 2

Characteristics of radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | | Units | Radar 1 | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 6 | Radar 7 | Radar 8 | Radar 9 |
| Function | |  | Instrumentation | Instrumentation | Instrumentation | Instrumentation | Instrumentation | Surface and air search | Multifunction Surface and air search | Research and Earth imaging | Search |
| Platform type (airborne, shipborne, ground) | |  | Ground | Ground | Ground | Ground | Ground | Ship | Ship | Airborne | Airborne |
| Tuning range | | MHz | 5 300 | 5 350-5 850 | 5 350-5 850 | 5 400-5 900 | 5 400-5 900 | 5 300 | 5 450-5 825 | 5 300 | 5 250-5 725 |
| Modulation | |  | N/A | None | None | Pulse/chirp pulse | Chirp pulse | Linear FM | None | Non-linear/ linear FM | CW pulse |
| Tx power into antenna | | kW | 250 | 2 800 | 1 200 | 1 000 | 165 | 360 | 285 | 1 or 16 | 0.1- 0.4 |
| Pulse width | | µs | 1.0 | 0.25, 1.0, 5.0 | 0.25, 0.5, 1.0 | 0.25-1 (unmodulated) 3.1-50 (chirp) | 100 | 20.0 | 0.1/0.25/1.0 | 7 or 8 | 1.0 |
| Pulse rise/fall time | | µs | 0.1/0.2 | 0.02-0.5 | 0.02-0.05 | 0.02-0.1 | 0.5 | 0.5 | 0.03/0.05/0.1 | 0.5 | 0.05 |
| Pulse repetition rate | | pps | 3 000 | 160, 640 | 160, 640 | 20-1 280 | 320 | 500 | 2 400/1 200/ 750 | 1 000-4 000 | 200-1 500 |
| Chirp bandwidth | | MHz | N/A | N/A | N/A | 4.0 | 8.33 | 1.5 | N/A | 62, 124 | N/A |
| RF emission bandwidth | –3 dB  –20 dB | MHz | 4.0  10.0 | 0.5-5 | 0.9-3.6  6.4-18 | 0.9-3.6  6.4-18 | 8.33  9.9 | 1.5  1.8 | 5.0/4.0/1.2  16.5/12.5/7.0 | 62, 124  65, 130 | 4.0  10.0 |
| Antenna pattern type (pencil, fan, cosecant-squared, etc.) | |  | Pencil | Pencil | Pencil | Pencil | Pencil | Cosecant-squared | Fan | Fan | Pencil |
| Antenna type (reflector, phased array, slotted array, etc.) | |  | Parabolic reflector | Parabolic | Parabolic | Phased array | Phased array | Parabolic | Travelling wave feed horn array | Two dual polarized horns on single pedestal | Slotted array |

TABLE 2 (*cont.*)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Units | Radar 1 | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 6 | Radar 7 | Radar 8 | Radar 9 |
| Antenna polarization |  | Vertical/left-hand circular | Vertical/left-hand circular | Vertical/left-hand circular | Vertical/left-hand circular | Vertical/left-hand circular | Horizontal | Horizontal | Horizontal and vertical | Circular |
| Antenna main beam gain | dBi | 38.3 | 54 | 47 | 45.9 | 42 | 28.0 | 30.0 | 26 | 30-40 |
| Antenna elevation beamwidth | degrees | 2.5 | 0.4 | 0.8 | 1.0 | 1.0 | 24.8 | 28.0 | 28.0 | 2-4 |
| Antenna azimuthal beamwidth | degrees | 2.5 | 0.4 | 0.8 | 1.0 | 1.0 | 2.6 | 1.6 | 3.0 | 2-4 |
| Antenna horizontal scan rate | degrees/s | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | 36, 72 | 90 | N/A | 20 |
| Antenna horizontal scan type (continuous, random, 360°, sector, etc.) | degrees | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | Continuous  360 | 30-270  Sector | Fixed to left or right of flight path | Continuous |
| Antenna vertical scan rate | degrees/s | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A | N/A | N/A | N/A |
| Antenna vertical scan type (continuous, random, 360°, sector, etc.) | degrees | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A (Tracking) | N/A | Fixed | Fixed in elevation  (–20 to –70) | N/A |
| Antenna side‑lobe (SL) levels (1st SLs and remote SLs) | dB | –20 | –20 | –20 | –22 | –22 | –20 | –25 | –22 | –25 |
| Antenna height | m | 20 | 20 | 8-20 | 20 | 20 | 40 | 40 | To 8 000 | 9 000 |
| Receiver IF 3 dB bandwidth | MHz | 1 | 4.8, 2.4, 0.25 | 4, 2, 1 | 2-8 | 8 | 1.5 | 1.2, 10 | 90, 147 | 1 |
| Receiver noise figure | dB | 6 | 5 | 5 | 11 | 5 | 5 | 10 | 4.9 | 3.5 |
| Minimum discernable signal | dBm | –105 | –107 | –100 | –107, –117 | –100 | –107 | –94 (short/medium pulse)  –102  (wide pulse) | –90, –87 | –110 |

TABLE 2 *(cont.)*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Unit | Radar 10 | Radar 10A | Radar 11 | Radar 12 | Radar 13 | Radar 14 | Radar 14A | Radar 15 |
| Function |  | Radionavigation, Surface and Air Search | Radionavigation, Surface and Air Search | Radiolocation | Radiolocation | Radiolocation | Radiolocation | Radiolocation | Radiolocation |
| Platform type (airborne, shipborne, ground) |  | Shipborne  Ground | Ground  (bistatic) | Ground | Shipborne | Ground | Ground | Ground  (bistatic) | Ground |
| Tuning range | MHz | 5 250-5 875 | 5 250-5 875 | 5 250-5 350 | 5 400-5 900 | 5 450-5 850 | 5 300-5 800 | 5 300-5 800 | 5 400-5 850 |
| Modulation |  | Bi-phase Barker Code | Bi-phase Barker Code | Coded Pulse | Coded Pulse | Pulsed, non-coherent | NA | NA | Un-Modulated Pulse |
| Tx power into antenna | kW | 90 | 90 | 0.400 | 25 | 750 | 50 | 50 | 1 000 |
| Pulse width | uµs | 0.30-14.0 | 0.30-14.0 | 0.08 | 0.32 | 1 | NA | NA | .25-1 |
| Pulse rise/fall time | µs | 0.04-0.1 | 0.04-0.1 | .03/.03 | .015/.035 | .108/.216 | .100/.100 | .100/.100 | .150/.200 |
| Pulse repetition rate | pps | 4 000-5 000 | 4 000-5 000 | 5 000 | 8 000 | 160-1 280 | NA | NA | 160 - 640 |
| Chirp bandwidth | MHz | 1.5 | 1.5 | N/A | N/A | NA | NA | NA | NA |
| RF emission –3 dB bandwidth –20 dB | MHz | 4  12  20 at –40 dB | 4  12  20 at –40 dB | 6 11 | 1.55 20 | .8 4.1 | 470 490 | 470 490 | 1.8 10 |
| Antenna pattern type (pencil, fan, cosecant-squared, etc.) |  | Fan | Fan | N/A | N/A | Pencil | Pencil | Pencil | N/A |
| Antenna type (reflector, phased array, slotted array, etc.) |  | Passive Phased Array | Passive Phased Array | Phased array | Phased array | Parabolic | Phased array | Phased array | Horn |

TABLE 2 (*cont.*)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Unit | Radar 10 | Radar 10A | Radar 11 | Radar 12 | Radar 13 | Radar 14 | Radar 14A | Radar 15 |
| Antenna polarization |  | Horizontal | Horizontal | Vertical | Vertical | Linear Vertical | NA | NA | Vertical, Linear |
| Antenna main beam gain | dBi | 33 (<55) | 33 (<55) | 16 | 25 | 42.94 | 40 | 40 | 42 |
| Antenna elevation beamwidth | degrees | 7 | 7 | 12.5 | 26 | 2.5 | 2.5 | 2.5 | 1.2 |
| Antenna azimuthal beamwidth | degrees | 1.8 | 1.8 | 12.5 | 2 | 2.5 | 2.5 | 2.5 | 1.2 |
| Antenna horizontal scan rate | degrees/s | 6-60 | 6-60 | N/A | N/A | 25 | 30 | 30 | Variable - 45 |
| Antenna horizontal scan type (continuous, random, 360°, sector, etc.) | degrees | 360 | 360 | N/A | 360 | 360 | 360 | 360 | 360 |
| Antenna vertical scan rate | degrees/s | N/A | N/A | N/A | N/A | 25 | N/A | N/A | variable - 45 |
| Antenna vertical scan type (continuous, random, 360°, sector, etc.) | degrees | N/A | N/A | N/A | Electronically Steered | N/A | Electronically Steered | Electronically Steered | N/A |
| Antenna side‑lobe (SL) levels (1st SLs and remote SLs) | dB | –29 | –29 | N/A | N/A | –8.7 | –40 | –40 | –22 |
| Antenna height | m | 45 | 30 | N/A | 30 | NA | NA | NA | NA |
| Receiver IF 3 dB bandwidth | MHz | 11 | 11 | 10 | 7 | 2.75 | NA | NA | 20 |
| Receiver noise figure | dB | 3 | 3 | 10 | 4 | 3 | 4 | 4 | 2.3 |
| Minimum discernable signal | dBm | –115 | –115 | –111 | –116 | –107 | –100 | –100 | –112 |

TABLE 2 (*cont.*)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | | Unit | Radar 16 | Radar 17 | Radar 18 | Radar 19 | Radar 20 | Radar 21 | Radar 22 | Radar 23 |
| Function | |  | Aeronautical radionavigation | Multifunction | Multi-function | Multi-function | Multi-function | Multi-function | Multi-function | Multi-function |
| Platform type (airborne, shipborne, ground) | |  | Airborne | Airborne | Ground | Ground | Shipborne | Ground/ship | Surface and air search, ground-based on vehicle | Search, ground-based on vehicle |
| Tuning range | | MHz | 5 440 | 5 370 | 5 600-5 650 | 5 300-5 700 | 5 400-5 700 | 5 300-5 750 | 5 400-5 850 | 5 250-5 850 |
| Modulation | |  | N/A | N/A | NA | Un-modulated Pulse | Un-modulated Pulse | N/A | Coded pulse/barker code and Frequency hopping | Coded pulse/barker code and Frequency hopping |
| Tx power into antenna | | kW | 0.200 peak | 70 peak | 7.5 | 250 | 350 | 300-400 peak | 12 peak | 70 |
| Pulse width | | µs | 1-20 | 6.0 | 0.0005-0.20 | 0.8 to 2.0 | 2 | .05..4.0 | 4.0-20.0 | 3.5/6.0/1.0 |
| Pulse rise/fall time | | µs | 0.1 | 0.6 | 0.0005/0.0005 | 0.08 | .096/0.33 | 0.1 | 0.2 | 0.3 |
| Pulse repetition rate | | pps | 180-1 440 | 200 | 3 000 | 250-1 180 | 250-500 | 200-1 300 | 1 000-7 800 | 2 500-3 750 |
| Chirp bandwidth | | MHz |  |  | NA | NA | NA | NA | NA | NA |
| RF emission bandwidth | –3 dB  –20 dB | MHz |  |  | 2  15 | 1.25  8.3 | 0.4  2.88 | NA | 5  Not available | 5  Not available |
| Antenna pattern type (pencil, fan, cosecant-squared, etc.) | |  | Pencil | Fan | Pencil | Pencil | Pencil | Conical | Pencil | Pencil |
| Antenna type (reflector, phased array, slotted array, etc.) | |  | Slotted array | Parabolic | Parabolic Reflector | Parabolic Reflector | Parabolic Reflector | Parabolic | Phased array | Phased array |

TABLE 2 (*cont.*)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Unit | Radar 16 | Radar 17 | Radar 18 | Radar 19 | Radar 20 | Radar 21 | Radar 22 | Radar 23 |
| Antenna polarization |  | Horizontal | Horizontal | Horizontal | Horizontal | Horizontal | Vertical | Vertical | Horizontal |
| Antenna main beam gain | dBi | 34 | 37.5 | 38.5 | 44.5 | 40 | 44.5 | 35 | 31.5 |
| Antenna elevation beamwidth | degrees | 3.5 | 4.1 | 2.2 | 1 | 1.7 | 2.0 | 30 | 30 |
| Antenna azimuthal beamwidth | degrees | 3.5 | 1.1 | 2.2 | 1 | 1.7 | 2.0 | 2 | 2 |
| Antenna horizontal scan rate | degrees/s | 20 | 24 | 3.4 | Variable | 6 | 36 | Variable | Variable |
| Antenna horizontal scan type (continuous, random, 360°, sector, etc.) | degrees | Continuous | 180  Sector | 360 | NA | 360 | 360 | 360 | 360  sector |
| Antenna vertical scan rate | degrees | 45 | N/A | 6.5 | Variable | NA | 3 | NA | NA |
| Antenna vertical scan type (continuous, random, 360°, sector, etc.) | degrees | Sector | N/A | NA | NA | NA | 30 | Sector | Sector |
| Antenna side‑lobe (SL) levels (1st SLs and remote SLs) | dB | –31 | –20 | –31 | –25 | –29 | –30 | –40 | –30 |
| Antenna height | m | Aircraft altitude | Aircraft altitude | 10 | 10 | 10 | 10..40 | 10 | 6-13 |
| Receiver IF 3 dB bandwidth | MHz | 1.0 | 0.6 | 3 | 0.75 | 0.5 | 0.8 | 4 | 5 |
| Receiver noise figure | dB | 5 | 6 | 4 | 3 | 2 | 3 | 5 | 13 |
| Minimum discernable signal | dBm | –109 | –106 | –123 | –109 | –115 | –120 | –103 | –108 |

TABLE 2 (*end*)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Characteristics | | Unit | Radar 24\* | Radar 25 | Radar 26 |
| Function | |  | Detect and avoid | Radiolocation | Instrumentation |
| Platform type (airborne, shipborne, ground) | |  | Airborne | Ground | Ground |
| Tuning range | | MHz | 5 350-5 460 | 5 250-5 900 | 5 400-5 900 |
| Modulation | |  | Coded pulse | Coded pulse | Un-modulated Pulse |
| Tx power into antenna | | kW | 1.3 | 5-4250 | 200-5 500 |
| Pulse width | | µs | 1.0/1.25/2.5/5.0 | 1-25 | 0.5-10 |
| Pulse rise/fall time | | µs | 0.05 | 0.0082-0.0132/ 0.012-0.016 | 0.02-0.15/0.02-0.15 |
| Pulse repetition rate | | pps | 15 000/20 000/ 1 000/5 000 | 40-320 | 100-1 000 |
| Chirp bandwidth | | MHz | N/A | NA | NA |
| RF emission bandwidth | –3 dB  –20 dB | MHz | 7.2/8.2/8.7/47 25.3/15.9/15.1/60.6 | 1-100  5-210 | 0.5-2  4-20 |
| Antenna pattern type (pencil, fan, cosecant-squared, etc.) | |  | Fan | Pencil | Pencil |
| Antenna type (reflector, phased array, slotted array, etc.) | |  | Phased array | Parabolic | Parabolic, Cassegrain Feed |
| Antenna polarization | |  | Vertical | Left-hand Circular | Vertical Linear, LHC |
| Antenna main beam gain | | dBi | 22 | 57 | 55 |
| Antenna elevation beamwidth | | degrees | 5.4 | 0.5 | 0.5 |
| Antenna azimuthal beamwidth | | degrees | 55.6 | 0.5 | 0.5 |
| Antenna horizontal scan rate | | degrees/s |  | 22 | 25 |
| Antenna horizontal scan type (continuous, random, 360°, sector, etc.) | | degrees | 110 Sector | 360 | 360 |
| Antenna vertical scan rate | | degrees | 230 | 15 | 20 |
| Antenna vertical scan type (continuous, random, 360°, sector, etc.) | | degrees | Electronic scan sector (–40° to 40°) | Sector (–10 to +90) | Sector (–5 to +90) |
| Antenna side‑lobe (SL) levels (1st SLs and remote SLs) | | dB | –13 | –18 | –19 |
| Antenna height | | m | 1 500-15 000 | 50 | 40 |
| Receiver IF 3 dB bandwidth | | MHz | 7.2/8.2/8.7/47 | 1-300 | 1-10 |
| Receiver noise figure | | dB | 3 | 4 | 4 |
| Minimum discernable signal | | dBm | –95 | –130 | –110 |

\*[Editor’s notes: Question has been raised concerning the suitability of this frequency band for detect sense-and-avoid radar in this frequency range for which RR No. **4.10** applies. It is noted that a draft new report is under consideration by the WP 5B to analyse the suitability of the existing allocation for detect sense-and-avoid system.]

# 3 Operational characteristics

## 3.1 Aeronautical radionavigation radars

Radars operating in the ARNS in the frequency band 5 350-5 460 MHz are primarily airborne systems used for flight safety. Both weather detection and avoidance radars, which operate continuously during flight, as well as windshear detection radars, which operate automatically whenever the aircraft descends below 2 400 ft (732 m), are in use. Both radars have similar characteristics and are principally forward-looking radars which scan a volume around the aircraft’s flight path. These systems are automatically scanned over a given azimuth and elevation range, and are typically manually (mechanically) adjustable in elevation by the pilot (who may desire various elevation “cuts” for navigational decision-making). Within this frequency range airborne doppler navigation radars are also used for acquiring information such as ground speed and aircraft drift angle with respect to the ground.

With the emergence of UAS, new detect and avoid radars (Radar 24, Table 2), operating in the 5 350‑5 460 MHz frequency band will be developed and employed for the purpose of mitigating collision risk with other aircraft during all phases of flight. The minimum operational performance standards for detect and avoid radars specify that, based on interference within a channel, the radar shall be capable of switching automatically between a minimum of three frequency channels within the utilized band. This requirement would allow the detect and avoid system to maintain the ability to operate under safety critical conditions while in the presence of other systems operating in the same frequency band.

[Editor’s Note: The mitigation techniques for Radar 24 are expected to be further developed and [quantified].]

## 3.2 Radiolocation radars

There are numerous radar types, accomplishing various missions, operating within the radiolocation service throughout the frequency range 5 250-5 850 MHz. Table 2 gives the technical characteristics for several representative types of radars that use these frequencies that can be used to assess the compatibility between radiolocation radars and systems of other services. The operational use of these radars is briefly discussed in the following text.

Test range instrumentation radars are used to provide highly accurate position data on space launch vehicles and aeronautical vehicles undergoing developmental and operational testing. These radars are typified by high transmitter powers and large aperture parabolic reflector antennas with very narrow pencil beams.

The radars have auto tracking antennas which either skin track or beacon track the object of interest. (Note that radar beacons have not been presented in Table 2; they normally are tunable over the frequency range 5 400-5 900 MHz, have transmitter powers in the range 50‑200 W peak, and serve to rebroadcast the received radar signal.) Periods of operation can last from minutes up to 4‑5 h, depending upon the test program. Operations are conducted at scheduled times 24 h/day, 7 days/week.

Shipboard sea and air surveillance radars are used for ship protection and operate continuously while the ship is underway as well as entering and leaving port areas. These radars operate continuously during the shipʼs deployment, based on shipʼs schedule and availability. These radars perform missions such as marine environmental protection; law enforcement in ports, and inland waterways, coastal security; humanitarian assistance, and/or disaster response and search and rescue missions involving small cross section targets such as light aircraft, lifeboats, canoes, dinghies, and swimmers with life jackets. These surveillance radars usually employ moderately high transmitter powers and antennas which scan electronically in elevation and mechanically a full 360° in azimuth. Operations can be such that multiple ships are operating these radars simultaneously in a given geographical area.

Other special-purpose radars are also operated in the frequency band 5 250-5 850 MHz. Radar 7 (Table 2) is an airborne synthetic aperture radar which is used in land-mapping and imaging, environmental and land-use studies, and other related research activities. It is operated continuously at various altitudes and with varying look-down angles for periods of time up to hours in duration which depends upon the specific measurement campaign being performed.

# 4 Protection criteria

The desensitizing effect on radars operated in this frequency band from other services of a CW or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density can simply be added to the power spectral density of the radar receiver thermal noise, to within a reasonable approximation. If power spectral density 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 power spectral density becomes simply *I*0 + *N*0. An increase of about 1 dB for the radiolocation radars except ground based meteorological radar would constitute significant degradation. Such an increase corresponds to an (*I* + *N*)/*N* ratio of 1.26, or an *I*/*N* ratio of about −6 dB. For the radionavigation service and meteorological[[1]](#footnote-1) radars 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 about –10 dB. However, further study is required to validate this value. These protection criteria represent the aggregate effects of multiple interferers, when present; the tolerable *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.

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. 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.

# 5 Interference mitigation techniques

In general, mutual compatibility between radiolocation (except ground based meteorological radars) and aeronautical radionavigation is fostered by the scanning of the antenna beams, which limits main beam couplings. Additional mitigation is afforded by differences between the waveforms of the two types of radars and the associated rejection of undesired pulses via receiver filtering and signal processing techniques such as limiting, sensitivity time control and signal integration. Additionally, interference can be mitigated by separation in carrier frequency or discrimination in time through the use of asynchronous pulse rejection/suppression techniques. In radar-to-radar interactions, separation in frequency is not always necessary for compatible operation because high degrees of isolation in power coupling and in time either occur naturally or can be achieved by good design. Additional details of interference mitigation techniques employed by radar systems are contained in Recommendation ITU‑R M.1372.

1. The protection criteria for ground-based meteorological radars is found in Recommendation ITU‑R M.1849. [↑](#footnote-ref-1)