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| **Recommendation ITU-R M.2008-1**  **(02/2014)** |
| **Characteristics and protection criteria for radars operating in the aeronautical radionavigation service in the frequency band 13.25-13.40 GHz** |
| **M Series**  **Mobile, radiodetermination, amateur**  **and related satellite services** |

Foreword

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| **SM** | Spectrum management |
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| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R M.2008-1

Characteristics and protection criteria for radars operating in the  
aeronautical radionavigation service in the frequency  
band 13.25-13.40 GHz

(2012-2014)

Scope

This Recommendation specifies the characteristics and protection criteria of radars operating in the aeronautical radionavigation service (ARNS) in the frequency band 13.25-13.4 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

13.25-13.4 GHz, radar, characteristics, protection.

Abbreviations/Glossary

ARNS Aeronautical radionavigation service

PSD Power spectral density

UA Unmanned aircraft

UAS Unmanned aircraft system

The ITU Radiocommunication Assembly,

considering

*a)* that antenna, signal propagation, target detection, and large 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 13.25-13.4 GHz is allocated on a primary basis to aeronautical radionavigation, Earth exploration-satellite (active), and space research (active) services;

*b)* that the Earth exploration-satellite (active) and space research (active) services operating in the frequency band 13.25-13.4 GHz shall not cause harmful interference to, or constrain the use and development of, the ARNS;

*c)* that representative technical and operational characteristics of systems operating in frequency bands allocated to the ARNS are required to determine the feasibility of introducing new types of systems;

*d)* that procedures and methodologies are needed to analyse compatibility between radars operating in the ARNS and systems in other services,

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 13.25-13.4 GHz and used in studies of compatibility with systems in other services;

**2** that Recommendation ITU-R M.1461 should be used in analysing compatibility between radars operating in the frequency band 13.25-13.4 GHz with systems in other services;

**3** that the criterion of interfering signal power to radar receiver noise power level (*I*/*N)* of −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.

Annex  
  
Technical and operational characteristics of radars operating in the  
aeronautical radionavigation service in the  
frequency band 13.25-13.40 GHz

# 1 Introduction

ARNS system operates worldwide on a primary basis in the frequency band 13.25-13.4 GHz. This Annex presents the technical and operational characteristics of representative ARNS radars operating in this frequency band.

Airborne doppler navigation systems are installed in aircraft (helicopters, as well as certain airplanes) and used for specialized applications such as continuous determination of ground speed and drift angle information of an aircraft with respect to the ground. The Radio Technical Commission for Aeronautics has developed a minimum operational performance standard for this equipment “*DO-158 – Airborne Doppler Radar Navigation Equipment*”. In addition, radars used for collision avoidance on-board unmanned aircraft (UA) are also planned to support the integrations of unmanned aircraft system (UAS) in non-segregated airspace.

# 2 Technical parameters

The technical parameters of radionavigation radars operating in the frequency band 13.25-13.4 GHz are presented in Table 1. All systems are operated worldwide aboard aircraft. The radars are used for aircraft on-board navigation systems for accurate navigation in all weather conditions.

TABLE 1

| Parameter | | Units | Radar 1 | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 6 | Radar 7 | Radar 8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Platform | |  | Aircraft (helicopter) | Aircraft (helicopter) | Aircraft (airplane) | Aircraft (airplane) | Aircraft (helicopter) | Aircraft (airplane) | Aircraft (airplane) | Aircraft (helicopter) |
| Platform maximum operational altitude | | m | 3 600 | 3 660 | 10 400 | 15 000 | 0-4 500 | 15 000 | 15 000 | 3 500 |
| Radar type | |  | Doppler navigation radar | Doppler navigation radar | Doppler navigation radar | Doppler navigation radar | Doppler radar velocity sensor | Doppler radar velocity sensor | Doppler navigation radar | Doppler navigation radar |
| The range of measured ground speed | | km/h | 333 | 553 | 750 | 1 047 | 250 | 1 100 | 180-1 300 | 50-399 |
| Frequency | | GHz | Fixed single channel | Fixed single channel | Fixed single channel | Fixed single channel | Fixed single channel | Fixed single channel | 13.25 to 13.40 | 13.295.to 13.355 |
| Emission type | |  | Continuous wave | Intermittent continuous wave | Frequency modulated-continuous wave | Continuous wave | Frequency modulated-continuous wave | Unmodulated pulse | Unmodulated continuous wave | Unmodulated continuous wave |
| Pulse width | | μs | Not applicable | 1-4 | Not applicable | Not available | Not applicable (FM) | 4-7 | Not applicable | Not applicable |
| Pulse rise and fall times | | ns | Not applicable | 20 | Not applicable | Not available | Not applicable (FM) | 0.2, 0.2 | Not applicable | Not applicable |
| RF emission bandwidth | −3 dB −20 dB −40 dB | kHz | Not applicable | 2 800 20 000 | 100 250 350 | Not applicable | Not available Not available 150 | 1 000 5 600 95 000 | Not available | Not available |
| Pulse repetition  frequency | | pps | Not applicable | Not available | Not applicable | Not applicable | Not applicable | 80 000 | Not applicable | Not applicable |
| Peak transmitter  power | | W | 0.85 | 0.132 | 0.18 | 1.0 | 0.050 | 40 20 Average | 0.125...10 | 0.15...10 |

TABLE 1 (*continued*)

| Parameter | Units | Radar 1 | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 6 | Radar 7 | Radar 8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Receiver IF −3dB bandwidth | kHz | 1.4 Estimated | 1.6 Estimated | 55 000 | 2.9 Estimated | 14 | 2 500 | 15 000 | 100 000 |
| Sensitivity | dBm | −135 for 0 dB *S*/*N* | −135 | −134 for  0 dB *S*/*N* | −138 for 3 dB *S*/*N* | −130 for 3 dB *S*/*N* (V = 100 m/s)  −160 for 3 dB *S*/*N* (V = hover) | −96 for 3 dB *S*/*N* (V = 100 m/s) | −110 (acquisition mode)  −120 (tracking mode) | −144 |
| Receiver noise figure | dB | 22 (Homodyne Receiver) | 22 (Dual Conversion Homodyne Receiver) | 12 (Double Conversion Super Heterodyne Receiver) | 22 (Homodyne Receiver) | 22 (Homodyne Receiver) | 7.5 | Not available | Not available |
| Antenna type |  | Parabolic reflector | Phased array | Phased array | Phased array | Printed circuit array | Printed circuit array | Phased array | Horn-reflector |
| Antenna placement |  | Points towards Earth | Points towards Earth | Points towards Earth | Points towards Earth | Points towards Earth | Points towards Earth | Points towards Earth  (Off-nadir angle 9…11 degrees) | Points towards Earth  (Off-nadir angle 18 degrees) |
| Antenna gain | dBi | 27 | 27 | 26 | 29.5 | 26.5 | 18 | 20 | 27.8 |
| First antenna side lobe | dBi | 5.5 | Not available | 9 | 14.2 at 4 degrees | −10 | −10 | 7 | −7.2 |
| Horizontal beamwidth | degrees | 7 | 3.3 | 9 | 4.7 | 4.0 | 20 | Not available | Not available |
| Vertical beamwidth | degrees | 4.5 | 5 | 3 | 2.5 | 3.4 | 4.2 | Not available | Not available |
| Polarization |  | Linear | Not available | Not available | Linear | Linear | Linear | Not available | Not available |
| Number of beams |  | 4 | 4 | 4 | 4 | 4 | 2 | 3 or 4 | 3 |

TABLE 1 (*end*)

| Parameter | Units | Radar 1 | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 6 | Radar 7 | Radar 8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna beam configuration |  | Employs Janus system. Approximate four corners of a pyramid with each 18 degrees off‑nadir | Not available | Employs Janus system. Approximate four corners of a pyramid with each 16 degrees off‑nadir and  10.5 degrees laterally | Employs Janus system | Employs Janus system. Approximate four corners of a pyramid with each 20 degrees off‑nadir | Two beams | Not available | Not available |
| Antenna scan |  | Scan is one beam at a time for each corner of the pyramid | Scan is one beam at a time for each corner of the pyramid | Scan is one beam at a time for each corner of the pyramid | Not available | Scan is one beam at a time for each corner of the pyramid | Not available | Not available | Not available |
| Protection criteria | dB | −10 | −10 | −10 | −10 | −10 | −10 | −10 | −10 |

*Notes to the Table:*

NOTE 1 – The service ceiling of helicopters is generally lower than 7 000 m above mean sea level (MSL), while the service ceiling of fixed-wing maritime patrol aircraft is approximately 15 000 m MSL.

NOTE 2 – The sensitivity calculation (assuming a minimum 3 dB *S*/*N* requirement for tracking) for a Doppler system must account for the bandwidth of the receiver’s tracker. Sensitivity calculated with respect to the wide-open receiver bandwidth will yield a relatively low figure compared with the sensitivity based on the tracker’s dynamic bandwidth. In a current-generation tracker, this bandwidth is comparable to the bandwidth of the back-scattered radar signal’s spectrum, which itself varies with the velocity of the aircraft.

NOTE 3 – The actual instantaneous pointing direction of individual antenna beams depends on the installation attitude of the airborne Doppler radar with respect to the aircraft reference axes (it is not always level), as well as the pitch and roll state of the aircraft. Helicopters flying search patterns or making abrupt acceleration/deceleration manoeuvres will often have roll and pitch values in excess of 30 degrees for short periods of time. The attitude excursions for high‑performance military helicopters are even higher.

NOTE 4 – For systems where no noise figure is available, assume a value of 12 dB for systems employing IF receivers and 22 dB for Homodyne (zero IF) receivers. Reference Fried, W. R.: Principles and Performance Analysis of Doppler Navigation Systems, IRE Trans., Vol. ANE-4, pp.176-196, December 1957.

# 3 Characteristics of aeronautical radionavigation systems

Aircraft radionavigation radars in the frequency band 13.25-13.4 GHz operate continuously during flight to determine speed and heading. This encompasses an altitude range from just off the ground to approximately 4 500 m for helicopter and 15 000 m for aircraft. Flight times can vary for many hours, and typically the majority of the flight time is spent *en route*, but also some linger time at either the departure or destination points is expected. The Janus doppler radar navigation system uses four antenna beams as shown in Fig. 1; two fore and two aft, on the two sides of the ground track, to compute the aircraft velocity vector referenced to the terrain by measuring the doppler shift of the ground echo from the beams. The beams may transmit in pairs or sequentially, depending on the system design. Figure 2 shows the antenna beam pattern on the iso-doppler lines. Antenna stabilizing hardware or software keeps the antenna pointing towards the ground. When the IF bandwidth, IF\_BWIFBW in Hertz, is not available, the following approximation may be used:



where:

*IF*\_*BW*:IF bandwidth (Hz)

*v*: Aircraft velocity (m/s)

*fc*: Centre frequency (Hz)

*Bw*: Antenna beam width 3 dB in radians

*a*: Beam depression angle

*s*: Speed of light (m/s).

For Janus radar systems an additional factor of 1.414 is included. Reference Fried, W.R.: Principles and Performance Analysis of Doppler Navigation Systems, IRE Trans., Vol. ANE-4, pp. 176-196, December 1957.

FIGURE 1

Example antenna beam pattern configuration from the aircraft



Figure 2

Example antenna beam pattern on the iso-doppler lines



# 4 Characteristics of aeronautical radionavigation sense and avoid radar

The safe flight operation of UA necessitates advanced techniques to detect and track nearby aircraft, terrain, and obstacles to navigation. UA must avoid these objects in the same manner as manned aircraft. 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. The sense and avoid radar is an unmanned aircraft collision avoidance system whose primary function is to provide the capability to detect, track and report air traffic information to the user 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 avoidance manoeuvers. The technical parameters are provided in Table 2.

TABLE 2

Technical parameters of sense and avoid radar

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Units | Radar 1 | Radar 2 |
| Platform |  | Aircraft | Aircraft |
| Platform height | km | Up to 20 | Up to 15.5 |
| Radar type |  | Air-to-air traffic collision avoidance system (doppler radar navigation aids) | Air-to-air traffic collision avoidance system (doppler  radar navigation aids) |
| Ground speed | km/h | Up to 1 500 | Up to 1 500 |
| Frequency tuning range | GHz | 13.25-13.4 | 13.25-13.4 |
| Emission type |  | Phase coded pulses | Phase coded pulses |
| Pulse width | μs | 1-2 | 2.5 |
| Pulse rise and fall times | ns | 0.1 to 0.2 for rise and fall times | 0.1 to 0.2 for rise and fall times |
| RF emission bandwidth at  –40 dB | MHz | 30 | 28.5 |
| Pulse repetition frequency | pps | 6 000-8 000 | 30 000 |
| Average transmitter power | W | 25 to 35 (up to 50) | 25 to 35 (up to 50) |
| Receiver IF –3 dB bandwidth | MHz | 0.7-1.1 | 14 |

TABLE 2 (*end*)

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Units | Radar 1 | Radar 2 |
| Sensitivity | dBm | −122 for 10 dB *S*/*N* | –98.6 for 13.1 dB *S*/*N* |
| Receiver noise figure | dB | 3 | 2.7 |
| Calculated Rx noise power | dBW | –140.6 | –128.5 |
| Antenna type |  | Phased array | Phased array |
| Antenna placement |  | Nose of aircraft | Nose of aircraft |
| Antenna gain | dBi | 28-32 | 28-32 |
| First antenna side lobe | dBi | 15-19 | 19 |
| Horizontal beamwidth | degrees | 5 | 5 |
| Vertical beamwidth | degrees | 5 | 5 |
| Polarization |  | Linear vertical | Linear vertical and horizontal |
| Antenna scan | degrees | Vertical ±30 Horizontal ±110 | Vertical ±37 Horizontal ±110 |
| Protection criteria | dB | −10 | −10 |

# 5 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.

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.