



**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**

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<b>SNG</b>	Satellite news gathering
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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	kHz	Not applicable	2	100	Not applicable	Not available	1 000	Not available	Not available
	-20 dB			800	250		Not available	5 600		
	-40 dB			20 000	350		150	95 000		
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 <i>S/N</i>	-135	-134 for 0 dB <i>S/N</i>	-138 for 3 dB <i>S/N</i>	-130 for 3 dB <i>S/N</i> ( <i>V</i> = 100 m/s) -160 for 3 dB <i>S/N</i> ( <i>V</i> = hover)	-96 for 3 dB <i>S/N</i> ( <i>V</i> = 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,  $IF\_BW$  in Hertz, is not available, the following approximation may be used:

$$IF\_BW = 2 * v * f_c * B_w * \sin(a) / s$$

where:

- $IF\_BW$ : IF bandwidth (Hz)
- $v$ : Aircraft velocity (m/s)
- $f_c$ : Centre frequency (Hz)
- $B_w$ : 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.

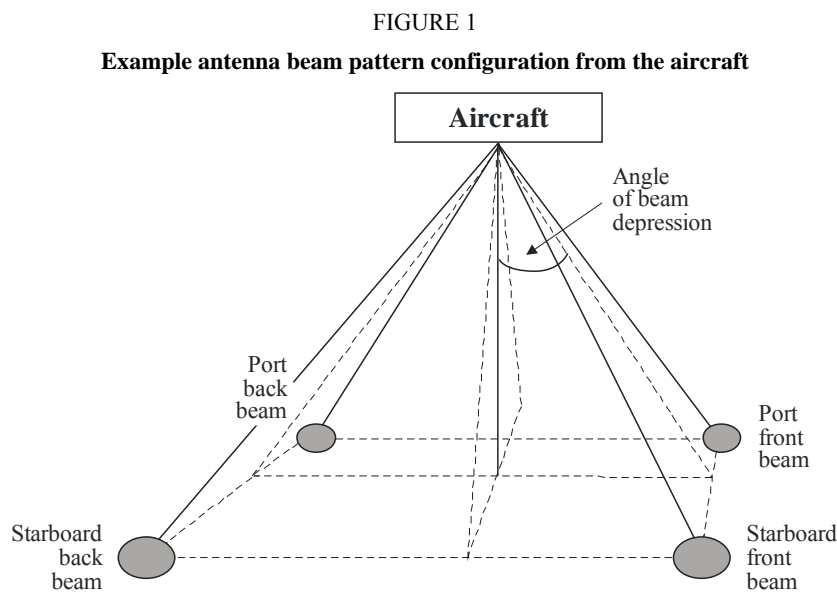
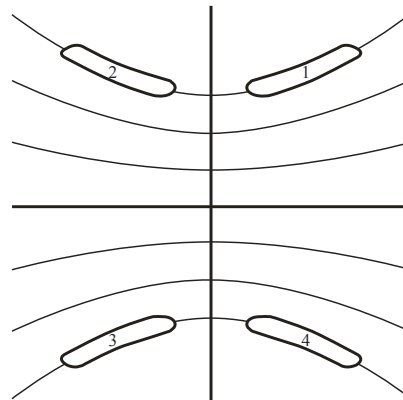




FIGURE 2

Example antenna beam pattern on the iso-doppler lines



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#### 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 manoeuvres. 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 <i>S/N</i>	-98.6 for 13.1 dB <i>S/N</i>
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	dB <sub>i</sub>	28-32	28-32
First antenna side lobe	dB <sub>i</sub>	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.