International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.2008

(03/2012)

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

International Telecommunication Union

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

Electronic Publication
Geneva, 2012

RECOMMENDATION ITU-R M.2008

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

(2012)

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 within this frequency band.

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);

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 aeronautical radionavigation service;

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 Annex 1 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 in this frequency band;

3 that the criterion of interfering signal power to radar receiver noise power level, I/N −10, 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 1

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

1 Introduction

The ARNS 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 systems (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		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/hr)		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 (kHz)	−3 dB −20 dB −40 dB	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	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	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

Table Notes

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. This type of system uses four antenna beams as shown in Fig. 1. 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_BWIF$_{BW}$ 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 1

Example antenna beam pattern configuration from the aircraft

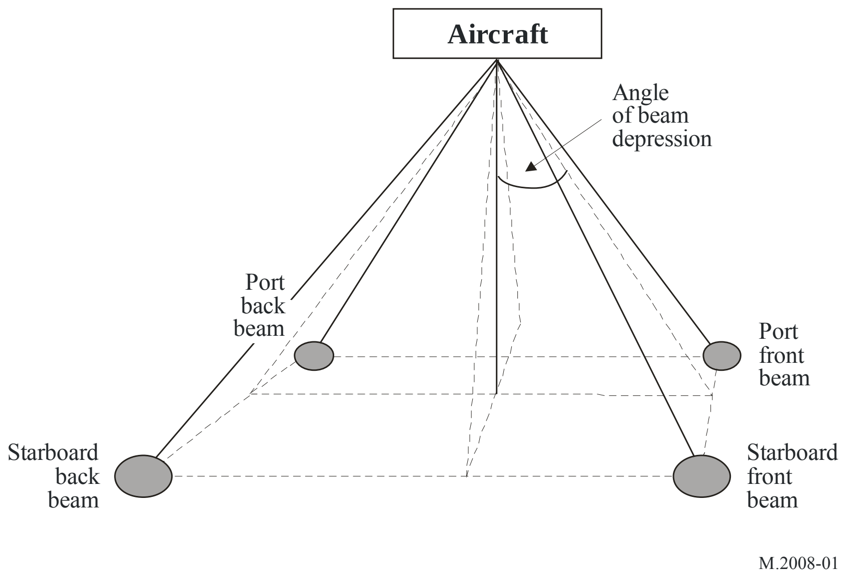
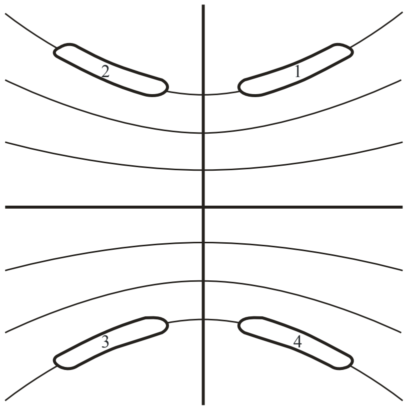


FIGURE 2

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	**Radar**
Platform	Aircraft
Platform height (km)	Up to 20
Radar type	Air to air traffic collision avoidance system (Doppler Radar navigation aids)
Ground speed (km/hr)	Up to 1 500
Frequency tuning range (GHz)	13.25-13.4
Emission type	Phase coded pulses
Pulse width (μs)	1-2
Pulse rise and fall times (ns)	0.1 to 0.2 for rise and fall times
RF emission bandwidth at –40 dB (MHz)	30
Pulse repetition frequency (pps)	6 000-8 000
Average transmitter power (W)	25 to 35 (up to 50)
Receiver IF –3dB bandwidth (MHz)	0.7-1.1
Sensitivity (dBm)	−122 for 10 dB SNR

TABLE 2 (*end*)

Parameter	Radar
Receiver noise figure (dB)	3
Antenna type	Phased array
Antenna placement	Nose of aircraft
Antenna gain (dBi)	28-32
First antenna side lobe (dBi)	15-19
Horizontal beamwidth (degrees)	5
Vertical beamwidth (degrees)	5
Polarization	Linear vertical
Antenna scan (degrees)	Vertical ±30 Horizontal ±110
Protection criteria (dB)	−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 $(I + N)/N$ ratio of about −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.