International Telecommunication Union

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Radiocommunication Sector of ITU

Recommendation ITU-R M.1465-4
(02/2022)

Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency range 3 100-3 700 MHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

Foreword

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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.1465-4

Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency range 3 100-3 700 MHz

(2000-2007-2015-2018-2022)

Scope

This Recommendation provides technical and operational characteristics, as well as protection criteria, of operational land/ship/air based radars in the frequency range 3 100-3 700 MHz[1]. The Recommendation includes representative characteristics on the transmitter, receiver, and antenna components, as well as deployment information, of these radars.

Keywords

Characteristics, protection criteria, ship radar, ground-based radar, airborne radar

Abbreviations/Glossary

AMSL: Above mean sea level

ATC: Air traffic control

CPFSK: Continuous-phase frequency shift keying

RR: Radio Regulations

Related ITU Recommendations

Recommendations

ITU-R M.1460: Technical and operational characteristics and protection criteria of radiodetermination radars in the frequency band 2 900-3 100 MHz

ITU-R M.1461: Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services

ITU-R M.1464: Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2 700-2 900 MHz

ITU-R M.1851: Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses

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 radars operating in the radiodetermination service are determined by the mission of the system and vary widely even within a frequency band;

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[1] Some systems operate in the frequency band extending down to 2 800 MHz.

c) that the radionavigation service is a safety service as specified by No. **4.10** of the Radio Regulations (RR) and freedom from harmful interference has to be ensured;

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

e) that procedures and methodologies are needed to analyse compatibility between radars operating in the radiodetermination service and systems in other services;

f) that the frequency band 3 100-3 400 MHz is allocated to the radiolocation service on a primary basis in all three Regions;

g) that the frequency band 3 400-3 600 MHz is allocated to the radiolocation service on a secondary basis in Region 1;

h) that the frequency band 3 400-3 600 MHz is allocated to the radiolocation service on a primary basis in Regions 2 and 3 under No. **5.433** of the RR, however, all administrations operating radiolocation systems in this band are urged to cease operations by 1985. Thereafter, administrations shall take all practicable steps to protect the fixed-satellite service and coordination requirements shall not be imposed on the fixed-satellite service;

i) that the frequency band 3 600-3 700 MHz is allocated to the radiolocation service on a secondary basis in Regions 2 and 3;

j) that the frequency band 3 100-3 300 MHz is also allocated to the radionavigation service on a primary basis in the countries listed in No. **5.428** of the RR;

k) that Recommendation ITU-R M.1464 contains characteristics of some systems operating in the frequency range 2 700-3 400 MHz,

recognizing

that RR Nos. **5.433**, **5.429**, **5.429A**, **5.429B**, **5.429C**, **5.429D**, **5.429E** and **5.429F** apply,

recommends

1 that the technical and operational characteristics of the radiolocation radars described in Annex 1 should be considered representative of those operating in the frequency range 3 100-3 700 MHz;

2 that Recommendation ITU-R M.1461 should be considered in analysing compatibility between radars operating in the radiodetermination service with systems in other services;

3 that 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 radiolocation systems, and that this represents the net protection level if multiple interferers are present;

4 that the characteristics in Table 1 should be used for sharing and compatibility studies with radar systems operating in 3.1-3.7 GHz.

Annex 1

Technical and operational characteristics of radiolocation radars operating in the frequency range 3 100-3 700 MHz

1 Introduction

The characteristics of radiolocation radars operating in the frequency range 3 100-3 700 MHz are presented in Table 1 and are discussed further in the following paragraphs.

TABLE 1

Table of characteristics of radiolocation systems in the frequency range 3 100-3 700 MHz[2, 3]

Parameter	Land-based systems							Ship systems				Airborne system
	L-A	L-B	L-C	L-D	L-E	L-F	L-G	S-A	S-B	S-C	S-D	A-A
Use	Surface and air search	Surface search	Multi-function Surface and air search	Multi-function surface and air search	Multi-function surface and air search	Multi-function surface and air search	Multi-function surface and air search	Surface and air search				Surface and air search
Modulation	P0N/Q3N	P0N	P0N/Q7N	P0N/Q7N	Q0N	M1N	Q3N	P0N	Q7N	P0N/Q7N	Q7N	Q7N
Tuning range (GHz)	3.1-3.7		2.8-3.4	2.8-3.5	3.3-3.4	3.1-3.5	3.1-3.5	3.3-3.4	2.9-3.7	3.1-3.5	2.9-3.5	3.1-3.7
Tx power into antenna (Peak) (kW)	640	1 000	200	60-70	0.33	500	100	1 000	4 000-6 400	60-200	4-90	1 000
Pulse width (μs)	160-1 000	1.0-15	50-500	3-150	0.65	0.1-1.0	0.5-50	0.25, 0.6	6.4-768	0.1-1 000	0.1-100	1.25(1)
Repetition rate (kHz)	0.020-2	0.536	0.2-50	0.8-50	160	50-200	1.0-20.0	1.125	0.152-6.0	0.3-10	0.5-10	2
Compression ratio	48 000	Not applicable	Up to 1 000	Up to 2 000	26	Not applicable	Not applicable	Not applicable	64-512	Up to 20 000	Up to 400	<10
Type of compression	Not available	Not applicable	LFM and NLFM	LFM and NLFM	Not applicable	Not applicable	Not applicable	Not applicable	CPFSK	Not available	Not available	LFM and NLFM
Duty cycle (%)	2-32	0.005-0.8	0.2-20	Max 12	Max 11	2.0-5.0	1.0-5.0	0.28, 0.67	0.8-30.0	Max 20	Max 20	5
Tx bandwidth (MHz) (−3 dB)	25/300	2	2	7-40	1-20	5	1.5	4, 16.6	4-800	25	3.15	> 30
Antenna gain (dBi)	39	40	31	40	22	22	37	32	42	Up to 40	Up to 40	40
Antenna type	Parabolic	Phased array	Phased array	Phased array	Phased array	Planar array	Phased array	Phased array			Slotted waveguide array	

[2] Recommendations ITU-R M.1460 and ITU-R M.1464 also give characteristics of radiolocation radars operating in the frequency range 2 700-3 400 MHz.

[3] The technical characteristics for these radars apply to the full tuning range shown.

TABLE 1 (*end*)

Parameter	Land-based systems							Ship systems				Airborne system
	L-A	L-B	L-C	L-D	L-E	L-F	L-G	S-A	S-B	S-C	S-D	A-A
Beamwidth (H, V) (degrees)	1.72	1.05, 2.2	1.5	1-4.5	15,15	15, 15	2.5, 2.5	1.75, 4.4, csc^2 to 30	1.7, 1.7	1.1-5, 1.1-5	1.5-6, 4-20	1.2, 6.0
Vertical scan type	Not available	Not applicable	Random	Random	Random	Electronic scan sector	Not available	Not applicable	Random	Not applicable	Not applicable	Not available
Maximum vertical scan (degrees)	93.5	Not applicable	90	90	75	90	70	Not applicable	90	90	90	± 60
Vertical scan rate (degrees/s)	15	Not applicable	50	Variable	35	10.0-50.0	Not applicable	Not applicable		Instantaneous		Electronic
Horizontal scan type	Not applicable	Rotating	Rotating	Rotating	Random	Not applicable	Rotating	Rotating	Random	Continuous 360 + Sector	Continuous 360 + Sector	Rotating
Maximum horizontal scan (degrees)	360							360				
Horizontal scan rate (degrees/s)	15	25.7	36	180	Variable	60-100	0	24	Not applicable	30-360	50-180	36
Polarization	RHCP	V	Linear	V	V	Linear	Linear	H	V	Not available	V	H
Rx sensitivity (dBm)	Not available	−112	−110	−115	−141	–114	–85	−112	Not available	Not available	Not available	Not available
Rx noise figure (dB)	3.1	4.0	1.5	4	3	3	5	4.8	5.0	1.5	1.5	3
Rx RF bandwidth (−3 dB) (MHz)	Not available	2.0	600	400	100	500	120	Not available		400		Not available
Rx IF bandwidth (−3 dB) (MHz)	380	0.67	2	30	5,10	12	18	8	10	10-30	2-20	1
Deployment area	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide

(1) 100 ns compressed.

2 Technical characteristics

The frequency range 3 100-3 700 MHz is used by radars with installations on land, on ships and on aircraft. In general, the predominant use by mobile radars is on ships and aircraft while the fixed, land-based systems are operated at test ranges and are often deployed aboard tethered balloons for surveillance over land or coastal areas. Functions performed include search for near-surface and high-altitude airborne objects, sea surveillance, tracking of airborne objects, and for multi-purpose test range instrumentation. Both unmodulated and angle modulated pulse modulation, duty cycles are employed for these search radar functions. Table 1 contains representative characteristics for land-based radar systems, ship systems and airborne systems operating in the frequency range 3 100-3 700 MHz.

2.1 Land-based radars

2.1.1 Land-based radar operations

Land-based radars operating in the frequency range 3 100-3 700 MHz are employed usually for test operations on and off test ranges. Many of these radars are mobile in the sense that they are often mounted on wheeled vehicles to relocate the radar to provide search and tracking functions for airborne vehicles along extended flight paths. Others are installed in fixed locations at test ranges where they also provide both search and tracking functions.

Land-based System L-B, in Table 1, is tethered at up to 4 600 m altitude to provide extended range surveillance of up to 275 km. Land-based system L-A depicted in Table 1 operates mainly during daylight hours in good flying weather with occasional night operations while the tethered balloon borne radars operate continuously. Land-based systems L-C, L-D, L-E, L-F, L-G are all-weather, full time and multi mission radars on mobile vehicle or stationary platform locations for air and surface search.

2.1.2 Transmitter

Transmitters are tunable and are subject to operating anywhere within the frequency range 3 100-3 700 MHz. Specifically, System L-F transmits in the 3 100-3 500 MHz range and System L-G transmits in the 3 100-3 500 MHz range. Unmodulated pulse, single-channel angle modulated and multichannel angle-modulated modulations are employed. Additionally, systems L-B, L-F, and L-G do not use pulse compression.

2.1.3 Receiver

Many of the test range radar receivers have special gating circuits for correlation of video data and data feed to various displays, operator consoles and recording devices. The video data received by the tethered balloon radar is relayed to ground operator facilities by both radio (fixed service) and wire.

2.1.4 Antenna

Systems L-A and L-B utilize parabolic dish antennas. Systems L-C, L-D, L-E, L-F utilize phased array antennas and L-G utilizes a planar array antenna. Systems L-C, L-D, L-E, L-F, and L-G antenna patterns can be modelled using uniform antenna pattern of Recommendation ITU-R M.1851. Antennas are designed for their special purpose on the test range but operate with main beam gain up to 40 dBi, are electronically steered and are usually directed skyward in random directions increasing the possibility of illuminating space borne objects and receiving energy from them. The tethered balloon radars direct their antennas at the horizon to a few degrees above it.

2.2 Shipborne radar

2.2.1 Ship-based operations

Representative types of shipboard radars operating in the frequency range 3.1-3.7 GHz are depicted in Table 1 as System S-A through S-D. System S-A is used as a primary aircraft carrier air traffic control system. System S-B is multifunction radars mainly deployed aboard escort ships. Operational areas of these shipboard radars include littoral and high seas. These radars are typically operated on a round-the-clock schedule. When providing escort for other ships, it is not uncommon to find up to ten of these radars operating simultaneously. In addition to the shipboard systems there are fixed systems on land that are used for training and testing. Also, routine maintenance and testing operations require that these radars be operated occasionally in certain port areas. System S-A equipped ship is almost always accompanied by at least one System S-B equipped ship.

2.2.2 Transmitter

System S-A transmits in the frequency band 3 500-3 700 MHz. System S-B transmits in the frequency range 2 900-3 700 MHz and utilizes a combination of phase modulation and frequency hopping. Emissions are frequency agile over ten frequency bands, each 40 MHz wide, designated as frequency bands 1 through 10. The sequence of variable pulse widths is random.

2.2.3 Receiver

System S-A receivers are as described in Table 1 and have the usual features of air traffic control (ATC) systems for false target/clutter reduction, moving target indication, short/long range selection and video feed to plan position indicator scopes; its tuning range is the same as the transmitter. The System S-B receiver operates in the frequency range 2 900-3 700 MHz. The receiver characteristics are not available but are assumed to be modern receivers with much processing gain needed to detect multiple and varied objects at extended ranges, in heavy clutter and in adverse weather.

2.2.4 Antenna

System S-A uses a mechanically rotating reflector type antenna with an azimuth beamwidth of 1.75° and csc^2 beam in elevation from 4.4° to 30° with a mainbeam gain of 32 dBi. The nominal antenna height is 46 m above mean sea level (AMSL). System S-B uses four planar electronically-steered phased-array antennas to provide 360° coverage with a mainbeam gain of 42 dBi. The antenna pattern for system S-B can be modelled using uniform antenna pattern of Recommendation ITU-R M.1851. The nominal height of the Radar S-B antenna is 20 m AMSL.

2.3 Airborne radar

Airborne radars found in this frequency band take advantage of the spectrum properties found at this wavelength to conduct long-range surveillance, target tracking and ATC. The spectrum characteristics for typical airborne radar found in this frequency band are depicted in Table 1. This system is a multifunction, phased-array radar that is deployed on surveillance aircraft of a number of administrations. The antenna of this system is a large, slotted waveguide array assembly mounted atop of the airframe. It provides 40 dBi mainbeam gain, first sidelobe at 27 dBi, and its remote sidelobe gain has been estimated to be 11.5 dBi.

The antenna pattern to consider in the sharing and compatibility studies is Recommendation ITU-R M.1851 with uniform distribution. The aircraft carrying these radars are capable of worldwide operations. In addition to their air surveillance and ATC functions they also have a sea surveillance mode. This airborne system is typically operated at about 9 000 m in altitude and can be operated for extended hours of up to 12 h depending upon aircrew availability. In some situations, constant surveillance is maintained on a 24 h per day basis by replenishment aircraft.

3 Protection criteria

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.

Systems which use pulse compression have their IF bandwidth matched to the compressed pulse and act as a matched filter for minimum S/N degradation. Pulse compression filters may be partially matched to and hence increase the effect of noise-like interference. In that case, an I/N ratio of −6 dB may not be adequate, and further studies or compatibility measurements may be necessary to assess the interference in terms of the operational impact on the radar's performance.

Continuous-wave interference of a noise-like type inflicts a desensitizing effect on radiodetermination radars, and that effect is predictably related to its intensity. Within any azimuth sectors in which such interference arrives, its power spectral density can, to a reasonable approximation, simply be added to the power spectral density of the radar-system thermal noise. If the power of radar-system noise in the absence of interference is denoted by N and that of noise-like interference by I, the resultant effective noise power becomes simply $I + N$.

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 to $I + N$. 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. (In modern radars, receiving-system noise is usually already near an irreducible minimum and nearly-optimum signal processing is becoming commonplace.)

These penalties vary depending on the radar's function and the nature of its targets. For most radar systems, 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 fourth 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 $1/((1.26)^{1/4})$, 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.