International Telecommunication Union

# ITU-R

Radiocommunication Sector of ITU

**Recommendation ITU-R M.1465-2**
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# 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**

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## 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.1465-2

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

(2000-2007-2015)

## 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. 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

MTI Moving target indication

PPI Planned position indicator

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;

*c)* that the radionavigation service is a safety service as specified by No. **4.10** of the Radio Regulations (RR) and harmful interference to it cannot be accepted;

*d)* that considerable radiolocation and radionavigation spectrum allocations (amounting to about 1 GHz) have been removed or downgraded since WARC-79;

*e)* that some Radiocommunication Study Groups are considering the potential for the introduction of new types of systems (e.g., fixed wireless access and high density fixed and mobile systems) or services in frequency bands between 420 MHz and 34 GHz used by radars in the radiodetermination service;

*f)* 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;

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

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

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

*j)* that the frequency band 3 400-3 600 MHz is allocated to the radiolocation service on a primary basis in Regions 2 and 3;

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

*l)* 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,

*recognizing*

*a)* that No. **5.433** of the RR states that in Regions 2 and 3, in the frequency band 3 400-3 600 MHz the radiolocation service is allocated on a primary basis. However, all administrations operating radiolocation systems in this frequency 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,

*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 used as a guideline 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.

# 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**

| **Parameter** | **Units** | **Land-based systems** | | **Ship systems** | | | | **Airborne system** |
|---|---|---|---|---|---|---|---|---|
| | | **A** | **B** | **A** | **B** | **C** | **D** | **A** |
| Use | | Surface and air search | Surface search | Surface and air search | | | | Surface and air search |
| Modulation | | P0N/Q3N | P0N | P0N | Q7N | P0N/Q7N | Q7N | Q7N |
| Tuning range | GHz | 3.1-3.7 | | 3.5-3.7 | 3.1-3.5 | 3.1-3.5 | | 3.1-3.7 |
| Tx power into antenna (Peak) | kW | 640 | 1 000 | 1 000 | 4 000-6 400 | 60-200 | 4-90 | 1 000 |
| Pulse width | µs | 160-1 000 | 1.0-15 | 0.25, 0.6 | 6.4-51.2 | 0.1-1000 | 0.1-100 | 1.25[(1)] |
| Repetition rate | kHz | 0.020-2 | 0.536 | 1.125 | 0.152-6.0 | 0.3-10 | 0.5-10 | 2 |
| Compression ratio | | 48 000 | Not applicable | Not applicable | 64-512 | Up to 20 000 | Up to 400 | 250 |
| Type of compression | | Not available | Not applicable | Not applicable | CPFSK | Not available | Not available | Not available |
| Duty cycle | % | 2-32 | 0.005-0.8 | 0.28, 0.67 | 0.8-2.0 | Max 20 | Max 20 | 5 |
| Tx bandwidth (–3 dB) | MHz | 25/300 | 2 | 4, 16.6 | 4 | 25 | 3,15 | > 30 |
| Antenna gain | dBi | 39 | 40 | 32 | 42 | Up to 40 | Up to 40 | 40 |
| Antenna type | | Parabolic | | Parabolic | PA | | | -SWA |
| Beamwidth (H,V) | degrees | 1.72 | 1.05, 2.2 | 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 | Not applicable | Random | Not applicable | Not applicable | Not available |
| Maximum vertical | degrees | 93.5 | Not | Not | 90 | 90 | 90 | ±60 |

| **Parameter** | **Units** | **Land-based systems** | | **Ship systems** | | | | **Airborne system** |
|---|---|---|---|---|---|---|---|---|
| | | **A** | **B** | **A** | **B** | **C** | **D** | **A** |
| scan | | | applicable | applicable | | | | |
| Vertical scan rate | degrees/s | 15 | Not applicable | Not applicable | | Instantaneous | | Not available |
| Horizontal scan type | | Not applicable | Rotating | Rotating | Random | Continuous 360 + Sector | Continuous 360 + Sector | Rotating |
| Maximum horizontal scan | degrees | 360 | | 360 | | | 360 | 360 |
| Horizontal scan rate | degrees/s | 15 | 25.7 | 24 | Not applicable | 30-360 | 50-180 | 36 |
| Polarization | | RHCP | V | H | V | Not available | V | Not available |
| Rx sensitivity | dBm | Not available | –112 | –112 | Not available | Not available | Not available | Not available |
| *S*/*N* criteria | dB | Not applicable | 0 | 14 | Not available | Not available | Not available | Not available |
| Rx noise figure | dB | 3.1 | 4.0 | 4.8 | 5.0 | 1.5 | 1.5 | 3 |
| Rx RF bandwidth (–3 dB) | MHz | Not available | 2.0 | Not available | | 400 | | Not available |
| Rx IF bandwidth (–3 dB) | MHz | 380 | 0.67 | 8 | 10 | 10-30 | 2-20 | 1 |
| Deployment area | | Worldwide | Worldwide | Worldwide | Worldwide | Worldwide | Worldwide | Worldwide |

(1) 100 ns compressed.

CPFSK: Continuous-phase FSK

PA: Phased array

SWA: Slotted waveguide array

## 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 is employed and the typical peak transmitter power ranges from 500 kW to 6 400 kW. Low duty cycles are employed for search radar functions with typical values ranging less than 1%. Receiver noise figures typically range from 3.1 dB to 16 dB. Table 1 contains representative characteristics for two land-based radar systems, two ship systems and one airborne system 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 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 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.

#### 2.1.2 Transmitter

Transmitters are tunable and are subject to operating anywhere within the frequency range 3 100-3 700 MHz. Unmodulated pulse, single-channel angle modulated and multichannel angle-modulated modulations are employed.

#### 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

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

Four representative types of shipboard radars operating in the frequency range 3.1-3.7 GHz are depicted in Table 1 as System A through D. System A is used as a primary aircraft carrier air traffic control system. System B is multifunction radar 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. A System A equipped ship is almost always accompanied by at least one System B equipped ship.

### 2.2.2 Transmitter

System A transmits in the frequency band 3 500-3 700 MHz with a peak power of 1 000 kW. System B transmits in the frequency range 3 100-3 500 MHz with a peak power of 6.4 MW 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 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 (MTI), short/long range selection and video feed to planned position indicator (PPI) scopes; its tuning range is the same as the transmitter. The System B receiver operates in the frequency range 3 100-3 500 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 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 B uses four planar electronically-steered phased-array antennas to provide 360° coverage with a mainbeam gain of 42 dBi. The nominal height of the Radar 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 and its sidelobe gain has been estimated to be –10 dBi. 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.