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Radiocommunication Sector of ITU

Recommendation ITU-R M.1730-2
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Characteristics of and protection criteria for the radiolocation service in the frequency band 15.4-17.3 GHz

M Series

Mobile, radiodetermination, amateur and related satellite services

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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.1730-2

Characteristics of and protection criteria for the radiolocation service in the frequency band 15.4-17.3 GHz

(2005-2009-2023)

Scope

This Recommendation provides the technical characteristics and protection criteria for the radiolocation systems operating and planned to operate in the band 15.4-17.3 GHz. It was developed as a resource document intended to support sharing studies in conjunction with Recommendation ITU-R M.1461 addressing analysis procedures for determining compatibility between radars operating in the radiolocation service and other services.

Keywords

Radiolocation, radar, protection criteria, pulsed interference, technical characteristics

Related ITU-R Recommendations, Reports

Recommendations

ITU-R M.1313 Technical characteristics of maritime radionavigation radars

ITU-R M.1372 Efficient use of the radio spectrum by radar stations in the radiodetermination service

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.1462 Characteristics of and protection criteria for radars operating in the radiolocation service in the frequency range 420-450 MHz

ITU-R M.1463 Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 1 215-1 400 MHz

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.1465 Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency range 3 100-3 700 MHz

ITU-R M.1466 Characteristics of and protection criteria for radars operating in the radionavigation service in the frequency band 31.8-33.4 GHz

ITU-R M.1638 Characteristics of and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 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 radiolocation service are determined by the mission of the system and vary widely even within a frequency band;

c) that ITU-R is considering the potential for the introduction of new types of systems or applications in frequency bands between 420 MHz and 34 GHz used by radars in the radiodetermination service;

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

e) that procedures and methodologies to analyse compatibility between radars in the radiodetermination service and systems in other services are contained in Recommendation ITU-R M.1461,

noting

a) that this Recommendation along with Recommendation ITU-R M.1461 are used as a guideline in analysing compatibility between radiodetermination radars and systems in other services;

b) that the criterion of interfering signal power to radar receiver noise power level are identified in Recommendation ITU-R M.1461,

recognizing

a) that the required protection criteria depend upon the specific types of interfering signals;

b) that the application of protection criteria may require consideration for inclusion of the statistical nature of the criteria and other elements of the methodology for performing compatibility studies (e.g. antenna scanning including motion of the transmitter and propagation loss). Further development of these statistical considerations may be incorporated into future revisions of this and other related Recommendations, as appropriate,

recommends

1 that the technical and operational characteristics of the radiolocation radars described in Annex 1 should be considered as representative of those operating or planned to operate in the frequency band 15.4-17.3 GHz;

2 that an I/N ratio of −6 dB, should be considered as the required protection level for radars in the frequency band 15.4-17.3 GHz where there is an allocation for Radiolocation Service, taking into account *recognizing a)* and *b)* above;

3 that in the case of pulsed interference, the criteria should be based on a case-by-case analysis taking into account the undesired pulse train characteristics and, to the extent possible, the signal processing in the radar receiver.

NOTE 1 – This Recommendation should be revised as more detailed information becomes available.

Annex 1

Characteristics of and protection criteria for radars operating or planned to operate in the radiolocation service in the frequency band 15.4-17.3 GHz

1 Introduction

The characteristics of radiolocation radars operating or planned to operate worldwide in the frequency band 15.4-17.3 GHz are presented in Table 1 and described further in the following paragraphs.

2 Technical characteristics

The frequency band 15.4-17.3 GHz is used by many different types of radars including land-based, transportable, shipboard and airborne platforms. Radiolocation functions performed in the frequency band include airborne and surface search, ground-mapping, terrain-following, maritime and target-identification. Radar operating frequencies can be assumed to be uniformly spread throughout each radar's tuning range. Table 1 contains technical characteristics of representative radiolocation radars deployed or planned to be deployed in the frequency band 15.4-17.3 GHz.

The major radiolocation radars operating or planned to operate in the frequency band 15.4-17.3 GHz are primarily for detection of airborne objects and some are used for ground mapping. They are required to measure target altitude, range, bearing, and form terrain maps. Some of the airborne and ground targets are small and some are at ranges as great as 300 nautical miles (556 km), so these radiolocation radars must have great sensitivity and must provide a high degree of suppression to all forms of clutter return, including that from sea, land and precipitation.

TABLE 1

Characteristics of radiolocation radars in the 15.4-17.3 GHz band

Characteristics	Units	System 1	System 2	System 3	System 4	System 5	System 6
Function		Search, track and ground-mapping radar (multi-function)	Search, track and ground-mapping radar (multi-function)	Air surveillance, landing aid, track while scan	Surveillance	Ground surveillance and track	Search, track and ground-mapping (multi-function)
Platform type		Airborne, low power	Airborne, high power	Shipboard, high power	Ground-based, low power	Ground-based, high power	Airborne (300-13 700 m)
Tuning range	GHz	16.2-17.3	16.29-17.21	15.7-17.3	16.21-16.5	15.7-16.2	15.4-17.3
Modulation		Variable linear FM	Linear FM pulse	Pulse, frequency hopping	Linear FM chirp	Pulse, frequency hopping	Linear FM chirp
Transmit peak power	W	80	700	20 k	2	10 k	500, 2 k, 10 k
Pulsewidth	μs	18.2; 49	120-443	0.1	5.5	36	0.05-50
Pulse rise/fall time	ns	20	4	7/70	10	8	5-100
Pulse repetition rate	pps	5 495; 2 041	900-1 600	4 000; 21 600	7 102	20 000	200-20 000
Maximum duty cycle		0.1	Not specified	0.00216	0.039	0.00072	Up to 0.2(1)
Output device		Travelling wave tube	Travelling wave tube	Travelling wave tube	Transistor	Travelling wave tube	Travelling wave tube
Antenna pattern type		Fan/pencil	Fan	Pencil	Pencil	Pencil	Pencil (ITU-R M.1851 cosine square distribution)
Antenna type		Slotted waveguide	Phased array	Planar phased array	Elliptical with parabolic contour	Double curved reflector with feed horn	Phased array
Antenna polarization		Linear vertical	Linear vertical	RH circular	Horizontal	Circular	Linear
Antenna gain	dBi	25.6	38.0	43.0	37.0	43	35
Antenna elevation beamwidth	degrees	9.7	2.5	1	1.1	1.6	3.2
Antenna azimuthal beamwidth	degrees	6.2	2.2	1	3.5	.25	3.2
Antenna horizontal scan rate		30 degrees/s	5 degrees/s	1 500 scans/min	7.8 or 15.6 degrees/s	60 rpm, 360 degrees/s	1-30 degrees/s

TABLE 1 (*end*)

Characteristics	Units	System 1	System 2	System 3	System 4	System 5	System 6
Antenna horizontal scan type (continuous, random, sector, etc.)		±45º to ±135º (mechanical)	±30º (electronic, conical)	±40º (mechanical)	180º (mechanical)	360º (continuous)	±45º (electronic)
Antenna vertical scan rate		30 degrees/s	5 degrees/s	1 500 scans/min	Not applicable	Not applicable	1, 5 degrees/s
Antenna vertical scan type		–10º to –50º (mechanical)	0º to –90º (electronic, conical)	+30º/–10º (mechanical)	+22.5º/–33.75º (mechanical)	Not applicable	+5° to –45° (electronic)
Antenna 1st side-lobe level		10 dBi at 31º	18 dBi at 1.7º	20 dBi at 1.6º	15 dBi at 2.4º	23 dBi at 1.6º	3.5 dBi at 5.2º
Antenna height		Aircraft altitude	Aircraft altitude	Mast/deck mount	Ground level	100 m	Aircraft altitude
1st/2nd receiver IF –3 dB bandwidths	MHz	215/68	26.7 (wideband); 7.2 (narrow-band)	70/40	500/0.750	50	25
Receiver noise figure	dB	4	2.7	Not specified	4	1 + (860/290) 860 = Receiver noise temperature K 290 = Earth noise temperature K 3.97	5
Minimum discernible signal	dBm	–89	–97.4	–80	–100.4	–92	–100
Chirp bandwidth	MHz	≤ 640	Not specified	30	0.750	Not specified	< 1 900(2)
Transmitter RF emission bandwidth : –3 dB –20 dB	MHz	 622; 271 725; 324	 1 200; 600; 180 1 220; 620; 200	 6.8; 37 20; 42	 0.608 2.35	 540 670	 1 850 1 854

(1) Sharing studies will be conducted using multiple duty cycles from low duty cycles such as 0.01 to high duty cycles up to 0.2.

(2) Sharing studies will focus on chirp bandwidths greater than 1 600 MHz.

Largely because of these mission requirements, the radiolocation radars using or planned to use the band 15.4-17.3 GHz tend to possess the following general characteristics:

– they tend to have high transmitter peak and average power, with notable exceptions;
– they typically use master-oscillator-power-amplifier transmitters rather than power oscillators. They are usually tuneable and some of them are frequency-agile. Some of them use linear-FM (chirp) or phase-coded intra-pulse modulation;
– some of them have antenna main beams that are steerable in both azimuth and elevation using electronic beam steering;
– they typically employ versatile receiving and processing capabilities, such as auxiliary side-lobe-blanking receive antennas, processing of coherent-carrier pulse trains to suppress clutter return by means of moving-target-indication, constant-false-alarm-rate techniques and, in some cases, adaptive selection of operating frequencies based on sensing of interference on various frequencies.

Table 1 summarizes technical characteristics of representative systems deployed or planned to be deployed in the whole or portions of the frequency band 15.4-17.3 GHz. This information is sufficient for general calculation to assess the compatibility between these radars and other systems. Some or all of the radiolocation radars whose characteristics are presented in Table 1 possess the properties above, although they do not illustrate the full repertoire of attributes that might appear in future systems.

2.1 Transmitters

The radars operating or planned to operate in the frequency band 15.4-17.3 GHz use a variety of modulations including unmodulated pulses, frequency-modulated (chirped) pulses and phase-coded pulses. Linear-beam and solid-state output devices are used in the final stages of the transmitters. The trend in new radar systems is toward linear-beam and solid-state output devices due to the requirements of Doppler signal processing. Also, the radars deploying solid-state output devices have lower transmitter peak output power and higher pulse duty cycles.

Transmitters using solid-state are lower power radars and those transmitters using crossed-field devices (magnetrons) and linear-beam (travelling wave tube) devices are higher power radars.

2.1.1 Frequency hopping

This type of radar using frequency hopping techniques typically divides its allocated frequency band into channels. The radar then randomly selects a channel from all available channels for transmission. This random occupation of a channel can occur on a per beam position basis where many pulses on the same channel are transmitted, or on a per pulse basis. This important aspect of radar systems should be considered, and the potential impact of frequency hopping radars should be taken into account in sharing studies.

2.2 Receivers

The newer-generation radar systems use digital signal processing after detection for range, azimuth and Doppler processing. Generally, the signal processing includes techniques that are used to enhance the detection of desired targets and to produce target symbols on the display. The signal-processing techniques used for the enhancement and identification of desired targets also provide some suppression of low-duty-cycle (less than 5%) pulsed interference that is asynchronous with the desired signal.

The signal processing in the newer generation of radars uses chirped and phase-coded pulses to produce a processing gain for the desired signal and may also provide suppression of undesired signals.

Some of the newer low-power solid-state radars use high-duty-cycle multichannel signal processing to enhance the desired signal returns. Some radar receivers have the capability to identify RF channels that have low levels of undesired signals and command the transmitter to transmit on those RF channels.

2.3 Antennas

A variety of different types of antennas are used on radars operating or planned to operate in the frequency band 15.4-17.3 GHz. Antennas in this band are generally of a variety of sizes and thus are of interest for applications where mobility and lightweight are important as well as long range performance. Many radars in the frequency band 15.4-17.3 GHz operate or are planned to operate in a variety of modes, including search, map and navigation (weather observation) modes. The antennas for such radars usually scan through 360° in the horizontal plane. Other radars in the frequency band are more specialized and limit scanning to a fixed sector. Most radars in the frequency band 15.4-17.3 GHz use or are planned to use mechanical scanning, however newer-generation radars use electronically-scanned array antennas. Horizontal, vertical and circular polarizations are used. Typical antenna heights for ground-based and ship-borne radars range from 8 m and 100 m above surface level, respectively.

3 Protection criteria

For the portion of the frequency band 15.4-17.3 GHz where there is a radiolocation allocation, a signal from another service resulting in an I/N ratio below −6 dB is acceptable by the radar users for signals from the other service with high-duty cycle (e.g. continuous wave, binary phase shift keying, quaternary phase shift keying, noise-like, etc.). An I/N ratio of −6 dB results in a $(I + N)/N$ of 1.26, or approximately a 1 dB increase in the radar receiver noise power. Further studies or compatibility measurements may be necessary to assess the interference in terms of the operational impact on the radar's performance. It should be noted that studies are being developed on the feasibility of the use of statistical and operational aspects on the protection criteria for radiodetermination radar systems. This statistical approach may be particularly relevant in the case of non-continuous signals. In the case of radar systems operating in the band for which an ITU-R Recommendation on radar characteristics and protection criteria exist, then the relevant Recommendation[1] should be consulted for specific guidance regarding the protection criteria.

The effect of pulsed interference is more difficult to quantify and is strongly dependent on receivers/processor design and mode of operation. In particular, the differential processing gains for valid-target return, which is synchronously pulsed and interference pulses, which are usually asynchronous, often have important effects on the impact of given levels of pulsed interference. Several different forms of performance degradation can be inflicted by such desensitization. Assessing it will be an objective for analysis of interactions between specific radar types.

In general, numerous features of radiodetermination radars can be expected to help suppress low-duty cycle pulsed interference, especially from a few isolated sources. Techniques for suppression of low-

[1] Some examples of ITU-R Recommendations containing technical characteristics and protection criteria for specific bands include: ITU-R M.1313, ITU-R M.1460, ITU-R M.1462, ITU-R M.1463, ITU-R M.1464, ITU-R M.1465, ITU-R M.1466 and ITU-R M.1638.

duty cycle pulsed interference are contained in Recommendation ITU-R M.1372 – Efficient use of the radio spectrum by radar stations in the radiodetermination service.

When multiple interferers are present, the recommended *I*/*N* protection criteria remains unchanged (because it depends on the type of radar receiver and its signal processing characteristics). The total interference level actually arriving at the radar receiver (which has to be checked against recommended *I*/*N* protection criteria) depends on the number of interferers, their spatial distribution and their signal structure and needs to be assessed in the course of an aggregation analysis of a given scenario. If interference were received from several azimuth directions, an aggregation analysis has to cumulate simultaneous contributions from all these directions, being received via the radar antenna's main beam and/or side-lobes, in order to assess compatibility.

4 Future radiolocation systems

In broad outline, radiolocation radars that might be developed in the future to operate in the frequency band 15.4-17.3 GHz are likely to resemble the existing radars described here.

Future radiolocation radars are likely to have at least as much flexibility as the radars already described, including the capacity to operate differently in different azimuth and elevation sectors.

It is reasonable to expect that some future designs may strive for a capability to operate in a wide band extending at least to the band limits used in this consideration.

Future radiolocation radars in this band are likely to have electronically-steerable antennas. However, current technology makes phase steering a practical and attractive alternative to frequency steering and numerous radiolocation radars developed in recent years for use in other bands have employed phase steering in both azimuth and elevation. Unlike frequency-steered radars, new phased-array radars can steer any fundamental frequency in the radar's operating band to any arbitrary azimuth and elevation within its angular coverage area. Among other advantages, that would facilitate electromagnetic compatibility in many circumstances.

Some future radiolocation radars are expected to have average-power capabilities at least as high as those of the radars described herein. However, it is reasonable to expect that designers of future radars will strive to reduce wideband noise emissions below those of the existing radars that employ magnetrons or crossed-field amplifiers. Such noise reduction is expected to be achieved by the use of solid-state transmitter/antenna systems. In that case, the transmitted pulses would be longer and the transmit duty cycles are substantially higher than those of most earlier tube-type radar transmitters.