RECOMMENDATION ITU-R M.1730

Characteristics of and protection criteria for the radiolocation service in the frequency band 15.7-17.3 GHz

(Question ITU-R 226/8)

(2005)

Scope

This Recommendation provides the technical characteristics and protection criteria for the radiolocation systems operating in the band 15 700-17 300 MHz which is allocated to the radiolocation service on a primary basis. 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.

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 band;

c) that ITU-R is considering the potential for the introduction of new types of systems or applications in 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;

f) that the frequency band 15.7-17.3 GHz is allocated to the radiolocation service on a primary basis,

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 in the frequency band 15.7-17.3 GHz;

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

3 that the criterion of interfering signal power to radar receiver noise power level identified in Recommendation ITU-R M.1461, an *I*/*N* ratio of –6 dB, should be used as the required protection level and that this represents the net protection level if multiple interferers are present.

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

Annex 1

Characteristics of and protection criteria for radars operating in the radiolocation service in the frequency band 15.7-17.3 GHz

1 Introduction

The characteristics of radiolocation radars operating worldwide in the frequency band 15.7-17.3 GHz are presented in Table 1 and described further in the following paragraphs.

2 Technical characteristics

The band 15.7-17.3 GHz is used by many different types of radars including land-based, transportable, shipboard and airborne platforms. Radiolocation functions performed in the 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 in the 15.7-17.3 GHz band.

The major radiolocation radars operating in this band are primarily used 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 15.7-17.3 GHz band

Characteristics	System 1	System 2	System 3	System 4	System 5
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
Platform type	Airborne, low power	Airborne, high power	Shipboard, high power	Ground-based, low power	Ground-based, high power
Tuning range (GHz)	16.2-17.3	16.29-17.21	15.7-17.3	16.21-16.5	15.7-16.2
Modulation	Variable linear FM	Linear FM pulse	Frequency hopping	Linear FM chirp	Frequency hopping
Transmit peak power (W)	80	700	20 k	2	10 k
Pulsewidth (μs)	18.2; 49	120-443	0.1	5.5	36
Pulse rise/fall time (ns)	20	4	7/70	10	8
Pulse repetition rate (pps)	5 495; 2 041	900-1 600	4 000; 21 600	7 102	20 000
Maximum duty cycle	0.1	Not specified	0.00216	0.039	0.00072
Output device	Travelling wave tube	Travelling wave tube	Travelling wave tube	Transistor	Travelling wave tube
Antenna pattern type	Fan/pencil	Fan	Pencil	Pencil	Pencil
Antenna type	Slotted waveguide	Phased array	Planar phased array	Elliptical with parabolic contour	Double curved reflector with feed horn
Antenna polarization	Linear vertical	Linear vertical	RH circular	Horizontal	Circular
Antenna gain (dBi)	25.6	38.0	43.0	37.0	43
Antenna elevation beamwidth (degrees)	9.7	2.5	1	1.1	1.6
Antenna azimuthal beamwidth (degrees)	6.2	2.2	1	3.5	.25
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

TABLE 1 *(end)*

Characteristics	System 1	System 2	System 3	System 4	System 5
Antenna horizontal scan type (continuous, random, sector, etc.)	±45º to ±135º (mechanical)	±30º (electronic, conical)	±40º (mechanical)	180º (mechanical)	360º (continuous)
Antenna vertical scan rate	30 degrees/s	5 degrees/s	1 500 scans/min	Not applicable	Not applicable
Antenna vertical scan type	–10º to –50º (mechanical)	0º to –90º (electronic, conical)	+30º/–10º (mechanical)	+22.5º/–33.75º (mechanical)	Not applicable
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
Antenna height	Aircraft altitude	Aircraft altitude	Mast/deck mount	Ground level	100 m
1st/2nd receiver IF –3 dB bandwidths (MHz)	215/68	26.7 (wideband); 7.2 (narrow-band)	70/40	500/0.750	50
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
Minimum discernible signal (dBm)	–89	–97.4	–80	–100.4	–92
Chirp bandwidth (MHz)	≤640	Not specified	30	0.750	Not specified
Transmitter RF emission bandwidth (MHz): –3 dB –20 dB	 622; 271 725; 324	 1 200; 600; 180 1 220; 620; 200	 6.8; 37 20; 42	 0.608 2.35	 540 670

Largely because of these mission requirements, the radiolocation radars using this band 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 mainbeams 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 in these bands. 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 in the 15.7-17.3 GHz band 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.

Typical transmitter RF emission (3 dB) bandwidths of radars operating in the band 15.7-17.3 GHz range from 60 kHz to 1 200 MHz. Transmitter peak output powers range from 2 W (33.01 dBm) for solid-state transmitters to 20 kW (73.01 dBm) for high-power radars using crossed-field devices (magnetrons) and linear-beam (travelling wave tube) devices.

2.1.1 Frequency hopping

Frequency hopping is one of the most common electronic counter-counter-measures (ECCMs). Radar systems that are designed to operate in hostile electronic attack environments use frequency hopping as one of its ECCM techniques. This type of radar 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 (10%) 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 in the 15.7-17.3 GHz band. 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 15.7-17.3 GHz band 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 band are more specialized and limit scanning to a fixed sector. Most radars in 15.7-17.3 GHz 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

In general cases, 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 (CW), binary phase shift keying (BPSK), quaternary phase shift keying (QPSK), 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

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[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.1638 and ITU-R M.1466.

low-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 mainbeam 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 15.7-17.3 GHz band 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.