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Radiocommunication Sector of ITU

Recommendation ITU-R M.1463-3
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**Characteristics of and protection
criteria for radars operating in the
radiodetermination service in
the frequency band 1 215-1 400 MHz**

M Series
**Mobile, radiodetermination, amateur
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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.1463-3*

Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 1 215-1 400 MHz

(2000-2007-2013-2015)

Scope

This Recommendation provides technical and operational characteristics, as well as protection criteria, of operational ground based radars in the frequency band 1 215-1 400 MHz. The Recommendation includes representative characteristics on the transmitter, receiver, and antenna components of these radars.

Keywords

Protection criteria, Airborne radar, Land based radar, Long range radar

Abbreviations/Glossary

CW Continuous wave

ESA Electronically steerable arrays

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 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;
- e)* 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;
- f)* that procedures and methodologies are needed to analyse compatibility between radars operating in the radiodetermination service and systems in other services;
- g)* that the frequency band 1 215-1 400 MHz is allocated to the radiolocation service on a primary basis;
- h)* that the frequency band 1 300-1 350 MHz is allocated on a primary basis to the aeronautical radionavigation service, limited to ground-based radars and associated airborne transponders;

* This Recommendation should be brought to the attention of Radiocommunication Study Group 7 and the International Civil Aviation Organization (ICAO).

- i) that the frequency band 1 215-1 300 MHz is additionally allocated on a primary basis to the radionavigation service in many countries;
- j) that the frequency band 1 215-1 300 MHz is allocated to the radionavigation-satellite service (space-to-Earth) on a primary basis;
- k) that the frequency band 1 215-1 300 MHz is allocated to the Earth exploration-satellite (active) and space research (active) services on a primary basis;
- l) that the frequency band 1 350-1 400 MHz is allocated to the fixed and mobile services on a primary basis, in Region 1, and that the frequency band 1 215-1 300 MHz is also allocated to the fixed and mobile services on a primary basis in the countries listed in RR No. **5.330**,

recommends

- 1** that the technical and operational characteristics of the radiodetermination radars described in the Annex should be considered representative of those operating in the frequency band 1 215-1 400 MHz;
- 2** that Recommendation ITU-R M.1461 be used as a guideline in analysing compatibility between radars operating in the radiodetermination service with systems in other services;
- 3** that in the case of continuous (non-pulsed) single or aggregate interference, an interfering signal power to radar receiver noise power level, I/N , of -6 dB should be used as the required protection level for the radiodetermination radars;
- 4** that in the case of pulsed interference, the criteria should be based on a case-by-case analysis, considering the undesired pulse train characteristics and, to the extent possible, the signal processing in the radar receiver.

Annex

Technical and operational characteristics of radiodetermination radars operating in the frequency band 1 215-1 400 MHz

1 Introduction

The characteristics of radiodetermination radars operating worldwide in the frequency band 1 215-1 400 MHz are presented in Table 1, and described further in the following paragraphs. Those characteristics specifically for wind profiler radars are found in § 4 of this Annex.

2 Technical characteristics

The frequency band 1 215-1 400 MHz is used by many different types of radars on fixed, mobile (including airborne) and transportable platforms. Radiodetermination functions performed in the frequency band include long range search tracking and surveillance. Radar operating frequencies can be assumed to be uniformly spread throughout the frequency band 1 215-1 400 MHz. Table 1 contains technical characteristics of representative radiolocation and radionavigation radars deployed in the frequency band 1 215-1 400 MHz.

Airborne radars found in this band take advantage of the favorable spectrum properties for long range surveillance. Operation at altitude (approx. 10 000 m) enables airborne systems to take advantage of a radio horizon in excess of 300 km.

2.1 Transmitters

The radars operating in the frequency band 1 215-1 400 MHz use a variety of modulations including continuous wave (CW) pulses, frequency modulated (chirped) pulses and phase coded pulses. Cross-field, 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 requirement of Doppler signal processing.

Also, the radars deploying solid state output devices have lower transmitter peak output power and higher pulsed duty cycles approaching 50% when operating on a single channel (a single channel may consist of three or four discrete frequencies in a 10 MHz bandwidth). There is also a trend towards frequency agile type radar systems which can suppress or reduce interference.

The majority of systems require and use more than one frequency to achieve the benefits of frequency diversity and/or to operate multiple functions simultaneously. Two frequencies are very common and the use of four or more is not unknown. Diversity considerations usually require that frequencies are not on adjacent channels and may require wide separation across the operating frequency band. In frequency hopping and detect and avoid configurations, radars use multiple frequencies across their tuning ranges.

Typical transmitter RF emission bandwidths of radars operating in the frequency band 1 215-1 400 MHz range from 0.5 to 3.0 MHz. Transmitter peak output powers range from 25 kW (73.9 dBm) for solid state transmitters to 5 MW (97 dBm) for high power radars using klystrons.

2.2 Receivers

The newer generation radar systems use digital signal processing after detection for range, azimuth and Doppler processing. Generally, included in the signal processing are techniques 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 provides some suppression of low-duty cycle interference, less than 5%, that is asynchronous with the desired signal.

Also, the signal processing in the newer generation radars using chirped and phase coded pulses produces a processing gain for the desired signal and may also provide suppression of undesired signals.

Some of the newer low-power solid state transmitters use high-duty cycle multiple receiver channel signal processing to enhance the desired signal returns.

These systems tend to have wideband RF front ends capable of receiving all frequencies without RF tuning followed by coherent superheterodyne receivers. Electronically steerable arrays (ESAs) consisting of hundreds of elements with integrated RF chains have broader RF and IF bandwidths. Modification of these elements to improve filter characteristics is practically not possible.

Some radar receivers have the capability to identify RF channels that have low undesired signals and command the transmitter to transmit on those RF channels.

2.3 Antennas

A variety of types of antennas are used on radars operating in the frequency band 1 215-1 400 MHz. Newer generation radars using reflector type antennas have multiple horns. Dual horns are used for transmit and receive antennas to improve detection in surface clutter. Also, multiple-horn stack-beam reflector antennas are used for three-dimensional radars. The multiple horn antennas will reduce the level of interference. Distributed phased array antennas are also used on some radars in the frequency band 1 215-1 400 MHz. The distributed phase array antennas have transmit/receive modules mounted on the antenna. Also, radars using phased array antennas generally have lower side-lobe levels than reflector type antennas, and have a narrow scanning beam in elevation, or use the digital beam-forming principles. Use of ESAs is likely to become widespread not only in fixed ground applications but also in airborne and maritime applications.

Since the radars in the frequency range 1 215-1 400 MHz perform search, track, and long range surveillance functions the antennas scan 360° in the horizontal plane. Horizontal, vertical and circular polarizations are used.

2.3.1 Typical radar antenna coverage patterns

Many 1 215-1 400 MHz frequency band air-traffic control radars have a cosecant squared type of antenna pattern which radiates most of the energy upward from several degrees above the horizon to near about 40°.

Single static planar ESA panels found in airborne systems are not capable of providing complete 360 degree coverage as is possible with mechanically rotating antennas. Therefore ESA radar systems often consist of multiple panels. The aperture area of a single panel can be as large as 20 square metres.

Because a number of different antennas can be used with the various radars operating in the frequency band 1 215-1 400 MHz, this Recommendation does not attempt to provide a representative antenna patterns for the systems in Table 1.

TABLE 1
1 215-1 400 MHz radiodetermination system characteristics

Parameter	Units	System 1	System 2	System 3	System 4	System 5	System 6	System 7	System 8	System 9	System 10
Peak power into antenna	dBm	97	80	76.5	80	73.9	96	93	78.8	82	80-85
Frequency range	MHz		1 215-1 390			1 215-1 400	1 280-1 350	1 215-1 350	1 240-1 350	1 215-1 400	1 215-1 400
Pulse duration	μs	2	88.8; 58.8 (Note 1)	0.4; 102.4; 409.6 (Note 2)	39 single frequency 26 and 13 dual frequency (Note 3)	2 each of 51.2 2 each of 409.6	2	6	115.5; 17.5 (Note 4)	14	0.5 to 100
Pulse repetition rate	pps	310-380 staggered	291.5 or 312.5 average	200-272 long-range 400-554 short-range	774 average	240-748	279.88 to 370.2	279.88 to 370.2	319 average	7 000	100 to 10 000
Chirp bandwidth for frequency modulated (chirped) pulses	MHz	Not applicable	0.77 for both pulse widths	2.5 for 102.4 μs 0.625 for 409.6 μs	Not applicable	1.25	Not applicable	Not applicable	1.2	2	2
Phase-coded sub-pulse width	μs	Not applicable	Not applicable	Not applicable	1	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Compression ratio		Not applicable	68.3:1 and 45.2:1	256:1 for both pulses		64:1 and 256:1	Not applicable	Not applicable	150:1 and 23:1		Up to 200
RF emission bandwidth (3 dB)	MHz	0.5	1.09	2.2; 2.3; 0.58	1	0.625 or 1.25	1.2	1.3	1.2	3	3
Output device		Klystron	Transistor	Transistor	Cross-field amplifier	Transistor	Magnetron/ Amplatron	Klystron	Transistor	Transistor	Transistor
Antenna type		Horn-fed reflector	Stack beam reflector	Rotating phased array	Parabolic cylinder	Planar array with elevation beam steering	47' × 23' (14.3 × 7 m) cosecant squared	45' × 19' (13.7 × 5.8 m) cosecant squared	Horn-fed reflector	Phased array	Phased array
Antenna polarization		Horizontal, vertical, LHCP, RHCP	Vertical, circular	Horizontal	Vertical	Horizontal	CP/LP	Linear orthogonal and CP	Vertical; RHCP	Vertical	Vertical

TABLE 1 (*continued*)

Parameter	Units	System 1	System 2	System 3	System 4	System 5	System 6	System 7	System 8	System 9	System 10
Antenna maximum gain	dBi	34.5, transmit 33.5, receive	32.4-34.2, transmit 33.8-40.9, receive	38.9, transmit 38.2, receive	32.5	38.5	34	35	34.5	30	35-40
Antenna elevation beamwidth	degrees	3.6 shaped to 44	3.63-5.61, transmit 2.02-8.79, receive	1.3	4.5 shaped to 40	2	3.75 (cosecant squared)	3.75 (cosecant squared)	3.7 shaped to 44 (cosecant squared)	20 (sinc)	3.75
Antenna azimuthal beamwidth	degrees	1.2	1.4	3.2	3.0	2.2	1.2	1.3	1.2	2	2
Antenna horizontal scan characteristics	rpm	360° mechanical at 5 rpm	360° mechanical at 5 rpm	360° mechanical at 6 rpm for long range and 12 rpm for short range	360° mechanical at 6, 12 or 15 rpm	5	6	5	360° mechanical at 5 rpm	360° Electronically at variable rate	360° at 12-15 rpm or Sector scan at variable rate
Antenna vertical scan characteristics	degrees	Not applicable	−7 to +30 in 12.8 or 13.7 ms	−1 to +19 in 73.5 ms	Not applicable	−6 to +20	−4 to +20	−4 to +20	Not applicable	Not applicable	Not applicable
Receiver IF bandwidth	kHz	780	690	4 400 to 6 400	1 200	1 250 625	720 to 880 (log) 1 080 to 1 320 (MTI)	270 to 330 (20 series log) 360 to 480 (20 series MTI) 540 to 660 (60 series log) 720 to 880 (60 series MTI)	1 200	Up to 10 000	2 000
Receiver noise figure	dB	2	2	4.7	3.5	2.6	4.25	9	3.2	3	3

TABLE 1 (*end*)

Parameter	Units	System 1	System 2	System 3	System 4	System 5	System 6	System 7	System 8	System 9	System 10
Platform type		Fixed	Fixed	Transportable	Transportable	Fixed terrestrial	Fixed terrestrial	Fixed terrestrial	Fixed	Airborne (Note 5)	Shipbased/terrestrial
Time system operates	%	100	100	100	100	100	100	100	100	100	100

LHCP: left-hand circularly polarized

RHCP: right-hand circularly polarized

NOTE 1 – The radar has 44 RF channel pairs with one of 44 RF channel pairs selected in normal mode. The transmitted waveform consists of a 88.8 μ s pulse at frequency f_1 followed by a 58.8 μ s pulse at frequency f_2 . Separation of f_1 and f_2 is 82.854 MHz.

NOTE 2 – The radar has 20 RF channels in 8.96 MHz increments. The transmitted waveform group consists of one 0.4 μ s P0 pulse (optional) which is followed by one 102.4 μ s linear frequency modulated pulse (if 0.4 μ s P0 is not transmitted) of 2.5 MHz chirp which may be followed by one to four long-range 409.6 μ s linear frequency modulated pulses each chirped 625 kHz and transmitted on different carriers separated by 3.75 MHz. Normal mode of operation employs frequency agility whereby the individual frequencies of each waveform group are selected in a pseudo-random manner from one of the possible 20 RF channels within the frequency band 1 215-1 400 MHz.

NOTE 3 – The radar has the capability of operating single frequency or dual frequency. Dual RF channels are separated by 60 MHz. The single channel mode uses the 39 μ s pulse width. In the dual channel mode, the 26 μ s pulse is transmitted at frequency f , followed by the 13 μ s pulse transmitted at $f+60$ MHz.

NOTE 4 – This radar utilizes two fundamental carriers, F1 and F2, with two sub-pulses each, one for medium range detection and one for long range detection. The carriers are tunable in 0.1 MHz increments with a minimum separation of 26 MHz between F1 (below 1 300 MHz) and F2 (above 1 300 MHz). The carrier sub-pulses are separated by a fixed value of 5.18 MHz. The pulse sequence is as follows: 115.5 μ s pulse at F1 + 2.59 MHz, then a 115.5 μ s pulse at F2 + 2.59 MHz, then a 17.5 μ s pulse at F2 – 2.59 MHz, then a 17.5 μ s pulse at F1 – 2.59 MHz. All four pulses are transmitted within a single pulse repetition interval.

NOTE 5 – This radar is an airborne system operating at altitudes up to 10 000 meters. It is using multiple panels to achieve 360 degrees coverage.

NOTE 6 – This radar can be used as ship-based, fixed terrestrial or transportable terrestrial system and can be used in a rotating mode, or in a steering mode for sector scan. The duty cycle of this radar system is typically 10%.

3 Protection criteria

The desensitizing effect, on radiodetermination radars from other services of a CW or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density can, to within a reasonable approximation, simply be added to the power spectral density of the radar receiver thermal noise. If power spectral density 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 power spectral density becomes simply $I_0 + N_0$. An increase of about 1 dB would constitute significant degradation, equivalent to a detection-range reduction of about 6%. Such an increase corresponds to an $(I + N)/N$ ratio of 1.26, or an I/N ratio of about -6 dB. This represents the aggregate effect of multiple interferers, when present; the tolerable 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. If CW interference were received from most azimuth directions, a lower I/N ratio would need to be maintained.

The aggregation factor can be very substantial in the case of certain communication systems in which a great number of stations can be deployed.

The effect of pulsed interference is more difficult to quantify and is strongly dependent on receivers/processor design, pulse compression 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 analyses 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-duty cycle pulsed interference are contained in Recommendation ITU-R M.1372.

4 Wind profiler radars

A wind profiler radar is a Doppler radar for measuring wind from the ground, utilizing the radar echo from clear-air turbulence. Clear-air turbulence causes the fluctuation of the refractive index in which the scale is half the radar wavelength (Bragg scattering). A wind profiler radar uses a number of skyward pointing antenna beams. From the Doppler shift along an antenna beam direction, the wind velocity along the radar beam can be measured. Assuming horizontal homogeneity of the wind field, three components of a wind vector can be measured by at least three beam observations. Observable height range of radars depends upon transmit power, antenna size and radar frequency as well as the magnitude of refractivity fluctuation of the atmosphere.

Currently several frequencies are used for wind profiler radars, including 50 MHz, 400 MHz, 900 MHz, and 1 300 MHz. There are advantages and disadvantages relating to the use of each of these frequencies. Usually systems operating near 400 MHz with large antenna apertures are used to observe the wind at upper troposphere or lower stratosphere. In contrast, systems operating at 900 MHz or higher can measure only up to several kilometers in height. However, the advantage of higher frequency systems are compact antenna size and shorter “blind” range, which means that these systems are suitable for boundary layer wind measurements and for low-cost implementation. Table 2 contains the characteristics of wind profiler radars specifically operating in the frequency range 1 300-1 375 MHz. Recommendation ITU-R M.1227 contains additional information and characteristics of wind profiler radars, to include those operating around 1 000 MHz.

TABLE 2

Characteristics of wind profiler radars operating in the frequency band 1 300-1 375 MHz

Parameter	Units	Value
Peak power into antenna		1 kW (60 dBm)
Pulse duration	μs	0.5, 1, 2
Pulse repetition rate	kHz	1-25
RF emission bandwidth	MHz	8
Transmitter output device		Transistor
Antenna type		Parabolic reflector
Antenna polarization		Horizontal
Antenna maximum gain	dBi	33.5
Antenna elevation beamwidth	Degrees	3.9
Antenna azimuthal beamwidth	Degrees	3.9
Antenna horizontal scan		Not applicable
Antenna vertical scan		−15° to +15° (approximately 15 s)
Receiver IF bandwidth	MHz	2.5
Receiver noise figure	dB	1.5
Platform type		Fixed site
Percentage of time system operates	%	100