RECOMMENDATION ITU-R M.1638

Characteristics of and protection criteria for sharing studies for radiolocation, aeronautical radionavigation and meteorological radars operating in the frequency bands between 5 250 and 5 850 MHz

(2003)

Summary

This Recommendation describes the technical and operational characteristics of, and protection criteria for, radars operating in the frequency band 5 250-5 850 MHz. These characteristics are intended for use when assessing the compatibility of these systems with 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 radiolocation, radionavigation and meteorological radars are determined by the mission of the system and vary widely even within a band;

c) that the radionavigation service is a safety service as specified by No. 4.10 of the Radio Regulations (RR) and requires special measures to ensure its freedom from harmful interference;

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

e) that some ITU-R technical 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 bands between 420 MHz and 34 GHz used by radionavigation, radiolocation and meteorological radars;

f) that representative technical and operational characteristics of radiolocation, radionavigation and meteorological radars are required to determine the feasibility of introducing new types of systems into frequency bands in which the latter are operated;

g) that procedures and methodologies to analyse compatibility between radars and systems in other services are provided in Recommendation ITU-R M.1461;

h) that radiolocation, radionavigation and meteorological radars operate in the bands between 5 250-5 850 MHz;

j) that ground-based radars used for meteorological purposes are authorized to operate in the band 5 600-5 650 MHz on a basis of equality with stations in the aeronautical radionavigation service (ARNS) (see RR No. 5.452), *recommends*

1 that the technical and operational characteristics of the radiolocation, radionavigation and meteorological radars described in Annex 1 be considered representative of those operating in the frequency bands between 5 250 and 5 850 MHz (see Note 1);

2 that Recommendation ITU-R M.1461 be used as a guideline in analysing compatibility between radiolocation, radionavigation and meteorological radars with systems in other services; that the criterion of interfering signal power to radar receiver noise power level I/N, of −6 dB be used as the required protection trigger level for the radiodetermination sharing studies with other services. This protection criterion represents the net protection level if multiple interferers are present.

NOTE 1 – Recommendation ITU-R M.1313 should be used with regard to the characteristics of maritime radionavigation radars in the frequency band 5 470-5 650 MHz.

Annex 1

Characteristics of radiolocation, aeronautical radionavigation and meteorological radars

1 Introduction

The bands between 5 250 and 5 850 MHz are allocated to the ARNS and radiolocation service on a primary basis as shown in Table 1. Ground-based radars used for meteorological purposes are authorized to operate in 5 600-5 650 MHz on a basis of equality with stations in the maritime radionavigation service (see RR No. 5.452).

TABLE 1

Band (MHz)	**Allocation**
5 250-5 255	Radiolocation
5 255-5 350	Radiolocation
5 350-5 460	Aeronautical radionavigation
5 460-5 470	Radiolocation
5 470-5 650	Maritime radionavigation[(1)]
5 650-5 725	Radiolocation
5 725-5 850	Radiolocation

(1) In accordance with RR No. 5.452, between 5 600 and 5 650 MHz, ground-based radars for meteorological purposes are authorized to operate on a basis of equality with stations in the maritime radionavigation service.

The radiolocation radars perform a variety of functions, such as:

– tracking space launch vehicles and aeronautical vehicles undergoing developmental and operational testing;

– sea and air surveillance;

– environmental measurements (e.g. study of ocean water cycles and weather phenomena such as hurricanes);

– Earth imaging; and

– national defence and multinational peacekeeping.

The aeronautical radionavigation radars are used primarily for airborne weather avoidance and windshear detection, and perform a safety service (see RR No. 4.10).

The meteorological radars are used for detection of severe weather elements such as tornadoes, hurricanes and violent thunderstorms. These weather radars also provide the quantitative area precipitation measurements so important in hydrologic forecasting of potential flooding. This information is used to provide warnings to the public and it therefore provides a safety-of-life service.

Recommendation ITU-R M.1313 contains the characteristics of maritime radionavigation radars in the frequency band 5 470-5 650 MHz.

2 Technical characteristics

The bands between 5 250 and 5 850 MHz are used by many different types of radars on land-based fixed, shipborne, airborne, and transportable platforms. Tables 2 and 3 contain technical characteristics of representative systems deployed in these bands. This information is generally sufficient for general calculations to assess the compatibility between these radars and other systems.

However, these Tables do not contain characteristics of frequency-hopping radars which are operating in this frequency range. Frequency hopping is one of the most common Electronic-Counter-Counter-Measures (ECCM). 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.

TABLE 2

Characteristics of aeronautical radionavigation and meteorological radar systems

Characteristics	Radar A	Radar B	Radar C	Radar D	Radar E	Radar F	Radar G	Radar H	Radar I	Radar J
Function	Meteorological	Meteorological	Meteorological	Aeronautical radionavigation	Meteorological	Meteorological	Meteorological	Meteorological	Meteorological	Meteorological
Platform type (airborne, shipborne, ground)	Ground/ship	Airborne	Ground	Airborne	Ground	Ground	Ground	Ground	Ground	Ground
Tuning range (MHz)	5 300-5 700	5 370	5 600-5 650	5 440	5 600-5 650	5 300-5 700	5 600-5 650	5 600-5 650	5 600-5 650	5 250-5 725
Modulation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Conventional	With Doppler capability	With Doppler capability
Tx power into antenna	250 kW peak 125 W avg.	70 kW peak	250 kW peak 1 500 W avg.	200 W peak	250 kW peak	250 kW peak	250 kW peak	250 kW peak 150 W avg.	250 kW peak 150 W avg.	2.25 kW peak
Pulse width (μs)	2.0	6.0	0.05-18	1-20	1.1	0.8-2.0	3.0	0.8-5	0.8-5	0.1
Pulse rise/fall time (μs)	0.2	0.6	0.005	0.1	0.11	0.08	0.3	0.2-2	0.2-2	0.005
Pulse repetition rate (pps)	50, 250 and 1 200	200	0-4 000	180-1 440	2 000	250-1 180	259	250-1 200	50-1 200	100 000
Output device	Coaxial magnetron	Coaxial magnetron	Klystron	Magnetron	Klystron	Tunable magnetron	Coaxial magnetron	Coaxial magnetron or Klystron	Coaxial magnetron	Coaxial magnetron
Antenna pattern type (pencil, fan, cosecant-squared, etc.)	Conical	Fan	Pencil	Pencil	Pencil	Pencil	Pencil	Pencil	Pencil	Pencil
Antenna type (reflector, phased array, slotted array, etc.)	Solid metal parabolic	Parabolic	Parabolic	Slotted array	Parabolic	Parabolic	Solid parabolic	Solid parabolic	Solid parabolic	Solid parabolic
Antenna polarization	Vertical	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal and/or vertical	Horizontal or vertical	Horizontal or vertical
Antenna main beam gain (dBi)	39	37.5	44	34	50	40	40	40-50	40-50	35-45

TABLE 2 (*end*)

Characteristics	Radar A	Radar B	Radar C	Radar D	Radar E	Radar F	Radar G	Radar H	Radar I	Radar J
Antenna elevation beamwidth (degrees)	4.8	4.1	0.95	3.5	< 0.55	< 1.0	1.65	0.5-2	0.5-2	2.4-12
Antenna azimuthal beamwidth (degrees)	0.65	1.1	0.95	3.5	< 0.55	< 1.0	1.65	0.5-2	0.5-2	1.5-12
Antenna horizontal scan rate (degrees/s)	0.65	24	0-36 (0-6 rpm)	20	21-24	30-48	30-48	6-18 (1-3 rpm)	6-18 (1-3 rpm)	1.2
Antenna horizontal scan type (continuous, random, 360°, sector, etc.) (degrees)	360	180 Sector	360	Continuous	Continuous 360 Sector	360	360	360	360	360
Antenna vertical scan rate (degrees/s)	N/A	N/A	N/A	45	15	15	15	1-10	1-14	N/A
Antenna vertical scan type (continuous, random, 360°, sector, etc.) (degrees)	N/A	N/A	N/A	Sector	Stepwise, 0.5-60	Stepwise, –2 to +60	–1 to +60	–1 to +90	–5 to +90	N/A
Antenna side-lobe (SL) levels (1st SLs and remote SLs) (dB)	–26	–20	–35	–31	–27	–25	–25	–25 to –35	–25 to –35	–20
Antenna height (m)	30	Aircraft altitude	10	Aircraft altitude	30	30	30	6-30	6-30	10
Receiver IF 3 dB bandwidth (MHz)	0.5	0.6	20	1.0	0.91	0.6	0.25 to 0.5	0.7 to 4	0.1 to 3.0	10
Receiver noise figure (dB)	7	6	4	5	2.3	3	3	3.5-8	1.5-8	3
Minimum discernable signal (dBm)	–110	–106	–97	–109	–109	–109 to –112	–114	–113 to –120	–113 to –120	–113 to –118

TABLE 3

Characteristics of radiolocation systems

Characteristics	Radar K	Radar L	Radar M	Radar N	Radar O	Radar P	Radar Q	Radar R	Radar S
Function	Instrumentation	Instrumentation	Instrumentation	Instrumentation	Instrumentation	Surface and air search	Surface and air search	Research and Earth imaging	Search
Platform type (airborne, shipborne, ground)	Ground	Ground	Ground	Ground	Ground	Ship	Ship	Airborne	Airborne
Tuning range (MHz)	5 300	5 350-5 850	5 350-5 850	5 400-5 900	5 400-5 900	5 300	5 450-5 825	5 300	5 250-5 725
Modulation	N/A	None	None	Pulse/chirp pulse	Chirp pulse	Linear FM	None	Non-linear/ linear FM	CW pulse
Tx power into antenna	250 kW	2.8 MW	1.2 MW	1.0 MW	165 kW	360 kW	285 kW	1 or 16 kW	100-400 W
Pulse width (µs)	1.0	0.25, 1.0, 5.0	0.25, 0.5, 1.0	0.25-1 (plain) 3.1-50 (chirp)	100	20.0	0.1/0.25/1.0	7 or 8	1.0
Pulse rise/fall time (µs)	0.1/0.2	0.02-0.5	0.02-0.05	0.02-0.1	0.5	0.5	0.03/0.05/0.1	0.5	0.05
Pulse repetition rate (pps)	3 000	160, 640	160, 640	20-1 280	320	500	2 400/1 200/ 750	1 000-4 000	200-1 500
Chirp bandwidth (MHz)	N/A	N/A	N/A	4.0	8.33	1.5	N/A	62, 124	N/A
RF emission bandwidth –3 dB –20 dB (MHz)	4.0 10.0	0.5-5	0.9-3.6 6.4-18	0.9-3.6 6.4-18	8.33 9.9	1.5 1.8	5.0/4.0/1.2 16.5/12.5/7.0	62, 124 65, 130	4.0 10.0
Antenna pattern type (pencil, fan, cosecant-squared, etc.)	Pencil	Pencil	Pencil	Pencil	Pencil	Cosecant-squared	Fan	Fan	Pencil
Antenna type (reflector, phased array, slotted array, etc.)	Parabolic reflector	Parabolic	Parabolic	Phased array	Phased array	Parabolic	Travelling wave feed horn array	Two dual polarized horns on single pedestal	Slotted array

TABLE 3 (*end*)

Characteristics	Radar K	Radar L	Radar M	Radar N	Radar O	Radar P	Radar Q	Radar R	Radar S
Antenna polarization	Vertical/left-hand circular	Vertical/left-hand circular	Vertical/left-hand circular	Vertical/left-hand circular	Vertical/left-hand circular	Horizontal	Horizontal	Horizontal and vertical	Circular
Antenna main beam gain (dBi)	38.3	54	47	45.9	42	28.0	30.0	26	30-40
Antenna elevation beamwidth (degrees)	2.5	0.4	0.8	1.0	1.0	24.8	28.0	28.0	2-4
Antenna azimuthal beamwidth (degrees)	2.5	0.4	0.8	1.0	1.0	2.6	1.6	3.0	2-4
Antenna horizontal scan rate (degrees/s)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	36, 72	90	N/A	20
Antenna horizontal scan type (continuous, random, 360°, sector, etc.) (degrees)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	Continuous 360	30-270 Sector	Fixed to left or right of flight path	Continuous
Antenna vertical scan rate (degrees/s)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A	N/A	N/A	N/A
Antenna vertical scan type (continuous, random, 360°, sector, etc.) (degrees)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A (Tracking)	N/A	Fixed	Fixed in elevation (–20 to –70)	N/A
Antenna side-lobe (SL) levels (1st SLs and remote SLs) (dB)	–20	–20	–20	–22	–22	–20	–25	–22	–25
Antenna height (m)	20	20	8-20	20	20	40	40	To 8 000	9 000
Receiver IF 3 dB bandwidth (MHz)	1	4.8, 2.4, 0.25	4, 2, 1	2-8	8	1.5	1.2, 10	90, 147	1
Receiver noise figure (dB)	6	5	5	11	5	5	10	4.9	3.5
Minimum discernable signal (dBm)	–105	–107	–100	–107, –117	–100	–107	–94 (short/medium pulse) –102 (wide pulse)	–90, –87	–110

3 Operational characteristics

3.1 Meteorological radars

Both airborne and ground-based meteorological radars operate within the frequency range 5 250-5 850 MHz, and the technical characteristics are given in Table 1.

The ground-based weather radar systems are used for detection of severe weather and flight planning activities and are often located near airports worldwide. Therefore, these radars are also in operation continuously 24 h/day.

Meteorological radars provide quantitative area precipitation measurements and in most cases belong to networks which coordinate such measurements over national or regional areas. Those which use Doppler radar technology also observe precipitation velocity, which indicates the presence and motion of severe weather elements such as tornadoes, hurricanes and violent thunderstorms as well as windshear and turbulence. Quantitative measurements from both kinds of radar are used in real time as a critical and unique data source for hydrological, meteorological and environmental forecasting. Through numerical data assimilation, modelling and forecasting of weather, flooding and pollution, particularly on the occasion of damaging events, the data are used to increase the accuracy and timeliness of forecasts and warnings. The data may be used directly, for example to assess lightning risk. Many applications can be critical to safety and protection of the general public (both life and property) and the safety and security of military operations.

The airborne meteorological radars are used for both hurricane research and reconnaissance. The aircraft penetrate the eyewall repeatedly at altitudes up to 20 000 ft (6 096 m) and as low as 1 500 ft (457 m). The aircraft collect research-mission data critical for computer models that predict hurricane intensity and landfall. Other aircraft penetrate hurricanes at higher, less turbulent altitudes (30 000-45 000 ft, or 9 144-13 716 m) to determine the position of the hurricane eye.

3.2 Aeronautical radionavigation radars

Radars operating in the ARNS in the frequency band 5 350-5 460 MHz are primarily airborne systems used for flight safety. Both weather detection and avoidance radars, which operate continuously during flight, as well as windshear detection radars, which operate automatically whenever the aircraft descends below 2 400 ft (732 m), are in use. Both radars have similar characteristics and are principally forward-looking radars which scan a volume around the aircraft's flight path. These systems are automatically scanned over a given azimuth and elevation range, and are typically manually (mechanically) adjustable in elevation by the pilot (who may desire various elevation "cuts" for navigational decision-making).

3.3 Radiolocation radars

There are numerous radar types, accomplishing various missions, operating within the radiolocation service throughout the range 5 250-5 850 MHz. Table 3 gives the technical characteristics for several representative types of radars that use these frequencies that can be used to assess the compatibility between radiolocation radars and systems of other services. The operational use of these radars is briefly discussed in the following text.

Test range instrumentation radars are used to provide highly accurate position data on space launch vehicles and aeronautical vehicles undergoing developmental and operational testing. These radars are typified by high transmitter powers and large aperture parabolic reflector antennas with very narrow pencil beams. The radars have autotracking antennas which either skin track or beacon track the object of interest. (Note that radar beacons have not been presented in the Tables; they normally are tuneable over 5 400-5 900 MHz, have transmitter powers in the range 50-200 W peak, and serve to rebroadcast the received radar signal.) Periods of operation can last from minutes up to 4-5 h, depending upon the test program. Operations are conducted at scheduled times 24 h/day, 7 days/week.

Shipboard sea and air surveillance radars are used for ship protection and operate continuously while the ship is underway as well as entering and leaving port areas. These surveillance radars usually employ moderately high transmitter powers and antennas which scan electronically in elevation and mechanically a full 360° in azimuth. Operations can be such that multiple ships are operating these radars simultaneously in a given geographical area.

Other special-purpose radars are also operated in the band 5 250-5 850 MHz. Radar Q (Table 3) is an airborne synthetic aperture radar which is used in land-mapping and imaging, environmental and land-use studies, and other related research activities. It is operated continuously at various altitudes and with varying look-down angles for periods of time up to hours in duration which depends upon the specific measurement campaign being performed.

4 Protection criteria

The desensitizing effect on radars operated in this band 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 simply be added to the power spectral density of the radar receiver thermal noise, to within a reasonable approximation. 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 for the meteorological and radiolocation radars would constitute significant degradation. Such an increase corresponds to an $(I + N)/N$ ratio of 1.26, or an I/N ratio of about –6 dB. For the radionavigation service and meteorological radars, considering the safety-of-life function, an increase of about 0.5 dB would constitute significant degradation. Such an increase corresponds to an $(I + N)/N$ ratio of about –10 dB. However, further study is required to validate this value. These protection criteria represent the aggregate effects 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.

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 receiver/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 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 – Efficient use of the radio spectrum by radar stations in the radiodetermination service.

5 Interference mitigation techniques

In general, mutual compatibility between radiolocation, aeronautical radionavigation and meteorological radars is fostered by the scanning of the antenna beams, which limits main beam couplings. Additional mitigation is afforded by differences between the waveforms of the two types of radars and the associated rejection of undesired pulses via receiver filtering and signal processing techniques such as limiting, sensitivity time control and signal integration. Additionally, interference can be mitigated by separation in carrier frequency or discrimination in time through the use of asynchronous pulse rejection/suppression techniques. In radar-to-radar interactions, separation in frequency is not always necessary for compatible operation because high degrees of isolation in power coupling and in time either occur naturally or can be achieved by good design. Additional details of interference mitigation techniques employed by radar systems are contained in Recommendation ITU-R M.1372.