International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.2057-1
(01/2018)

Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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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.2057-1

Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications

(2014-2018)

Scope

This Recommendation specifies the system characteristics of automotive radars operating under the radiolocation service in the frequency band 76-81 GHz. These technical and operational characteristics should be used in compatibility studies between automotive radars operating in the radiolocation service and systems operating in other services.

Keywords

Characteristics, protection criteria, automotive radar, intelligent transport systems

Abbreviations/Glossary

ACC Adaptive cruise control

CA Collision avoidance

FMCW Frequency modulated continuous wave

ITS Intelligent transport systems

Related ITU Recommendations and Reports

Recommendation ITU-R M.1452 – Millimetre wave vehicular collision avoidance radars and radiocommunication systems for intelligent transport system applications

The ITU Radiocommunication Assembly,

considering

a) that antenna, signal propagation, target detection, and large bandwidth characteristics for automotive radars are needed to optimally achieve their functions in certain frequency bands;

b) that the technical characteristics of radars operating in the radiodetermination service are determined by the needs of the system and may vary widely from band to band;

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

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

recommends

that the systems characteristics for automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems (ITS) applications as described in Annex 1 should be used for sharing/compatibility studies.

Annex 1

Systems characteristics of automotive radar systems operating in the frequency band 76-81 GHz for intelligent transport system applications

1 Introduction

In the frequency band 76-81 GHz, radar systems in support of enhanced road safety are operated. Evolving demands related to automotive safety applications, including the reduction of traffic fatalities and accidents require a range resolution for automotive radar systems leading to a necessary bandwidth of up to 4 GHz.

2 Technical characteristics of automotive radar systems operating in the frequency band 76-81 GHz

Regarding functional and safety requirements, the automotive radar systems operating in the 76-81 GHz range can be separated in two categories:

– **Category 1**: adaptive cruise control (ACC) and collision avoidance (CA) radar, for measurement ranges up to 250 metres the typical technical characteristics are listed in Table 1 as Radar A. For these applications, a maximum continuous bandwidth of 1 GHz is required. Such radars are considered to add additional comfort functions for the driver, giving support for more stress-free driving.

– **Category 2**: Sensors for high resolution applications such as blind spot detection, lane-change assist and rear-traffic-crossing-alert, detection of pedestrians and bicycles in close proximity to a vehicle, for measurement ranges up to 100 metres the typical technical characteristics are listed in Table 1 as Radar B, Radar C and Radar D. For these high resolution applications, a necessary bandwidth of 4 GHz is required. Such radars directly add to the passive and active safety of a vehicle and are therefore an essential benefit towards improved traffic safety. The increased requirements for active and passive vehicle safety are already reflected in the requirements for vehicle testing. Radar E operates with a higher field of view to enable high-resolution applications such as pedestrian detection, parking-aid, and emergency braking at low speed (< 30 km/h).

The technical parameters of radiolocation radar systems operating in the frequency bands 76-77 GHz and 77-81 GHz are presented in Table 1.

TABLE 1

Automotive radar characteristics in the frequency band 76-81 GHz

Parameter	**Units**	**Radar A**[(1)] **Automotive radar** **For front applications for e.g. for ACC**	**Radar B** **Automotive high-resolution radar** **For front applications**	**Radar C** **Automotive high-resolution radar** **For corner applications**	**Radar D** **Automotive high-resolution radar**	**Radar E** **Automotive high-resolution radar** **Very short range applications (e.g. parking-aid, CA at very low speed)**
Sub-band used	GHz	76-77	77-81	77-81	77-81	77-81
Typical operating range	m	Up to 250	Up to 100	Up to 100	Up to 100	Up to 50
Range resolution	cm	75	7.5	7.5	7.5	7.5
Typical emission type		FMCW, Fast-FMCW	FMCW, Fast-FMCW	FMCW, Fast-FMCW	FMCW	FMCW, Fast-FMCW
Max necessary bandwidth	GHz	1	4	4	4	4
Chirp bandwidth	GHz	1	2-4	2-4	2-4	2
Typical sweep time	μs	10 000-40 000 for FMCW 10-40 for fast-FMCW	10 000-40 000 for FMCW 10-40 for fast-FMCW	10 000-40 000 for FMCW 10-40 for fast-FMCW	2 000-20 000 for FMCW	10 000-40 000 for FMCW 10-40 for fast-FMCW
Maximum e.i.r.p.	dBm	55	33	33	45	33
Maximum transmit power to antenna	dBm	10	10	10	10	10

TABLE 1 (*continued*)

Parameter	Units	Radar A[(1)] Automotive radar For front applications for e.g. for ACC	Radar B Automotive high-resolution radar For front applications	Radar C Automotive high-resolution radar For corner applications	Radar D Automotive high-resolution radar	Radar E Automotive high-resolution radar Very short range applications (e.g. parking-aid, CA at very low speed)
Max power density of unwanted emissions	dBm/MHz	0 (73.5-76 GHz and 77-79.5 GHz) –30 otherwise	–30	–30	–13[(2)]	–30
Receiver IF bandwidth (–3 dB)	MHz	0.5-1	10	10	10	10
Receiver IF bandwidth (–20 dB)	MHz	0.5-20	15	15	15	15
Receiver sensitivity[(3)]	dBm	–115	–120	–120	–120	–120
Receiver noise figure	dB	15	12	12	12	12
Equivalent noise bandwidth (kHz)	kHz	25	16	16	16	16
Antenna main beam gain	dBi	Typical 30, Maximum 45	TX: 23 RX: 16	TX: 23 RX: 13	TX: 35 max. RX: 35 max	TX: 23 RX: 13
Antenna height	m	0.3-1 above road	0.3-1 above road	0.3-1 above road	0.3-1 above road	0.3-1 above road
Antenna azimuth 10 dB beamwidth	degrees	TX/RX: ±10	TX: ±22.5 RX: ±25	TX: ±23 RX: ±30	TX: ±30 RX: ±30	TX: ±50 RX: ±50

TABLE 1 (*end*)

Parameter	Units	Radar A[1] Automotive radar For front applications for e.g. for ACC	Radar B Automotive high-resolution radar For front applications	Radar C Automotive high-resolution radar For corner applications	Radar D Automotive high-resolution radar	Radar E Automotive high-resolution radar Very short range applications (e.g. parking-aid, CA at very low speed)
Antenna azimuth 3 dB beamwidth[4]	degrees	TX/RX: ±5	TX: ±12.5 RX: ±13.5	TX: ±12.5 RX: ±16	TX: ±16 RX: ±16	TX: ±27 RX: ±27
Antenna elevation -3 dB beamwidth	degrees	TX/RX: ±3	TX/RX: ±5.5	TX/RX: ± 5.5	TX/RX: ± 5.5	TX/RX: ± 5.5

(1) Radar type A is related to Recommendation ITU-R M.1452.

(2) Maximum power density of unwanted emission is specified at antenna input terminal.

(3) The receiver sensitivity is determined using the equivalent noise bandwidth.

(4) This parameter is used by the antenna pattern defined in § 3 below (φ_3).

3 Antenna pattern

The following equations provide the antenna radiation pattern that could be used in the analysis of interference:

$$G(\varphi, \theta) = G_{ref}(x)$$

$$G_{ref}(x) = G_0 - 12x^2 \qquad \text{for} \qquad 0 \le x < 1.152$$

$$G_{ref}(x) = G_0 - 15 - 15\log(x) \qquad \text{for} \qquad 1.152 \le x$$

with:

$$\alpha = \arctan\left(\frac{\tan\theta}{\sin\varphi}\right)$$

$$\Psi_\alpha = \frac{1}{\sqrt{\left(\frac{\cos\alpha}{\varphi_3}\right)^2 + \left(\frac{\sin\alpha}{\theta_3}\right)^2}}$$

$$\Psi = \arccos(\cos\varphi \, . \cos\theta)$$

$$x = \frac{\Psi}{\Psi_\alpha}$$

where:

- $G(\varphi,\theta)$: gain relative to an isotropic antenna (dBi)
- G_0: Maximum gain in or near the horizontal plane (dBi)
- θ: Absolute value of the elevation angle relative to the angle of maximum gain (degrees)
- θ_3: 3 dB beamwidth in the vertical plane (degrees)
- φ: Azimuth angle relative to the angle of maximum gain (degrees)
- φ_3: 3 dB beamwidth in the azimuth plane (degrees).

Antenna patterns using these formulas for the five radar types defined in Table 1 are presented in Annex 2.

4 Operational characteristics of automotive radar systems operating in the frequency bands 76-77 GHz and 77-81 GHz

Automotive radar applications are evolving from providing additional comfort functions, such as ACC and CA radar, to functions that significantly add to the passive and active vehicle safety. This requires systems that can detect objects in the close proximity (in the order of 15 metres) of the vehicle, such as pedestrians or bicycles. Such applications require radar sensors that have a target separation capability of less than 10 centimetres. Radar sensors that provide this resolution require an operating bandwidth of 4 GHz.

Radar A type sensors detect the relevant road traffic in order to adapt the speed of the vehicle to that of other vehicles ahead. To satisfy the demands for increased car safety, and depending on the application, one or more radar A type systems may be combined with additional radar B, C, D and E type sensors in one vehicle. Based on the sensor information, the data processing system in the vehicle will trigger the appropriate radar.

Radar B, C, D and E type sensors cover the close proximity of a vehicle and will add additional active and passive safety functions, e.g. autonomous emergency braking, active blind spot assistance and lane change assistance.

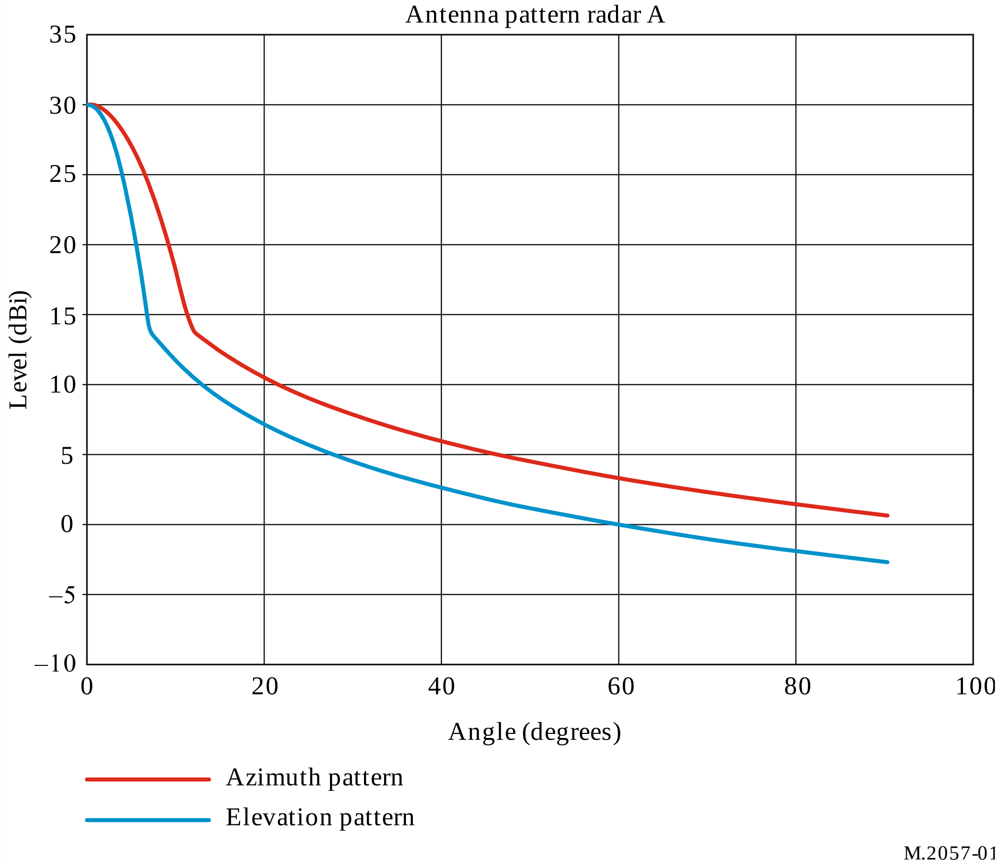
5 Protection criteria

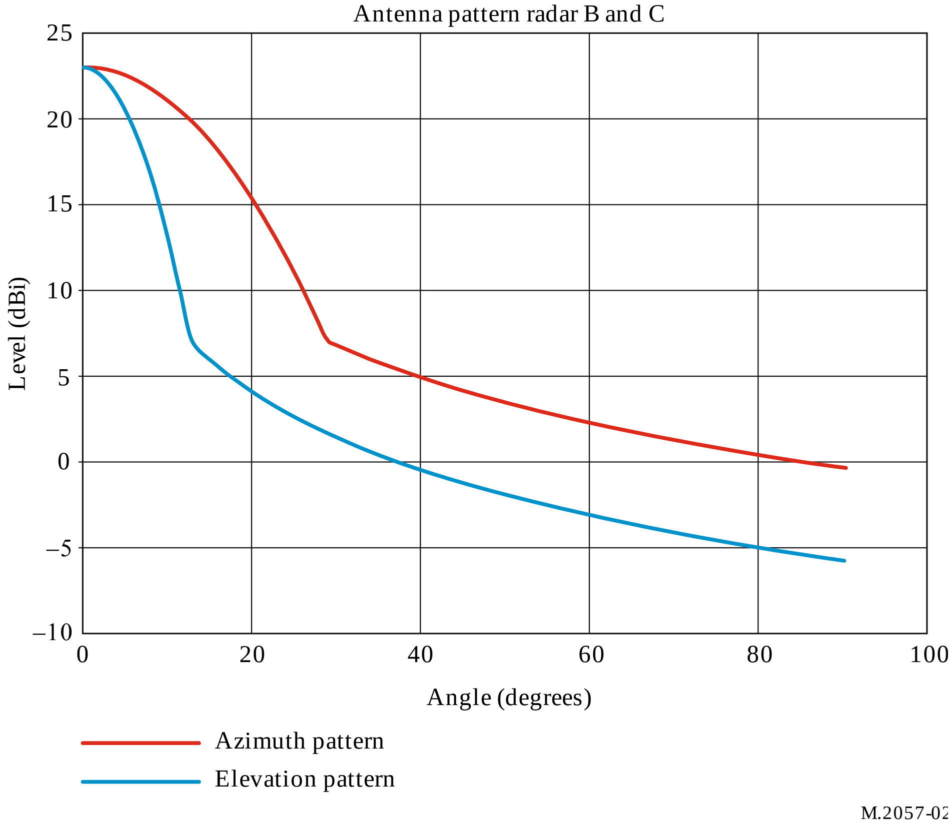
The desensitizing effect on radars operated in this frequency band from other services of a continuous wave, frequency modulated continuous wave (FMCW) or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density can simply be added to the power spectral density of the radar receiver thermal noise, to within a reasonable approximation. If the power spectral density of the 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 automotive radars would constitute significant degradation. Such an increase corresponds to an $(I + N)/N$ ratio of 1.26, or a protection criterion I/N of about –6 dB.

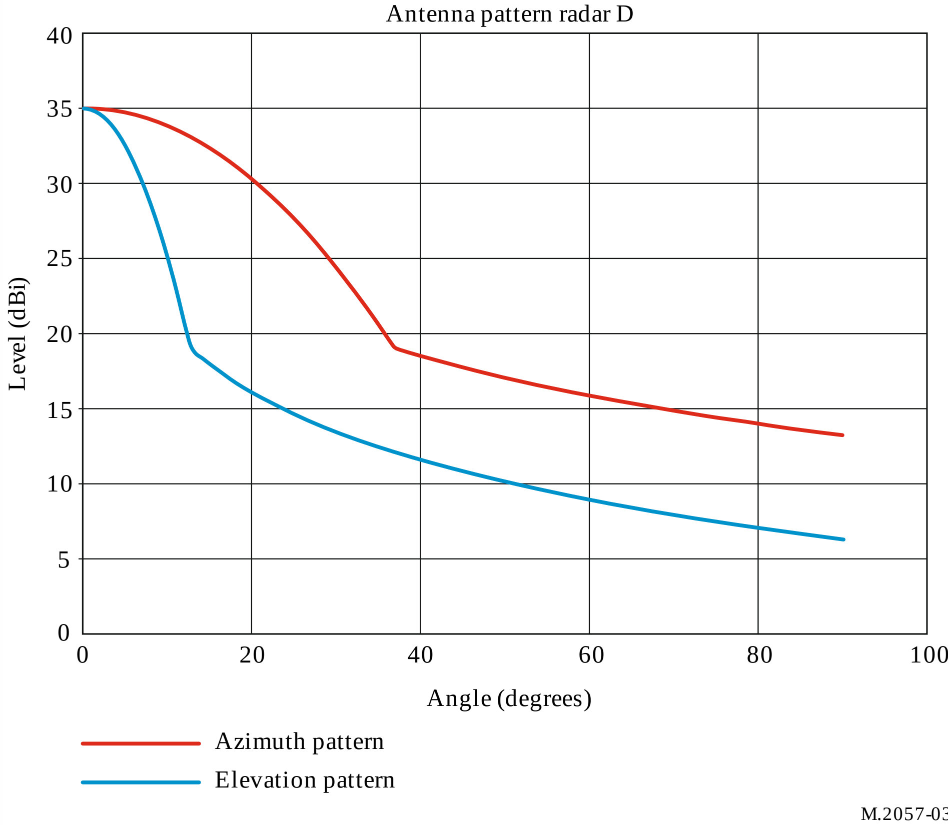
The aggregation factor can be very substantial in the case of certain communication systems, in which a great number of stations can be deployed. The effect of pulsed interference is more difficult to quantify and is strongly dependent on receiver/processor design and mode of operation. In particular, 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.

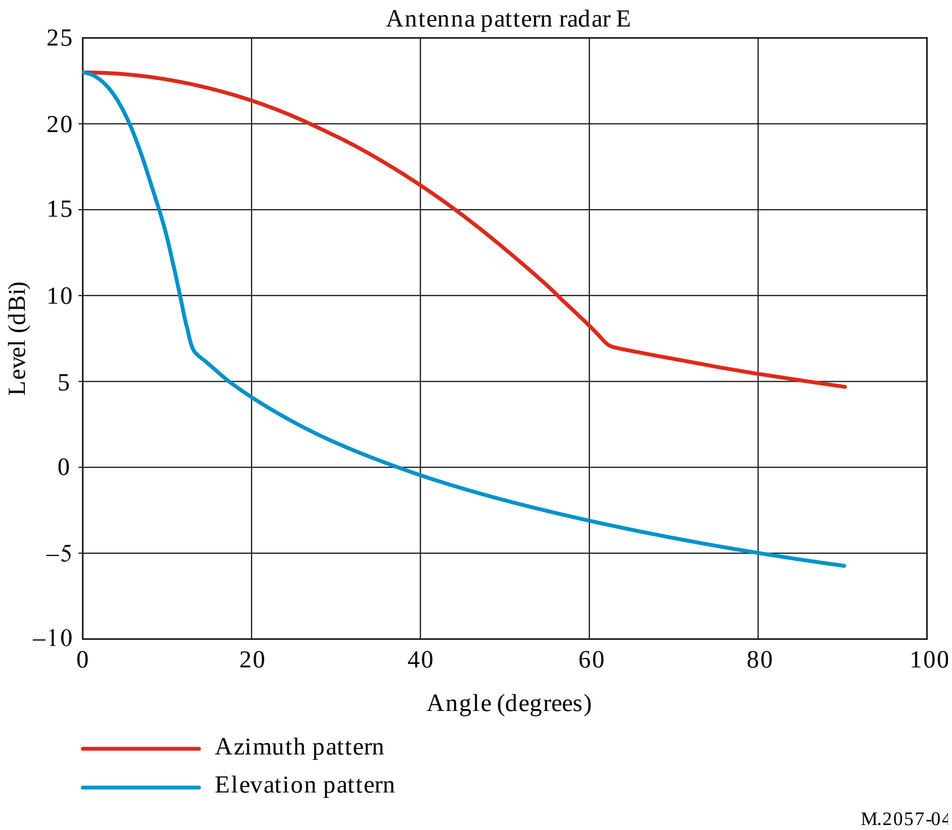
Annex 2

Antenna pattern examples in transmission for radar types defined in Table 1




Antenna pattern radar B and C
25
20
15
10
5
0
–5
–10
Level (dBi)
0
20
40
60
80
100
Angle (degrees)
Azimuth pattern
Elevation pattern
M.2057-02


Antenna pattern radar D
40
35
30
25
20
15
10
5
0
Level (dBi)
0
20
40
60
80
100
Angle (degrees)
Azimuth pattern
Elevation pattern
M.2057-03


Antenna pattern radar E
Level (dBi)
25
20
15
10
5
0
–5
–10
0
20
40
60
80
100
Angle (degrees)
Azimuth pattern
Elevation pattern
M.2057-04