

INTERNATIONAL
RECOMMENDATION

OIML R 91

Edition 1990 (E)

Radar equipment for the measurement of the speed
of vehicles

Cinémomètres radar pour la mesure de la vitesse des véhicules



Foreword

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DE MÉTROLOGIE LÉGALE

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RADAR EQUIPMENT

for the MEASUREMENT of the SPEED of VEHICLES

1 Scope

This Recommendation is applicable to microwave Doppler radar equipment for the measurement of traffic speed on roads, hereafter, in short, "radar". The Recommendation states the conditions that the radar must satisfy when the results of measurement are to be used in legal proceedings. The legal interpretation of the results of measurements, the choice of radar types and the conditions under which these instruments may be applied are left to national regulations.

2 Rules of correct operation

2.1 Handbook (see point 4)

Radars shall be installed and used in accordance with the instructions of a handbook issued by the manufacturer and approved with the instrument, at the time of pattern approval.

2.2 Certainty of vehicle identification

The construction of the radar, including the internal logic of the measurement process, shall ensure that, when the instrument is used in accordance with the handbook, an indicated speed cannot be attributed to the wrong vehicle even where vehicles are passing or overtaking, or when the radar is mounted on a moving vehicle.

The radar shall have a direction discriminator. However, because of its limited effect and stability, a direction discriminator (single sideband device) does not offer a complete solution; additional means shall be used. Where there is no other solution the radar shall invalidate its own result when two vehicles with different speeds pass simultaneously through the radiation beam.

2.3 Aiming device

The angle of incidence of the beam shall be controllable by means of an aiming device so that relative errors of measurement attributable to misalignment are not greater than ± 0.5 %. The angle shall be stable. The aiming device may be omitted if the radar is to be used with a beam that is practically parallel to the direction of traffic movement (incidence angles not exceeding 10°). The handbook shall give details for positioning and adjustment, for all foreseeable installations (roadside, bridges, patrol cars, prepared semipermanent sites, etc).

2.4 Radiation pattern of antenna

The approval of a given angle of incidence is left to national regulations. For beam axes not parallel to the direction of traffic movement, angles of 15° to 30° are recommended.

When the radar is installed and used in accordance with the handbook, no measurement shall be possible in those parts of the antenna lobe where an incorrect angle of incidence may result in relative measurement errors greater than ± 2 %. Errors resulting from a tilting of the radar in relation to the surface of the road shall also be considered.

Note: This requirement may be satisfied by signal processing or by special shaping of the radiation pattern. (For example, at an angle of incidence of 22°, an attenuation of any side lobe to – 15 dB, or – 30 dB after reflexion, together with a total main-lobe width of less than 12° at – 10 dB, may give satisfactory results).

The emitted power and the receiver sensitivity shall be matched in such a way that, in normal operation, measurements across more than two lanes (i.e. from the third lane) occur rarely. If in special situations longer ranges must be activated, the fact shall be stated in writing near the indicating device and on any records produced.

2.5 Time span for indication

If it is possible to use the radar without a suitable recording system (see point 2.6), the visual indication of speed shall remain visible and shall inhibit any further measurement until it is freed by a positive action. No event or action during this time may influence the result or have any effect on subsequent measurements. These requirements need not apply to results below a given speed limit.

If the indication is of the analog type, it may not drift by more than 1 km/h in 5 minutes.

2.6 Recording devices

If the radar records the results of measurement, the record shall indicate the date and time of the measurement, the measured speed and the vehicle's direction of travel. It shall be possible to discover from the record the sensitivity setting of the radar (see point 2.4). If the identity of the vehicle is not made recognizable by a photograph, records shall provide for its immediate identification in writing. The fact that checks as stated in point 2.9 have been performed shall be evident from the records. The requirements of point 2.2 shall be fulfilled.

If a camera is used, the correct relationship between the direction of radiation and that of the optical axis of the camera shall be ensured by positive mechanical links or by the operations described in the handbook by which the correct aiming of the system is verified from pictures.

2.7 Automatic and autonomous radar

Radars designed for operation under circumstances where it is not possible for an officer to verify continuously their satisfactory performance shall provide a level of confidence "near to certainty" that the error of each transmitted result shall be within the permissible limits. The manufacturer shall explain in the handbook the measures he has taken to satisfy that condition.

The level of confidence shall take account of uncertainties of measurement, as well as a possible single failure in the whole instrument. It shall be confirmed by the approval authority. If estimated by statistical methods, it shall be at least 99.8 % (see also point 7.3).

Note: The permanent automatic checking of the instrument's essential operations is required in point 3.4.2 of this Recommendation. Furthermore, with such unattended operation it is strongly advised that redundant measurement techniques such as, for example, taking two pictures of the vehicle separated by a specified time interval be used.

2.8 Automatic exclusion of inaccurate results when the power voltage varies

Speed indications shall be inhibited when the power voltage varies beyond limits at which the allowable errors may be surpassed.

2.9 Overall function test device

The radar shall incorporate some means of simulating a measurement that is independent of the measuring circuits, and by which, at switch-on and additionally at the operator's will, the instrument is checked overall. Such means shall make evident at least every nonintermittent failure of the low-frequency and result-handling circuits, including circuits necessary to satisfy point 3.4.2 and including the functioning and accuracy of indication. Records shall confirm that these tests have been performed.

These requirements need not apply if undetected intermittent or permanent failures can be excluded (see point 3.4.2).

- Notes: 1) For discontinuous (digital) signal handling channels, point 3.4.2.1 prescribes protective measures sufficient to ensure correct operation.
- 2) Analog channels may be checked by, for example, simulated Doppler signals injected near the output of the demodulator stage, or by a device modulating the microwave signal. Such means to verify, among other things, that the upper and lower sensitivity limits are correct, may be omitted if pattern approval tests show that variations of those limits are detected in another way or cannot influence measurement results (see point 3.4.2.2.2) and that the signal is reliably transformed into a speed indication.

3 Construction

3.1 Indicators and speed range

In radars useable without data recording, the indicators shall be readable by two operators simultaneously in lighting conditions corresponding to the conditions of use for which the instrument is suitable according to the handbook.

The speed range shall include at least the range (30 km/h, 150 km/h).

3.2 Mechanical strength

The radar shall be well and solidly built. The materials shall be chosen to ensure sufficient strength and stability.

3.3 Resistance to extremes of climate

3.3.1 When out of service, radars shall be capable of withstanding ambient temperatures of $-25\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$.

The manufacturer shall indicate the ambient temperature limits between which the radar will operate with errors within the permitted limits. When these temperature limits are passed, radars designed for unattended operation shall automatically go out of service. The range shall include at least the range ($0\text{ }^{\circ}\text{C}$, $+50\text{ }^{\circ}\text{C}$) (see point 7.1.1).

3.3.2 The radar shall be insensitive to relative humidity of the ambient air, both under static conditions of storage and in service as described in point 3.3.1. (For insensitivity to condensation, see Annex, point A.2.b).

3.3.3 The parts of the radar that are exposed to the weather shall be dust proof and splash proof when all accessories are fixed.

3.4 Reliability of electronic and logical components

3.4.1 Reaction to disturbance

Radars shall undergo tests showing their reactions to:

- power line variations,
- electrical bursts on the power line,
- external electromagnetic fields.

The relevant tests, severities and criteria for acceptance shall be as stipulated in the Annex to this Recommendation.

3.4.2 Protection against electronic failure

3.4.2.1 Discontinuous (digital) signals

3.4.2.1.1 Results conveyed by digital signals (transfer operations, logic operations, storage, indications, etc.) shall be made secure by additional logic-checking operations, individually (step by step) or collectively (over all). Any discrepancy shall block the measurement in process.

3.4.2.1.2 Elements and components used in such operations (program memories, transfer memories, processors, cabling, indicators, etc.) shall be implicitly checked at least every time the equipment is switched on, by special checking operations, unless they are checked automatically by the logical measures mentioned in point 3.4.2.1.1.

Errors of function that may be made evident as logical signals shall inhibit further measurement. Others (e.g. indicator errors) shall be clearly indicated and the handbook shall explain the measures to be taken.

3.4.2.1.3 Instructions (programs) and permanently stored data (e.g. scale factors, decision criteria, etc.) shall be checked at least every time the instrument is switched on, by methods that show that they are complete.

Note: Methods applicable to digital signals (point 3.4.2.1) were surveyed in OIML Recommendation R 74, "Electronic weighing instruments". That text makes (in a slightly different order) the following provisions:

- A. All relevant measurement data shall be checked for correct value whenever they are stored internally or transmitted to peripherals via an interface, by such means as: parity bit, check sum, double storage, or handshake-routine with retransmission.
- B. Upon switch-on (in the case of instruments permanently connected to the mains: at switch-on of indication), a special procedure shall be performed which shows all relevant signs of the indicator in their active and non-active state sufficiently long to be checked by the operator.
- C. Upon switch-on (in the case of instruments permanently connected to the mains: at switch-on of indication), all data storage components shall be checked automatically to verify that:
 - C.1. all procedures of internal transfer and storage of data relevant to the measurement result are performed correctly, by such means as:
 - write-read routines,
 - conversion and reconversion of codes,

- use of "safe coding" (check sum, parity bit),
- double storage,

C.2. the values of all permanently memorized instructions and data are correct, by such means as:

- summing of all instruction and data codes and comparing the sum with a fixed value,
- line and column parity bits (LRC and VRC according to ISO 1155, October 1973),

The use of:

- cyclic redundancy check (CRC 16, ISO 2111, June 1971),
- double storage of data, both in same code,
- double storage of data, second in inverse or shifted coding,
- storage of data in "safe coding", for example protected by check sum, line and column parity bits,

when verified by the type approval tests, is considered as satisfying C.2.

The use of parity bit alone is not sufficient where data are stored or read and are relevant to the metrological characteristics of the instrument.

3.4.2.2 Continuous signals (analogue signals)

3.4.2.2.1 Micro-wave circuits shall ensure a long-term stability of tuning (2 years) of approximately ± 0.2 % in frequency.

3.4.2.2.2 The gain of analogue channels shall have no influence on results, or its effects shall be periodically checked (see point 2.9).

4 Handbook

The manufacturer shall provide each radar with a handbook (see point 2.1) which shall be officially approved with the instrument's pattern. This handbook shall contain at least:

- the theory of operation of the equipment,
- an explanation of the general operating schematic,
- an accurate specification of normal operating conditions,
- the modes of operation,
- information on the principal causes of errors,
- a review of the influence quantities affecting the measurements, and of the partial errors they may induce,
- for radars designed to work without an operator, the information required in point 2.7.

5 Protection against tampering

It shall be possible to seal or otherwise protect those parts which, if tampered with, could lead to errors in measurement or to metrologically unreliable operation.

6 Identification of the equipment

The instrument, or each separately housed subunit, shall carry, in indelible lettering, the following indications:

- the name (or trade mark) and address of the manufacturer or his representative,

- the type indication and serial number of the instrument,
- an indication of necessary connecting units by type number and, if not interchangeable, by serial number.

7 Pattern approval

7.1 Metrological tests in the laboratory

7.1.1 Test conditions

	Reference value	Range
Ambient temperature	+ 20 °C	- 20 °C, + 60 °C (1)
Ambient humidity	60 %	either value, non condensing
Power voltage	nominal	- 10 %, + 20 % of nominal at least (2)
Frequency (if applicable)	nominal	nominal ± 3 %
Length of time since switched on	any	

Radars shall be tested at + 20 °C and at minimum and maximum applicable temperatures with different power voltages; humidity and power frequency shall be varied only if they have a noticeable influence.

For each factor mentioned above, its variation throughout the whole defined range shall not induce a change of indication greater than 50 % of the moduli of the maximum permissible errors given in points 7.1.2 and 7.1.3.

7.1.2 Testing of micro-wave section

Radiation pattern and power limitation:	the requirements of point 2.4 shall apply
Aiming device:	the requirements of point 2.3 shall apply
Frequency range and oscillator stability:	shall conform to national regulations.

Note: Pattern approval is also dependent on certification by the authority for communications equipment.

7.1.3 Testing of the low-frequency section

From the frequency f_d of the simulated Doppler signal the theoretical speed indication shall be computed thus:

$$v_d = 0.5 \times f_d \times \lambda / \cos \alpha$$

where: λ = the emitted wavelength
 α = the average effective angle of incidence (3)

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- (1) This range is for parts installed outdoors; for parts installed in cars or shelters, the range is defined by the manufacturer and shall include at least the range (0 °C, + 50 °C).
 - (2) The lower limit shall be the switch-off point as defined in point 2.8.
 - (3) This angle may be different from the geometric angle between beam axis and street direction, as a vehicle's speed may sometimes be measured shortly after the vehicle enters the beam, or - due to delaying actions of discriminating circuits, for instance - after its passing the beam axis. The resulting average is different for traffic entering the beam from behind or from the front. If the manufacturer wishes such differences to be considered he shall indicate the appropriate average values to be used in the computation.

All errors of indication (referred to v_d) under reference conditions shall be less than ± 1 km/h, or ± 1 % at speeds above 100 km/h.

For instruments with digital indication, f_d shall be varied until the average switching (rounding) point is found, which shall be presumed to be halfway in value between the two neighbouring indications. If, in fact, fractions of the least significant digit are discounted (rounding down), this is to be considered as an average scale shift.

7.1.4 Neither attenuation to the limit of reception of the signal mentioned in point 7.1.3 nor limitations of its duration shall provoke errors greater than those prescribed in point 7.1.3.

7.1.5 Discriminating circuits, preliminary tests

Functions mentioned in points 2.2, 2.5, 2.8 and (if applicable) 2.4 and 2.7 shall be tested using the following procedures:

- lowering the power voltage below the limit of 90 % nominal, to the point of automatic cut-off (point 2.8),
- sweeping the frequency f_d (point 7.1.3), mixing of two such frequencies, feeding them to the circuits with interruptions or in bursts

Specific values of frequency cannot be given, due to differences in emitter frequencies and beam widths. A frequency step corresponding to the arrival of a second vehicle with a speed difference of 3.5 km/h or more (3.5 % or more at speeds above 100 km/h) shall inhibit the output of a result, or the lower speed shall be output.

Brief frequency variations, simulating measurement instabilities, shall inhibit the output when their influence on the result can be more than 2 km/h (or more than 2 % at speeds above 100 km/h).

Further tests will result from the tests of electronic and logical components (points 7.2 and 3.4) which will be effected in the following stage.

7.2 Tests of effects of influence factors and disturbances

The tests that shall be performed and the criteria of acceptance are described in the Annex.

7.3 Metrological field tests (to be performed after the tests of point 7.2)

It is recommended that the metrological tests be completed by an operating test in actual traffic. This overall study of possible errors seems indispensable due to the complexity of factors affecting the result of a measurement (shape of antenna lobe, lateral distance between radar and passing vehicle, reflection characteristics of the latter, change of lane during passage through beam, braking, delays in measurement due to the presence of more than one vehicle, etc).

The error distribution shall be determined under conditions of variable speed and traffic density, and if possible at various temperatures.

The average error of all results shall be within ± 1 km/h.

For pattern approval, 500 measurements shall be made, of which none shall give a positive error larger than + 3 km/h (or + 3 % at speeds above 100 km/h). Results that are recognizable as faulty by any user familiar with the handbook shall be discounted.

If fewer measurements are made, they are to be considered as a sample which, by its result, shall validate the same error limits as would 500 measurements.

For autonomous radars, the results shall confirm the level of confidence required (see point 2.7).

The measuring system used for comparison shall have an uncertainty better than one third of that of the radar under test; 99.8 % of its results should have errors that are within ± 1 km/h (or ± 1 % at speeds above 100 km/h).

7.4 Conformity to approved pattern

The approved pattern is defined by the instrument's characteristics determining its metrological integrity.

As long as the metrological integrity depends on internal logical protections, the origin of the electronic elements is not so important. On the contrary, the structure of the checking circuits, the way in which they function and the programs which control them are important and are to be maintained in instruments manufactured according to an approved pattern. In consequence:

- the manufacturer shall submit details of the instrument's logic,
- he shall disclose and discuss with the metrology services all changes in the approved pattern in this regard,
- the relevant services shall develop and maintain a safe storage system for such information; one solution is to sign the documents submitted and place them in the custody of the manufacturer or his representative.

ANNEX

TESTS OF EFFECTS OF INFLUENCE FACTORS AND DISTURBANCES

These tests are listed in the order of the requirements of this Recommendation to which they relate.

International Document OIML D 11 "General requirements for electronic measuring instruments" (1986 edition) has been used wherever applicable and, for such tests, the appropriate severity level is given. Durability tests have been omitted because of the extent of internal logic protection required by this Recommendation.

If appropriate, tests are provided with references to the Publications of the International Electrotechnical Commission (IEC), where detailed information on test procedures and test equipment may be found.

A.1 Mechanical strength test (point 3.2 of the Recommendation)

Mechanical shock

The radar is tilted about one bottom edge with a height of the opposite edge of 50 mm and then allowed to fall freely. The test requires one fall about each bottom edge.

After the test, a check as per point 7.1.2 shall be performed (frequency and variations in radiated power).

Reference to OIML D 11: point A.2.5, severity level 2

Reference to IEC: Publication 68.2.31

A.2 Climatic resistance test (point 3.3 of the Recommendation)

a) Dry heat - cold

The test simulates storage conditions, with the exception that the radar shall be mounted on a tripod to provide maximum exposure.

The dry heat test shall have a duration of 2 hours at 70 °C, the cold test 2 hours at – 25 °C, the radar being out of service.

After each test a check of the oscillator frequency (point 7.1.2) and a check of the conversion factor of the indication (point 7.1.3) shall be performed.

Reference to OIML D 11: point A.2.1.1 and A.2.1.2, severity levels 4 (dry heat) and 3 (cold)

Reference to IEC: Publications 68.2.1, 68.2.2 and 68.3.1

b) Damp heat, condensing

Immediately following the cold test, those parts of the radar which in normal use may be exposed to cold (other parts may be protected by closed plastic bags) shall be placed in a room at + 20 °C, with a humidity of about 80 %. The radar shall be put into the operating state and switched on for one hour after leaving the cold chamber. Partial checks in accordance with points 7.1.2 (radiation power), 7.1.3 (accuracy) and 7.1.4 (sensitivity) shall show that no incorrect indications result from condensation.

c) Water splash test for parts exposed to water

One bucket of about 10 litres of water shall be thrown from a distance of 3 m against each side of the radar, once from above and once from below, with the instrument in operation.

Checks according to points 7.1.2 (power) and 7.1.3 (accuracy) shall show that the water splashes have no effect. The radar shall be inspected to check that no water has entered it.

A.3 Tests of reliability of electronic and logical components (point 3.4 of the Recommendation)

a) Power variations for battery-powered radars: see point 7.1.1.

b) Bursts

Bursts of voltage spikes are superimposed on the mains voltage, with an amplitude of 1 kV, throughout the time necessary to simulate five speed measurements.

Checks according to point 7.1.3 (accuracy) shall show either that the result corresponds to f_d or that the indication disappears.

Reference to OIML D 11: point A.2.8.2, severity level 2

Reference to IEC: Publication 801-4

c) Electromagnetic susceptibility

The radar is exposed to an electromagnetic field strength of 10 V/m at frequencies between 27 MHz and 500 MHz and of 3 V/m at frequencies between 500 MHz and 1 000 MHz, the amplitude modulation being at a frequency which corresponds to the Doppler frequency for a speed of 60 km/h.

Checks shall be performed according to points 7.1.3 (accuracy), 7.1.4 (sensitivity) and 7.1.5 (discrimination of speed variations and of the presence of more than one vehicle).

Reference to OIML D 11: point A.2.10, severity levels 6 and 8

Reference to IEC: Publication 801-3

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After completion of all the tests of the effects of influence factors and disturbances, all the tests of point 7.1 of the Recommendation shall be repeated with a suitable subset of characteristics to determine deviations from the initial intrinsic error.

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