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Ships and marine technology — Marine radar reflectors —

Part 2: **Active type**

Navires et technologie maritime — Réflecteurs radars de marine —

Partie 2: Type actif

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 8729-2 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 6, *Navigation and ship operations*.

ISO 8729 consists of the following parts, under the general title *Ships and marine technology — Marine radar reflectors:*

— *Part 1: Passive type*

— *Part 2: Active type*

Ships and marine technology — Marine radar reflectors —

Part 2: **Active type**

1 Scope

It is recognised that small vessels, often made of glass fibre reinforced plastic (GRP), can be poor reflectors of radar signals. In situations where radar is the prime observation tool used by ships at sea, the International Maritime Organisation considers that it is essential that small vessels, considered in this context to be those under 150 gross tonnage, be equipped with a radar reflector to enhance their radar return and thus improve their visibility to radar.

This International Standard specifies the minimum requirements for a radar reflector intended to enhance returns from small vessels as required by IMO Resolution MSC.164(78).

It provides the specification for the construction, performance, testing, inspection and installation of such radar reflectors.

NOTE Requirements that have been extracted from IMO Resolution MSC.164(78) *Revised performance standards for radar reflectors* are printed in italics.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

IEC 60945, *Marine navigation and radiocommunication equipment and systems — General requirements — Methods of testing and required test results*

ITU-R SM.329, *Unwanted emissions in the spurious domain*

ITU-R SM.1541, *Unwanted emissions in the out-of-band domain*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
radar reflector
device that is designed to enhance radar returns from vessels with small radar cross section

3.2
active radar reflector
device that receives, amplifies and retransmits a radar signal as a method of enhancing radar returns

NOTE An active radar reflector is often also known as a radar target enhancer (RTE).

3.3
radar cross section
RCS
equivalent echoing area which is 4 π times the ratio of the power per unit solid angle scattered in a specified direction to the power per unit area in a plane wave incident on the scatterer from a specified direction

NOTE It is dependent on the radar operating frequency and the three-dimensional orientation of the reflector. Polarization of the transmitter and the received wave affects the effective radar cross section of the reflector.

3.4
azimuthal polar diagram
polar diagram providing the RCS of the reflector with respect to its azimuthal angle

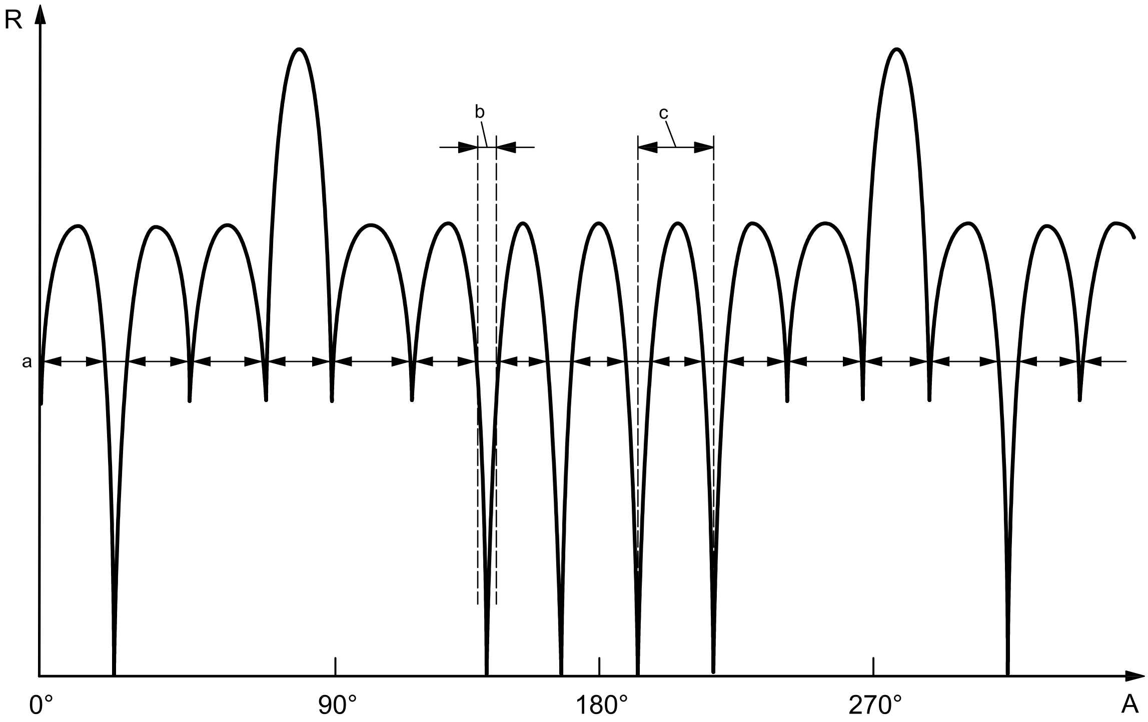
NOTE These diagrams can be produced for any angle of heel.

3.5
null
pronounced fall-off of RCS in the azimuthal polar diagram

3.6
stated performance level
SPL
performance level calculated from measurement data sets (i.e. azimuthal polar diagrams) taken during technical measurements of reflective performance

NOTE 1 SPL is the RCS value at which a null is 10° wide (see Figure 1). If there is more than one null with a width of at least 10°, then SPL is the lowest such value.

NOTE 2 If the azimuthal polar diagram does not show a null (as defined in 3.5) that is 10° wide, then the SPL is the RCS which is achieved over 280° of azimuth.



Key

A azimuth

R radar cross section

a Stated performance level.

b Null width ⩽ 10°.

c Spacing between nulls ⩾ 20°.

Figure 1 — Definition of stated performance level

3.7
self-oscillation
phenomenon whereby the receive and transmit antennas of an active reflector are unintentionally coupled, either inherently or by a reflecting surface closeby, so that feedback occurs between the two

NOTE Devices that are self-oscillating are also said to be unstable.

3.8
saturation
state whereby an active radar reflector is emitting the maximum power of which it is capable

NOTE 1 This power at which saturation occurs is known as the saturated power.

NOTE 2 The distance from the interrogating radar at which saturation occurs is a function of the power of the radar, the total gain of the reflector and the maximum power of the reflector.

4 Construction

4.1 General arrangement

The active radar reflector shall consist of a receive antenna (or antennas), an amplifier (or amplifiers) capable of operation across the X and S bands and a transmit antenna (or antennas). Typically there may also be an associated control box whose function is to switch the device on and off and to indicate to the user that the device is working.

4.2 Structure and materials

The materials used for the radar reflector shall be of sufficient strength and quality as to make the reflector capable of maintaining reflection performance under the conditions of stress due to sea states, vibration, humidity and change of temperature likely to be experienced in the marine environment. Use of ferrous metals should be avoided.

4.3 Enclosed size of the reflector

The volume of the reflector should not exceed 0,05 m^3*.*

4.4 Mass of the reflector

The reflector should weigh as little as practical in order to minimise its effect on the stability of small vessels.

5 Performance

5.1 Functionality

The active radar reflector shall receive a radar pulse, amplify it and retransmit it. The output shall only be an amplified version of the received pulse, without any form of processing except limiting.

5.2 Reflecting pattern

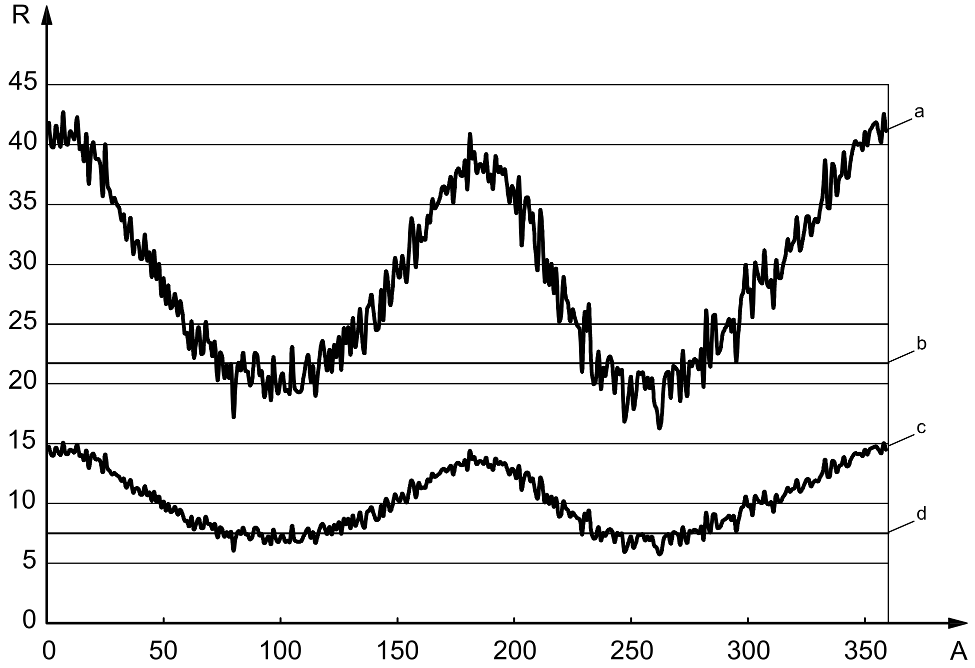
5.2.1 T*he radar reflector* shall *have a stated performance level of at least 7,5* m^2 *at* X *band (9,300* GHz *to 9,500* GHz*) and 0,5* m^2 *at* S *band (2,900* GHz *to 3,100* GHz*). The SPL* shall *be maintained over a total angle of at least 280°.*

The response shall*, at the calculated SPL for each azimuthal polar diagram,*

— *not have any nulls wider than a single angle of 10°, and*

— *not have a distance between nulls of less than 20°. Nulls of less than 5° shall be ignored for this calculation.*

NOTE Typical azimuthal polar diagrams for an active radar reflector in X band at 0° and 10° elevation are given in Figure 2.



Key

A azimuth

R radar cross section, expressed in m²

a 0° elevation

b stated performance level for 21,7 m²

c 10° elevation

d stated performance level for 7,5 m²

The 0° elevation response shows a calculated SPL of 21,7 m³ for 280° azimuth coverage and the response at 10° elevation is calculated at 7,5 m³, which is just compliant with respect to the minimum SPL requirement. These two plots also illustrate the expected antenna gain reduction with elevation change.

Figure 2 — Examples of typical RTE azimuthal polar diagrams and their associated SPL

5.2.2 *For power-driven vessels and sailing vessels designed to operate with little heel (catamaran/trimaran), this performance* shall *be maintained through angles of (athwartships) heel 10° either side of vertical. For other vessels, the reflector* shall *maintain this performance over 20° either side of vertical.*

5.3 Time delay and stretching

The time delay and stretching of the output shall not exceed 10 % of the length of the received pulse or 10 ns, whichever is greater.

5.4 Polarisation

The active reflector shall respond to radar using horizontal polarisation in both X and S bands. For S band, the active reflector may use circular polarised antennas for receiving and transmitting.

5.5 Stability and self-oscillation

The active reflector shall be inherently stable and it shall not be possible for instability to be induced under any conditions. Stability shall be demonstrated by the tests specified in 7.3.4 and 7.3.5.

5.6 Maximum power

The maximum power of the active reflector shall not exceed 10 W.

5.7 Tolerance to a radar in close proximity

The reflector must be able to withstand a continuous pulse power density of 2 kW/m^2. This is equivalent to a 25 kW radar, 1 µs, with a 1,83 m antenna [1)] at a range of 30 m.

6 Environmental requirements

The active radar reflector shall meet the dry heat, damp heat, low temperature, solar radiation, vibration, rain and spray and corrosion requirements of IEC 60945 where they are applicable. If the design of the active radar reflector system is such that some parts are intended to be installed in an exposed position and others in a protected position, then the tests to which each part shall be subjected shall be those which apply to the intended position.

7 Inspection and type tests

7.1 Inspection

A visual inspection shall be carried out to confirm that the construction and finish of the reflector is such that the unit is safe to handle. For example, burrs should be removed and, if applicable, wires fixed so that injury cannot occur during the handling of the reflector.

7.2 Testing

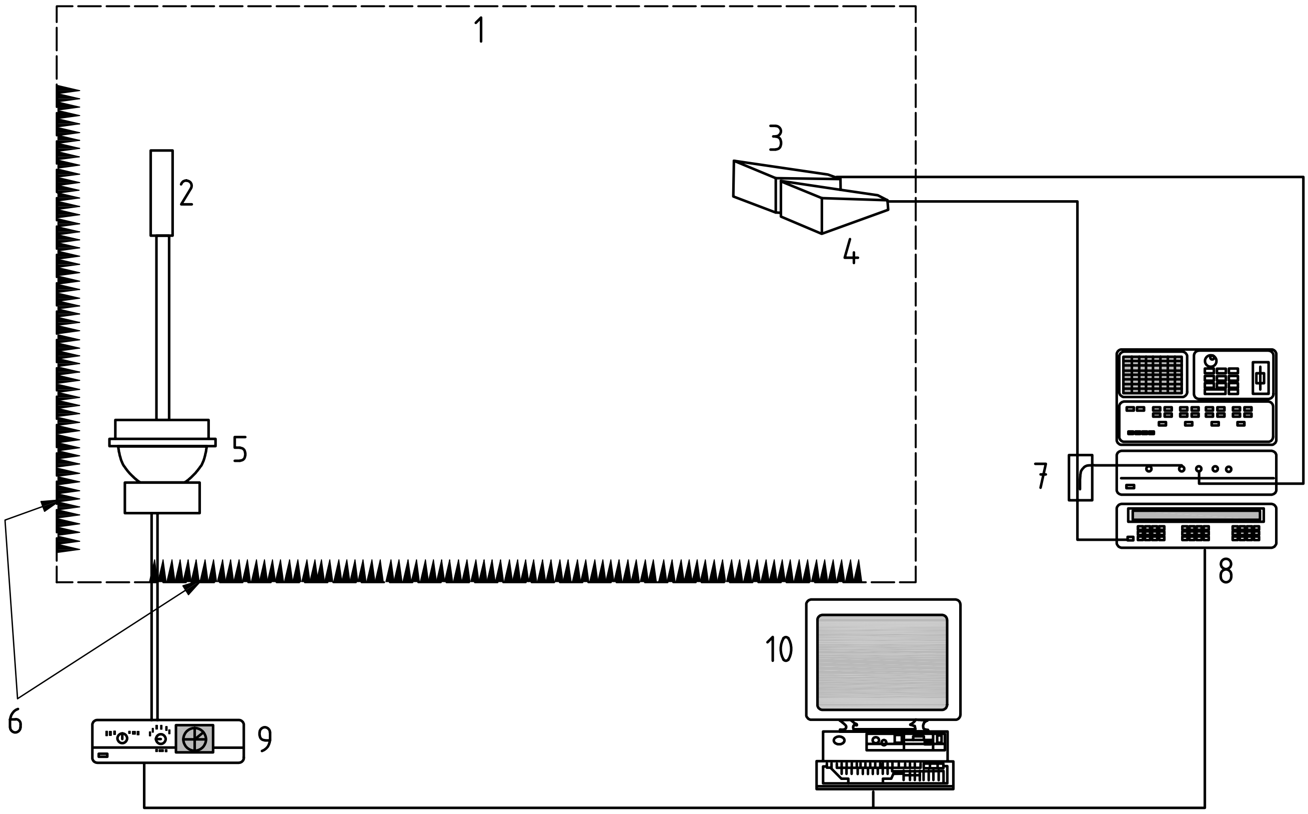
Tests will normally be carried out at test sites accepted by the type test authority for these tests. General requirements for the competence of testing and calibration laboratories are given in ISO 17025. The manufacturer shall, unless otherwise agreed, set up the equipment and ensure that it is installed in accordance with their installation requirements before type testing commences.

7.3 Performance tests

7.3.1 General

The reflective performance tests shall be conducted in a free-field environment where the background noise level has been reduced to the equivalent echoing area of 0,01 m^2 or less at frequencies between 2,900 GHz to 3,100 GHz and 9,300 GHz to 9,500 GHz. Typically, a fully anechoic microwave test chamber, specified for up to 10 GHz operation, would be used for the conduct of these tests. Before use, the reflector test range shall be calibrated using a precision sphere of known radar cross section. These tests may be carried out using a continuous wave (CW) or pulsed signal. CW signals are atypical of current magnetron radar but produce lower uncertainties in reflector testing. Due to the 100 % duty cycle of a non-fluctuating CW signal, the manufacturer should be consulted to ascertain the maximum time tests can be conducted and the duration of any rest period to allow for equipment under test (EUT) cooling. The tests should be carried out at both X band (9,410 GHz) and S band (3,050 GHz) with the same power density at the EUT turntable that was used for the chamber calibration. This power density should be at least 6 dB below the level required to saturate the EUT, unless otherwise stated in the test clause. For illustration, an instrumentation schematic is given in Figure 3.

1) 1,83 m ≈ 6 ft.



Key

1 fully anechoic chamber
2 equipment under test
3 receive antenna
4 transmit antenna
5 positioner (azimuth/elevation)
6 radar absorbent material
7 directional coupler
8 vector network analyser
9 position controller
10 PC

Figure 3 — Instrumentation schematic

7.3.2 SPL measurement

7.3.2.1 General

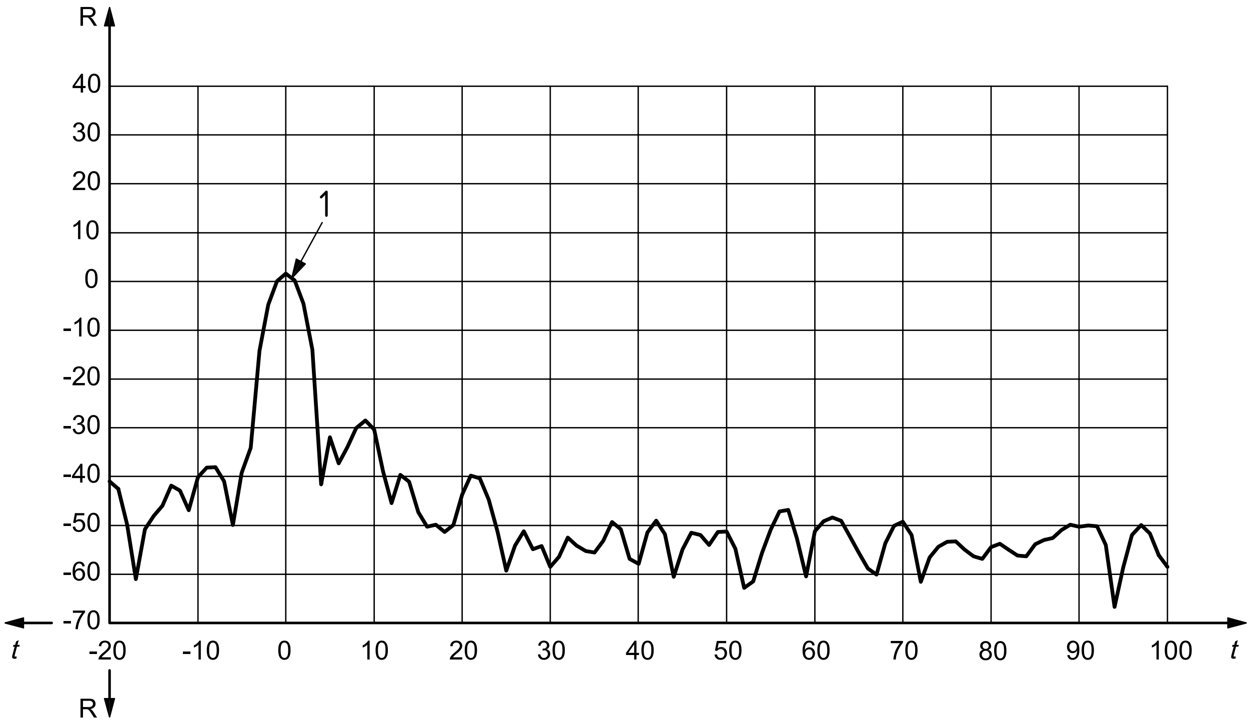
The test shall consist of a series of measurements to produce azimuthal polar diagrams of the reflector performance within the volume 360° azimuth and the required angle (±) of heel (see 5.2.2). Measurements shall be taken using a turntable capable of moving the EUT at intervals ⩽ 1° in azimuth and ⩽ 0,5° in elevation. The arrangement of the turntable shall give azimuth movement over elevation. Azimuthal polar diagrams shall be produced at 5° vertical intervals up to 10° or 20° depending on the designation of the EUT (see 5.2.2) both towards and away from the interrogating signal source. The turntable shall rotate at an angular speed to match instrumentation data capture rate, and measurement data should be recorded to a computer spreadsheet so that the SPL, which has a dynamic relationship with the 280° requirement and nulls, can be calculated for each plot.

7.3.2.2 SPL designation

Following the analysis of the azimuthal polar diagrams from the measurements of 7.3.2.1, the lowest SPL calculated shall be designated as the SPL for that particular radar reflector with respect to its declaration of use (see 5.2.1).

7.3.3 Time delay test

The EUT shall be placed in its normal mounting attitude in the anechoic chamber and the instrumentation set up to investigate the returned signal in the time/frequency domain. An instrumentation schematic is given in Figure 3. The EUT shall be rotated such that the maximum RCS position is aligned with the test antennas. For effective measurement of the EUT's stability and inherent time delay, swept frequency measurements will be made with a bandwidth of 200 MHz. This frequency domain data will be Fourier transformed into the time domain to give an RCS result plotted against time. Measurements will be made with the device switched off (to give a time reference) and with the device switched on. Typical results are given in Figures 4 and 5. The time delay can be seen as the time difference between the passive return from the EUT and the first active (main) return. Initial returned signals may be affected by any power management arrangements such as the use of a "wake up" trigger, and appropriate test allowance may be made.



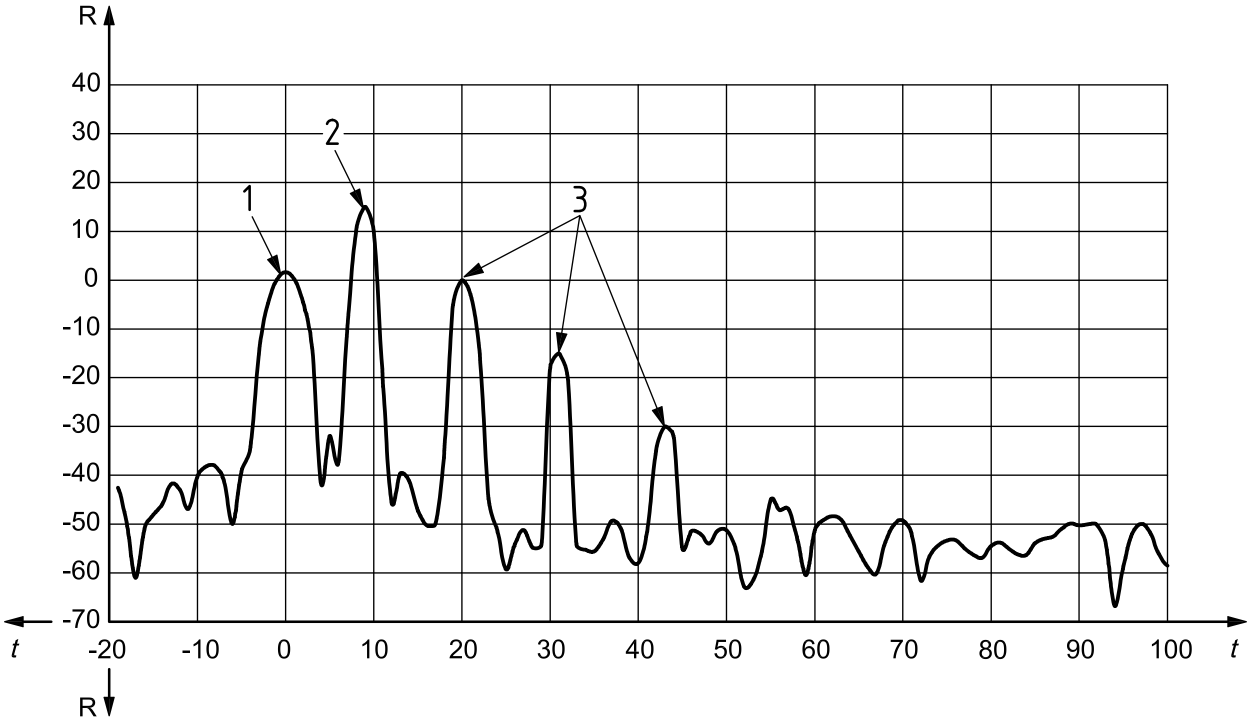
Key

R radar cross section, expressed in dBm^2

t time, expressed in ns

1 reflection from body of equipment under test

Figure 4 — RCS plotted against time (device switched off)



Key

R radar cross section, expressed in dBm^2

t time, expressed in ns

1 reflection from body of equipment under test

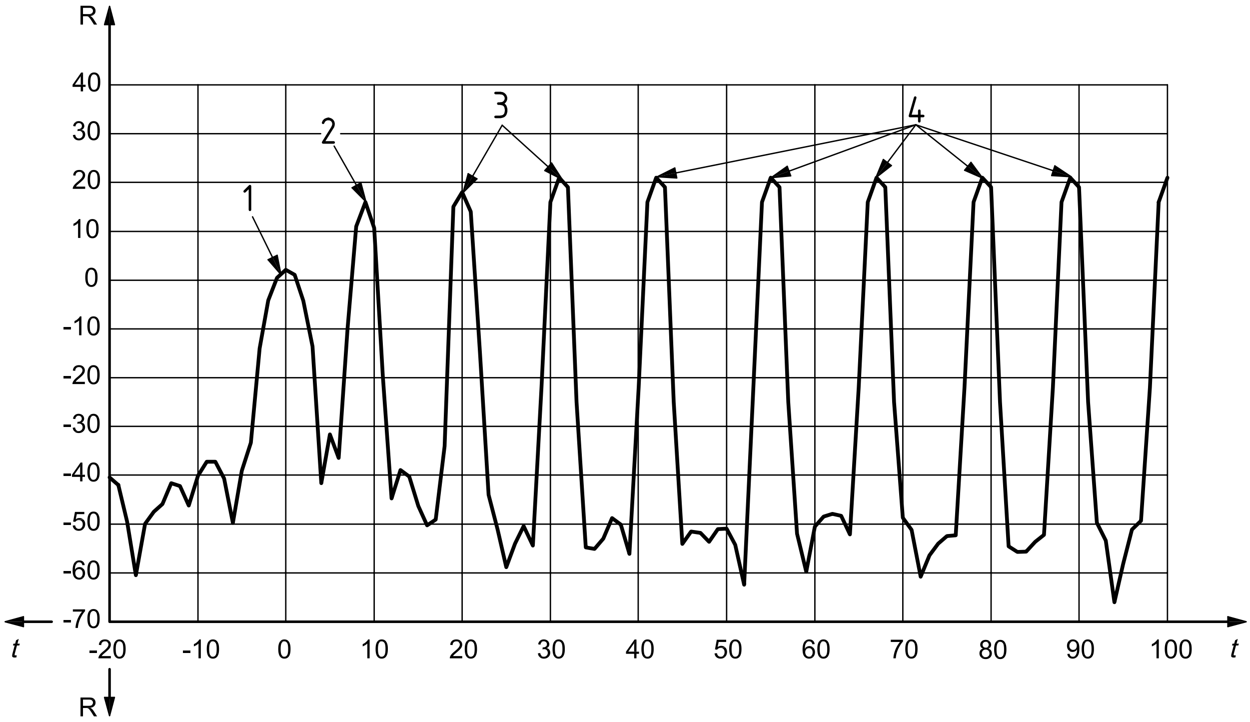
2 main return

3 coupled returns from equipment under test decreasing

Figure 5 — RCS plotted against time (device switched on, not in saturation)

7.3.4 Stability test

The time delay test shall be repeated and the power of the excitation signal increased until the main return reaches its maximum (saturates). If the coupled returns decrease (as shown in Figure 5), then the device is completely stable. If the returns increase with time until saturation is reached (when their level remains constant, as shown in Figure 6), then the device is unstable.



Key

R radar cross section, expressed in dBm^2

t time, expressed in ns

1 reflection from body of equipment under test

2 main return

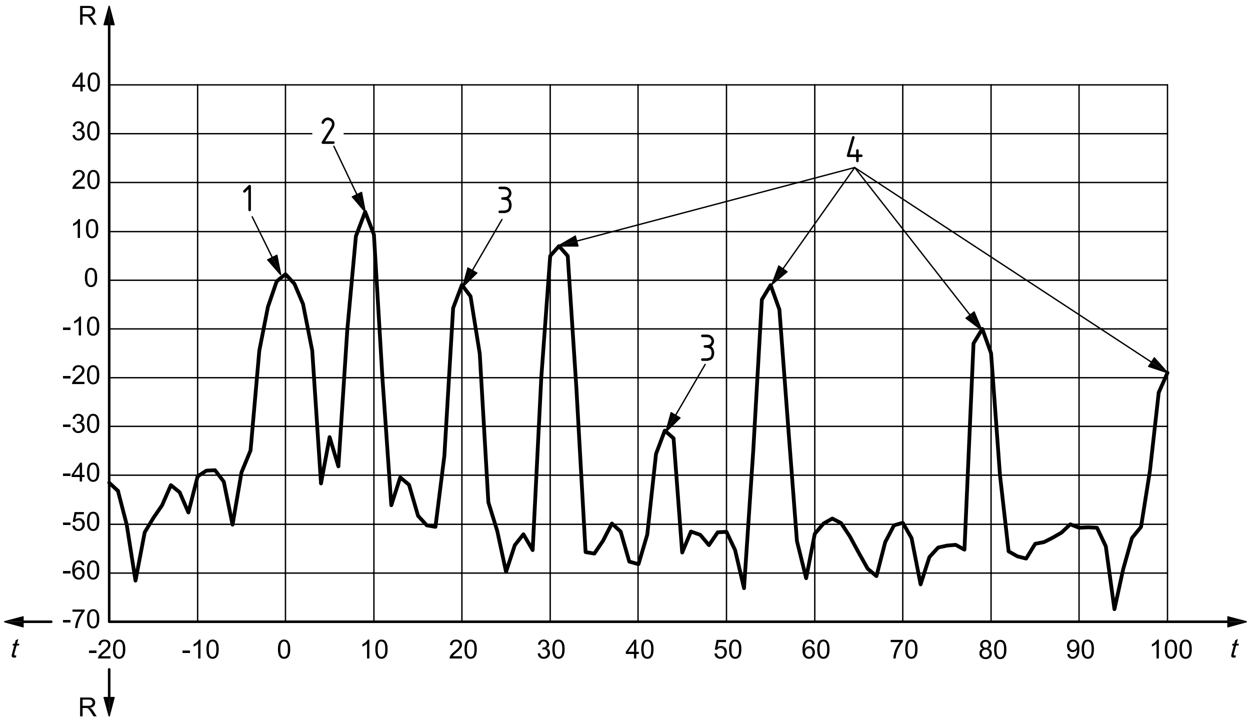
3 coupled returns from equipment under test increasing

4 coupled returns from equipment under test in saturation

Figure 6 — RCS plotted against time (device switched on, in saturation)

7.3.5 Induced instability test

The above test shall be repeated but with a corner reflector of RCS 10 m^2 for an X band test and ≈1 m^2 for S band, placed 3 m from the EUT. The corner reflector, shall be placed such that it is out of the normal test signal path and oriented so as to return the maximum signal to the active device. The EUT shall be rotated such that its maximum RCS position is aligned with the corner reflector, and the power of the interrogating signal shall be gradually increased to a level at which the EUT saturates. Figure 7 shows that when the corner reflector is introduced, a separate reflection 20 ns behind the main reflection is created. If the secondary returns decrease with time, as Figure 7 shows, then instability has not been induced.



Key

R radar cross section, expressed in dBm^2

t time, expressed in ns

1 reflection from body of equipment under test

2 main return

3 coupled returns from equipment under test decreasing

4 coupled returns from corner reflector decreasing

Figure 7 — RCS plotted against time (device switched on, not in saturation, with corner reflector)

7.3.6 Power emission test

The aim of this test is to confirm that the power output of the active radar reflector is sufficient to create a return which will be detected by the interrogating radar.

This test shall be conducted with the power density of the simulated radar signal, calculated for a range of five nautical miles [9 260 m [2)]], at the turntable as given in Table 1.

Table 1 — Power density required at the turntable

Frequency (GHz)	**Peak power density required** [a] (W/m^2)
3,050	0,011
9,410	0,023

[a] This power density has been calculated using 25 kW and 30 dBi for a typical X band radar and 30 kW and 26 dBi for a typical S band radar.

2) 1 nautical mile = 1 852 m (exactly).

If the EUT is saturated at these powers, then the power shall be reduced until the EUT is out of saturation.

The azimuthal polar diagram shall be produced and the SPL calculated as specified in 7.3.2.1 for 0° heel. The SPL shall have minimum values of 7,5 m^2 or 0,5 m^2, depending on the frequency.

7.3.7 Saturation power test

Power shall be applied to the input to the amplifier without antennas and increased until the amplifier is in a saturated condition. The output power shall then be measured. This output power shall be adjusted by the gain of the transmit antenna, and it shall be confirmed that the result is less than 10 W.

7.3.8 Tolerance to a radar in close proximity check

The manufacturer shall provide documentary evidence that the reflector can withstand the power density defined in 5.7.

7.3.9 Pulse length check

The interrogating signal, having a pulse length of 0,5 µs and interrogation interval of 1 000 Hz at levels saturating the active radar reflector, shall be emitted at frequencies of both 9,410 GHz and 3,050 GHz to detect the returned signal. It shall be confirmed that the pulse length of the returned signal differs by no more than 10 % (or 10 ns, whichever is greater) of the interrogating signal.

If acceptable to the approving authority, this confirmation may be demonstrated by theory.

7.4 Environmental tests

7.4.1 The reflector shall meet the requirements of the following tests specified in IEC 60945:

— dry heat test;

— damp heat test;

— low temperature test;

— vibration test;

— solar radiation test;

— rain and spray test (exposed items only);

— corrosion test.

If the design of the active radar reflector system is such that some parts are intended to be installed in an exposed position and others in a protected position, then the tests to which each part shall be subjected shall be those which apply to the intended position.

7.4.2 IEC 60945 requires performance tests or checks to be carried out during the test programme. Since a performance test needs specialised equipment used in a free-field environment for qualitative results, the “performance check” shall consist of a visual examination during the tests for any damage visible to normal eyesight. The reflector shall be supplied with its normal power during the tests and the current monitored. Any significant increase in current in the absence of a radar excitation signal would indicate a failure due to self oscillation. The performance test shall consist of the full reflective performance tests from 7.3.1 to 7.3.2.1 conducted on the sample reflector after completion of the environmental tests given in 7.4.1.

7.5 Mechanical strength test

The reflector shall be mounted in the recommended way and moved under water at a relative velocity of 1,3 m/s in both directions in each of the mutually perpendicular planes consecutively.

7.6 Electromagnetic emission tests

The reflector and any control electronics shall meet the requirements of the following tests specified in IEC 60945:

— conducted emissions;

— radiated emissions.

7.7 Electromagnetic immunity tests

The reflector and any control electronics shall meet the requirements of the following tests specified in IEC 60945:

— conducted RF disturbance;

— radiated disturbance;

— fast transients;

— electrostatic discharge.

The above tests shall be conducted both with and without a simulated radar signal present. The reflector shall not self transmit when no radar signal is present and shall not go into saturation when the radar signal is present.

7.8 Spurious emissions tests

Out -of-band domain emissions do not apply to devices of this power (see ITU-R SM.1541), and so only the spurious domain emission limits will apply to an active reflector. The reflector shall meet the requirements of ITU-R SM.329 with the Category A limits for radiodetermination service equipment. It is recommended that the device be triggered by two CW tones, 3,050 GHz and 9,410 GHz, and the spurious emissions be measured from 2 GHz to 26 GHz in a 1 MHz bandwidth in accordance with ITU-R SM.329. A suitable test method is given in Annex B.

8 Installation

8.1 Method

The radar reflector shall be installed in accordance with a method recommended by the manufacturer.

Fixing arrangements shall be provided so that the reflector can be fitted in its correct orientation either on a rigid mount or suspended in rigging.

8.2 Positioning

The radar reflector should be installed in the optimum position for the avoidance of shadow sectors and self-oscillation.

8.3 Mounting height

The mounting height of a reflector shall be higher than the value given in A.2. Figure A.1 is derived from a high probability of radar detection at ranges up to five nautical miles [9 260 m [3)]] using the IMO requirements for SPL levels. On some small vessels it will not be practical to achieve a mounting height of 4 m, and 2 m should be noted as the absolute minimum.

8.4 Mass

The maximum mass for mounting at 4 m above sea level (ASL) shall be 5 kg.

Reflectors designed for mounting at a greater height shall be of mass calculated as equivalent to, or less than, 5 kg.

If the height/mass value exceeds 4 m/5 kg, the following warning statement shall be clearly made in the manual (see Clause 9).

“This reflector exceeds the height/mass equivalent 4 m/5 kg and may not be suitable for small boats and yachts. It is, however, the owner's responsibility to ensure that he or she does not adversely affect the stability of his or her vessel to an unacceptable degree.”

8.5 Size

The physical size of the reflector should be minimized and should not exceed 0,05 m^3. If the size of the reflector exceeds 0,05 m^3, the following statement must be clearly made in the manual (see Clause 9).

“This reflector exceeds the recommended size limit for small craft.”

9 Manual

The manufacturer shall provide a manual or equivalent documentation that shall include at least the following.

— General description of the reflector and any associated items.

— Dimensions and mass of the reflector.

— Preferred mounting positions including the physical relationship with on-board radar and other reflective objects, including flat surfaces, in order to avoid self-oscillation.

— The measured compass safe distance (CSD) from the vessel's magnetic compass or a statement that the reflector should be mounted at least 5 m from the compass.

— The mass/height relationship and an explanation of the advice that the ratio of 4 m/5 kg be adopted if practical. *It is considered that the maximum mass of reflector which should be mounted at 4* m *ASL is 5* kg*. If the reflector is to be mounted higher than 4* m *ASL, then the reflector should weigh less than 5* kg *so that the overturning moment is not increased beyond that of a 5* kg *mass at 4* m *ASL*. It is, however, the owner’s responsibility to ensure that he or she does not adversely affect the stability of his or her vessel to an unacceptable degree.

— The minimum mounting height considered suitable as given in Figure A.1.

— Instructions for the avoidance of shadow sectors and self-oscillation.

— Wiring instructions.

3) 1 nautical mile = 1 852 m (exactly).

- Method of operation.
- Functionality checks.
- Troubleshooting instructions.

10 Marking

A label, or labels, shall be affixed to each reflector, on a surface that does not significantly affect the radar reflector performance, indicating:

- the manufacturer;
- the mark or type number;
- the year of manufacture;
- the minimum reflector mounting height;
- the mass of the reflector;
- the compass safe distance, if applicable;
- the recommended orientation when installed;
- one of the following statements, as applicable
  - “For use up to ± 10° heel”, or
  - “For use up to ± 20° heel”;
- any approval marking (for example EU “wheelmark” or other approval mark) as appropriate.

Annex A
(normative)

Guidance notes for the installation of active radar reflectors

A.1 Introduction

These notes are intended to provide manufacturers with guidance when writing the relevant sections in their manuals.

A.2 Height

A.2.1 As a general rule, radar reflectors should be mounted as high as practicable on the vessel. If it is not practicable to achieve the mounting height given in Figure A.1, then 2 m ASL should be considered as the absolute minimum.

A.2.2 The stated performance levels (SPL) required in this International Standard have been derived using the assumption that a reflector with the required SPL would be mounted 4 m ASL. Figure A.1 shows how the required SPL rises as the mounting height falls.

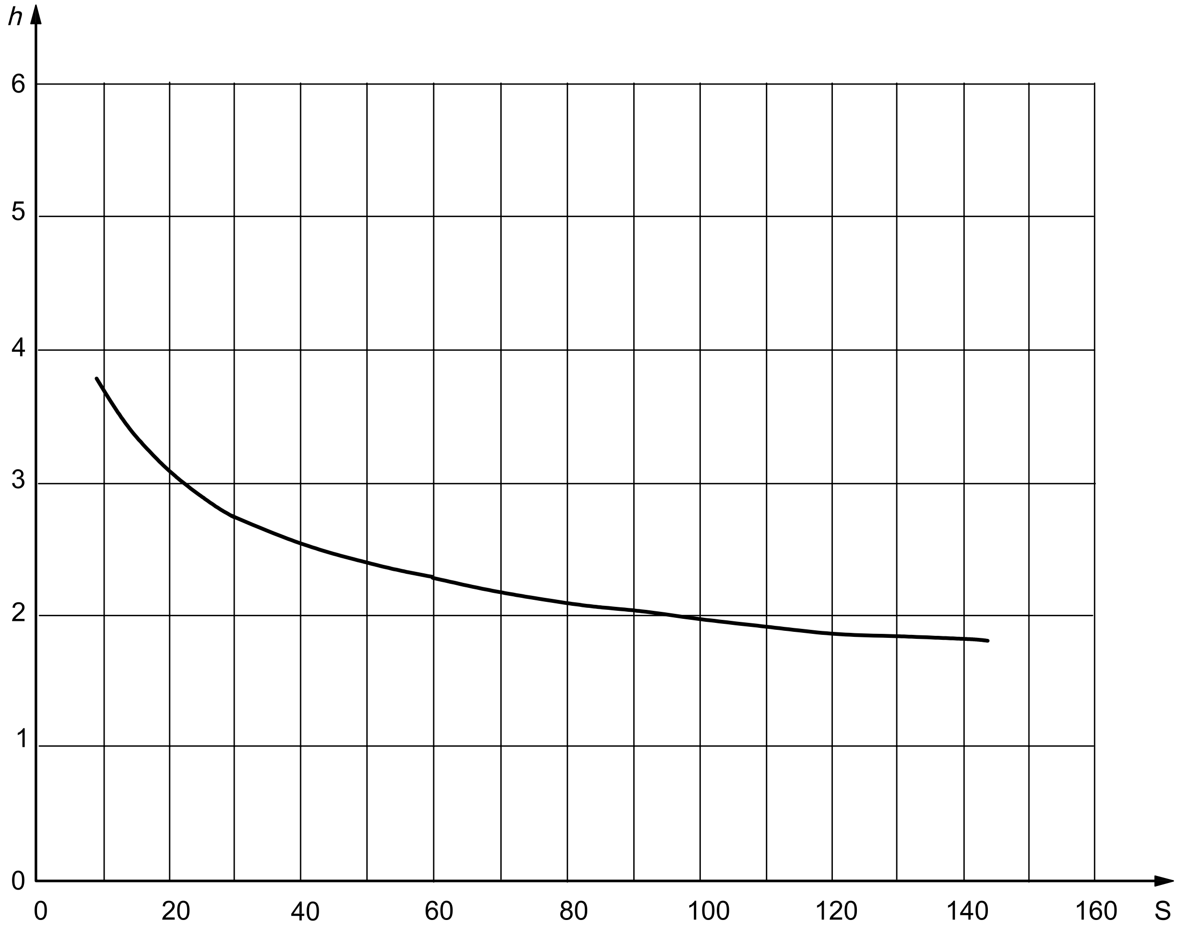
A.2.3 *It is considered that the maximum mass of reflector which should be mounted at 4* m *ASL is 5* kg*. If the reflector is to be mounted higher than 4* m *ASL, then the reflector should weigh less than 5* kg *so that the overturning moment is not increased beyond that of a 5* kg *mass at 4* m *ASL.* It is, however, the owner's responsibility to ensure that he or she does not adversely affect the stability of his or her vessel to an unacceptable degree.

A.2.4 If a reflector is to be mounted lower than 4 m ASL, then a reflector with an SPL greater than the minimum demanded in this specification should be considered. Figure A.1 shows the how the SPL required to give a 90 % probability of at least a 50 % paint to return ratio at a range of five nautical miles [9 260 m [4)]] varies with mounting height ASL.

A.3 Compass safe distance (CSD)

If the reflector is to be mounted less than 5 m from a magnetic compass used for steering, the user should check whether the CSD has been measured and noted on the reflector.

4) 1 nautical mile = 1 852 m (exactly).



Key

h reflector mounting height above sea level, expressed in m

S reflector stated performance level, X band at 0° elevation, expressed in m^2

Figure A.1 — Mounting height of reflectors

Annex B
(normative)

Test method for unwanted emissions of active radar reflectors

B.1 Introduction

An active radar reflector is a transmitter to be used in the radar band. If unwanted emissions occur, they can cause adjoining band disorders. Therefore, an active radar reflector's unwanted emissions shall meet the emission limits for primary radars stated below.

ITU-R has developed a recommendation for out-of-band (OOB) emission limits (ITU-R SM.1541).

This OOB recommendation is associated with the following recommendations:

— OOB emissions falling into an adjacent allocated band (ITU-R SM.1540);

— boundary between OOB and spurious emissions (ITU-R SM.1539);

— spurious emissions (ITU-R SM.329).

Spurious emission limits are given in Clause II of Appendix 3 of the Radio Regulations, together with the definition of the boundary between the OOB domain and the spurious domain. For radars, the Radio Regulations refer to the OOB recommendation for the definition of the boundary.

This annex contains extracts from the requirements of Appendix 3 of the Radio Regulations and the ITU Recommendations concerned with unwanted emissions for marine radars. It includes the requirements, the method of measurement, the result to be obtained and the interpretation of the results.

B.2 Requirements

The requirements are defined in the Radio Regulations, Appendix 3; related ITU-R recommendations are given in B.1.

The boundary between the OOB and spurious domains and the OOB mask are defined in ITU-R SM.1541, Annex 8 in the following manner;

a) (boundary and mask) — “the mask rolls off at 20 dB per decade from the 40 dB bandwidth to the spurious level specified in Appendix 3 of the Radio Regulations. The B_{-40} dB bandwidth can be offset from the frequency of maximum emission level, but the necessary bandwidth (1,152 of the Radio Regulations) should be contained completely within the allocated band”.

b) (exclusions) — “the OOB limits are not applicable inside exclusive radio-determination and/or Earth Exploration Satellite (EES) and Space research service bands, but do apply at the band edges.”

These requirements are given in Figures B.1 and B.2. The OOB masks shown in Figures B.1 and B.2 are calculated using the transmitted pulse width and rise (or fall) time.

The necessary bandwidth and the –40 dB bandwidth are generally centred about the operating frequency but may be offset to take account of spectrum asymmetry. The OOB mask commences at –40 dB bandwidth and falls off at the rate of –20 dB per decade until it meets the spurious emission limit at the OOB boundary.

When the –40 dB bandwidth falls outside the allocated band, the OOB mask commences at that point in the adjacent band.

The OOB mask can be offset further into the adjacent band to allow for spectrum asymmetries, but the necessary bandwidth associated with this mask shall be contained completely within the allocated band.

Emissions in the spurious domain (Figures B.1 and B.2) shall be at least 43 + 10 log peak envelope power (PEP) or 60 dB, whichever is the least stringent, below the carrier power, as measured in the far field of the radar. For most current marine radars the limit will be 60 dB, and this means that the spurious domain starts at $5 \times B_{-40}$ from the operating frequency of the radar.

B.3 Methods of measurement

The basic methods of measurement for unwanted emissions are contained in ITU-R M.1177. This describes two methods, referred to as the “direct” and “indirect” methods. Either method is admissible.

The reference layout of the “direct method” is given in Figure B.3.

The interrogating signal shall be executed by using a pulse width of 100 ns, as specified in the Radio Regulations, Appendix 3.

On the basis of the layout given in Figure B.3, the turntable shall be rotated and fixed at receiving max, receiving signal of measuring antenna.

The interrogating signal shall be adjusted to the saturation level of the EUT.

The receiving signal shall be measured by sweeping the frequencies of the measuring instrument from lower limit to upper limit frequencies, as specified in Table B.1.

Measurements are to be made for all frequencies in the measurement frequency bands specified in Table B.1.

Table B.1 — Measurement frequency ranges

Allocated band	Measurement band	
	lower limit	upper limit
2,9 GHz to 3,1 GHz	2 GHz	5^{th} harmonic
9,3 GHz to 9,5 GHz	0,7 of the waveguide cut-off	26 GHz

B.4 Required results

B.4.1 Necessary bandwidth

The necessary bandwidth as calculated from the measured pulse width, rise time and fall time shall be within the allocated frequency band.

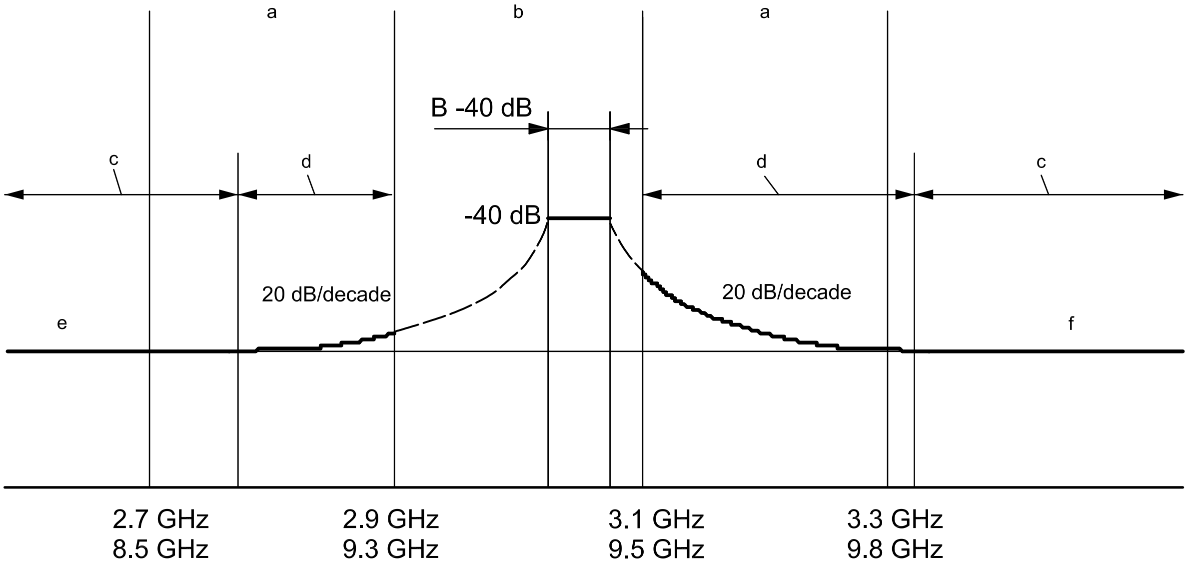
B.4.2 B_{-40} bandwidth

The B_{-40} bandwidth shall be calculated using the methods defined in ITU-R SM.1541, Annex 8. This bandwidth, together with the declared frequency of the pulse transmission, are used to determine which of the masks given in Figure B.1 or Figure B.2 shall be used for the purposes of conformity.

B.4.3 Emission spectrum

The emission spectrum shall be below the calculated mask, as determined by B.4.2, in both the OOB and spurious domains, for all appropriate frequencies over the ranges specified in Table B.1. The spurious emission limit applies in the spurious domain, regardless of frequency band.

For references relating to the emission spectrum, see the Bibliography items [3] to [7]. The latest versions of ITU-R Recommendations should be used.



a Adjacent radio-determination/Earth exploration satellite (RD/EES) band.

b Allocated band.

c Spurious domain.

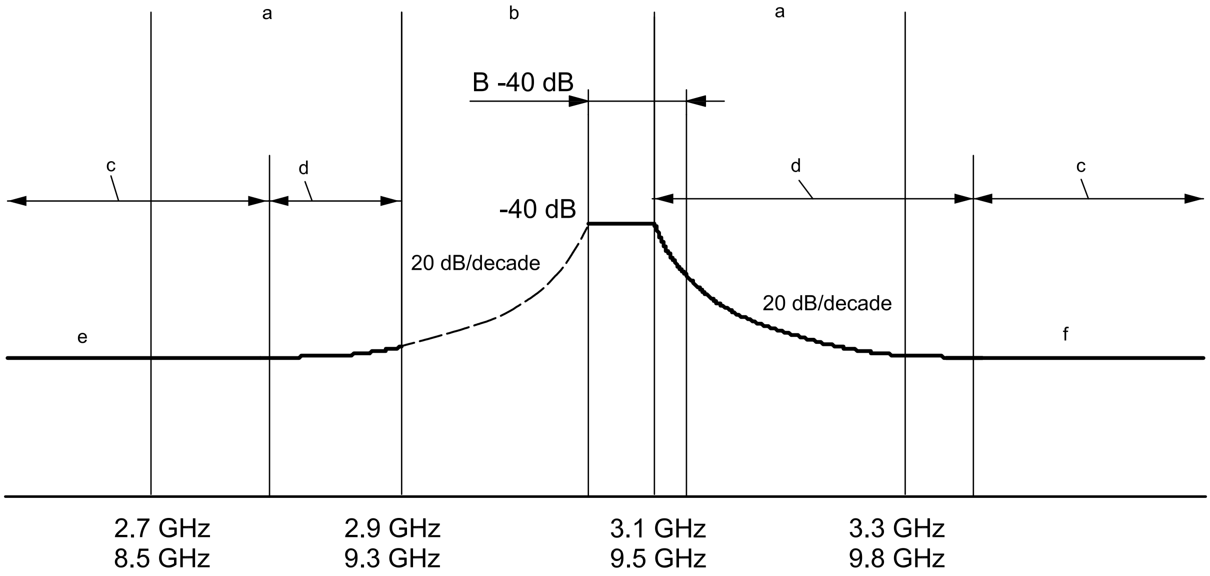
d Out-of-band (OOB) domain.

e Spurious emission limit.

f -60db or $-(43+10\log_{10}PEP)$.

NOTE OOB emission mask limits do not apply within the allocated or adjacent RD/EES bands.

Figure B.1 — B_{-40} falls within the allocated band



[a] Adjacent radio-determination/Earth exploration satellite (RD/EES) band.

[b] Allocated band.

[c] Spurious domain.

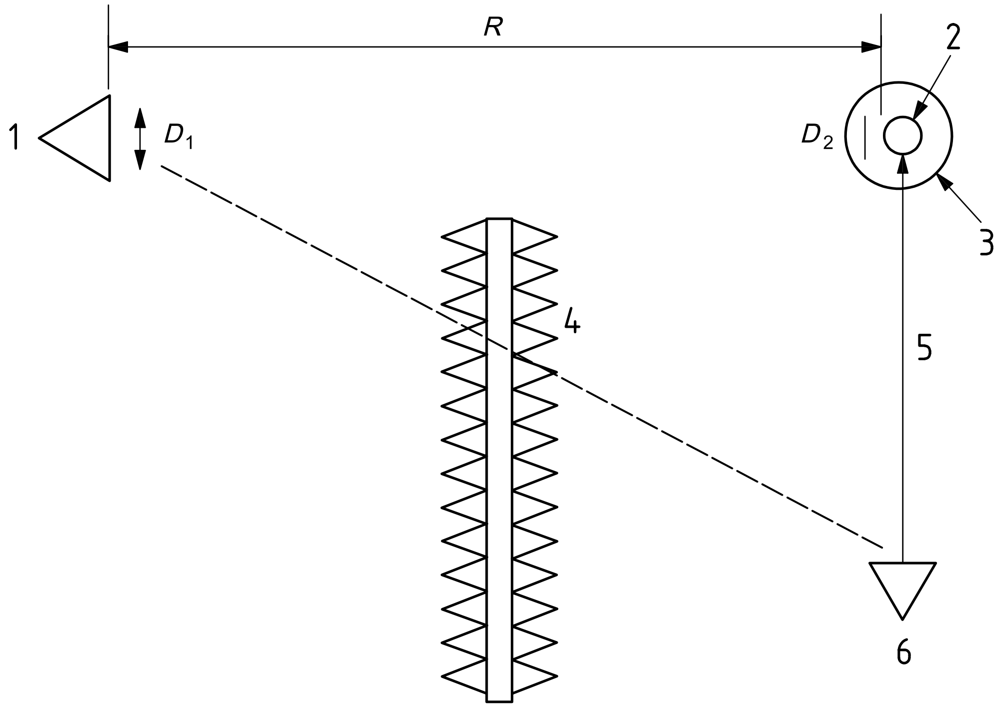
[d] Out-of-band (OOB) domain.

[e] Spurious emission limit.

[f] −60db or −(43+10log$_{10}$PEP).

NOTE OOB emission mask limits do not apply within the allocated or adjacent RD/EES bands.

Figure B.2 — B_{-40} falls outside the allocated band



Key

1 measurement antenna

2 equipment under test antenna

3 turntable

4 microwave absorber (for isolation)

5 interrogating signal

6 interrogating signal antenna

D_1 length of equipment under test antenna

D_2 length of interrogating signal antenna

R measurement distance

The measurement distance, R, is calculated as follows:

$R = 2(D_1+D_2)2/\lambda$

where λ is the wavelength of the interrogating signal.

Figure B.3 — Layout of the direct method

Bibliography

[1] IMO Resolution MSC.164(78), *Revised performance standards for radar reflectors*

[2] ITU-R M.1176, *Technical parameters of radar target enhancers*

[3] ITU-R M.1177, *Techniques for measurement of unwanted emissions of radar systems*

[4] ITU-R M.1313,*Technical characteristics of maritime radio navigation radars*

[5] ITU-R SM.1539, *Variation of the boundary between the out-of-band and spurious domains required for the application of Recommendations ITU-R SM.1541 and ITU-R SM.329*

[6] ITU-R SM.1540, *Unwanted emissions in the out-of-band domain falling into adjacent allocated bands*

[7] ITU-R — *Radio Regulations — Appendix 3: Spurious emissions*

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