IALA GUIDELINE

1???

ON RADAR REFLECTORS ON AIDS-TO-NAVIGATIONS

Edition 1.0

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DOCUMENT HISTORY

Revisions to this IALA Document are to be noted in the table prior to the issue of a revised document.

Date	Page / Section Revised	Requirement for Revision
03/2019	Initial document	
09/2020 and 10/2020	Further development of the document during ENG12	

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1 INTRODUCTION

Radar plays an important role in navigation of vessels. Radar is beside other means of navigation like AIS the most important technology for detecting the traffic situation around the own vessel with respect to landmarks, other vessels and aids to navigation (AtoN). Radar has the capability to detect objects even in poor visibility conditions like darkness, fog and with some restrictions also in heavy precipitation, snow or hail.

Especially when visual detection of objects by the captain is not possible (e.g. in foggy weather conditions), radar has to deliver reliable information to the skipper.

As a result, IMO came up with a performance standard for radar equipment, MSC.192(72), adopted in 2004. This standard defines radar detection ranges of typical objects like vessels of different sizes, shorelines and AtoNs under certain probabilities of detection, environment conditions and installation properties.

Big vessels, typically made of steel, are well suited to be detected by radar as metal is a good conductor for electrical currents and therefore reflects nearly all of the energy of an incident electromagnetic wave.

Other objects, especially when made of non-metal material like plastic, do not reflect the electromagnetic radar wave that good.

In addition, the geometry of an object as well as the roughness of its surface plays an important role in radar detection.

If an object like a AtoN cannot fulfil the requirements of IMO MSC,192(72), it shall be equipped with a radar reflector.

The equipping of an object with a radar reflector can increase the radar detection probability significantly.

Active and passive radar reflectors are available in many different sizes and shapes. They can be mounted on buoys, beacons, structures, vessels, etc.

This guideline has been developed to assist aids to navigation (AtoN) manufacturers and authorities when developing and selecting radar reflectors.

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According to the IMO Resolution Msc.192(79) (Adopted On 6 December 2004) Adoption Of The Revised Performance Standards For Radar Equipment, TABLE 2 “Minimum detection ranges in clutter-free conditions”, typical navigation buoys with a height of 3,5 m above sea level must be detectable in a range of 4.6 NM in the X-band and 3.0 NM in the S band. The typical navigation buoy is taken as 5.0 m2 for X-Band and 0.5 m2 for S-Band; for typical channel markers, with an RCS of 1.0 m2 (X-band) and 0.1 m2 (S-band) and height of 1 metre, a detection range of 2.0 and 1.0 NM respectively.

If these demands cannot be achieved by the buoys structure itself, the addition of a radar reflector is necessary.

It is not easy to determine the radar reflection behaviour of the buoy structure. The advantages of a radar reflector is, that it has a defined radar reflection characteristic.

Radar reflectors on structures……demand for it…

To enhance the visibility and the probability of detection using shipborne radar active or passive radar reflectors may be utilized. They can be mounted on buoys, beacons, structures, vessels etc.

A radar reflector is defined by IALA as a device specially arranged to have the property of reflecting incident electromagnetic energy parallel to the direction of incidence to enhance the radar response. Active radar reflectors are electronic devices, often referred to as radar target enhancers (RTE).

ISO: Passive radar reflectors are mechanical devices, which do not consist of any electrical devices that receive, amplify and return a radar signal.

This guideline only deals with passive radar reflectors. Shipborne radar reflectors are out of scope of this document. For more information look at:XXXXXXXXXXXXX IMO requires small vessels to have a radar reflector compliant with ISO 8729-1

RESOLUTION MSC.192(79) (adopted on 6 December 2004) ADOPTION OF THE REVISED PERFORMANCE STANDARDS FOR RADAR EQUIPMEN, TABLE 2 Minimum detection ranges in clutter-free conditions

Passive Radar reflectors are available in a wide variety of sizes, shapes and reflection characteristics.

2 SCOPE

Floating and fixed AtoN, especially fairway buoys and beacons, have been equipped with radar reflectors for a long time to safe and easy Radar navigation on waterways in coastal and inland areas.

A large number of different reflector types were developed for this purpose and used over the years. This guideline has been created to assist aids to navigation (AtoN) manufacturers and authorities when developing and selecting radar reflectors. It ……… describes properties and possible applications of different radar reflector.

It also contains remarks concerning …….

3 GENERAL INFORMATION

3.1 RADAR WAVE AND REFLECTION

In order to understand how radar reflectors work, it is essential to know about the propagation and the reflection of radar waves. A radar wave is an electromagnetic wave. It consists of an electric and a magnetic field. In free space, these two fields are perpendicular to each other. The propagation of the radar wave is perpendicular to both field vectors. In the medium air the radar wave propagates at the speed of light.

If the radar wave hits a metallic conductive object, the entire electromagnetic wave is reflected. Depending on the shape of the object on which the radar wave hits, the shape of the reflection is determined. In addition, a phase jump of 180 ° occurs in the electric field component.

If the object is electrically non-conductive and non-magnetic, a part of the energy penetrates the medium is on while the rest reflects at the boundary layer between both media will. Basically, a distinction is made between

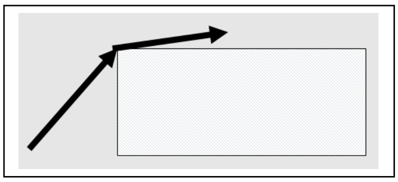
- directed reflection
- diffraction
- refraction and
- diffuse reflection.

3.1.1 DIRECTED REFLECTION

The radar principle is based on the retroreflection of the electromagnetic wave from objects. The strongest form of retroreflection is the "directed reflection", sometimes also called "mirror reflection". As described above, all or part of the energy of the wave is reflected back in a directed manner. Note the phase jump of 180° in the electric field component when the wave hits a metallic object.

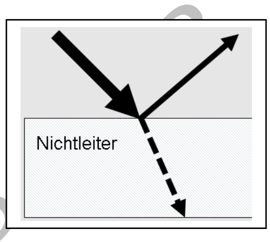
3.1.2 DIFFRACTION

Diffraction is formed on sharp edges, peaks or even on spherical surfaces ("circulating wave") and leads to the fact that radar waves can also get into "visual shadows" of objects. A part of the radar waves created by diffraction can also return to the radar antenna in certain cases.



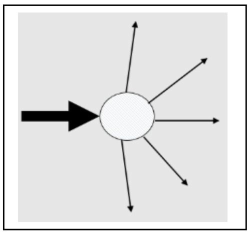
3.1.3 REFRACTION

Refraction usually occurs at the transition from a non-conducting, non-magnetic medium to another, non-electrically conducting, non-magnetic medium. In principle, as already mentioned above, the angle of incidence is equal to the angle of reflection. In addition, the wavelength and the propagation speed of the wave change when entering another material.



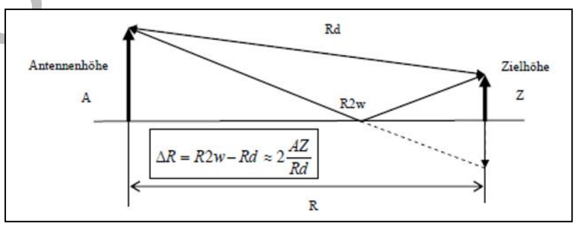
3.1.4 SCATTERING

Diffuse reflection is the reflection due to the roughness of the surface of an object. The rougher the surface, the larger the solid angle into which the energy is reflected. In the limit value case with roughness = 0, the "Diffuse Reflection" changes to the "Directed Reflection".



3.1.5 MULTIPATH PROPAGATION

When performing field measurements on reflection properties of objects, a special case must be considered. Normally the electromagnetic wave does not only propagate in a straight line from the radar antenna to the object (and back again on the same path), but a part of the energy is also reflected back towards the radar antenna via the "detour" via the reflection at the water surface, see figure XX



This causes the radar waves from the two spatial directions to overlap. In extreme cases, this multipath propagation can lead to an in-phase addition (+3 dB) or even to complete cancellation if the two waves are in opposite phases. This effect is most pronounced when the sea is calm and decreases as the sea state ("clutter") increases.

3.1.6 POLARIZATION OF ELECTROMAGNETIC WAVES

Put simply, the plane of polarization of an electromagnetic wave is the spatial plane in which the electric field component oscillates. A distinction is made between linear and circular polarization. The representatives of linear polarization include horizontal and vertical polarization.

4 RADAR REFLECTORS

4.1 REQUIREMENTS

Radar reflectors have the task of improving the visibility of objects in the radar image. Basically, there are three main requirements for a radar reflector:

- good azimuthal all-round visibility
- good visibility at the largest possible tilt angle and
- very good reflection properties in the relevant frequency range.

Depending on the application, a radar reflector must meet further requirements:

- corrosion resistance
- low weight
- low manufacturing costs
- protection against icing, - etc.

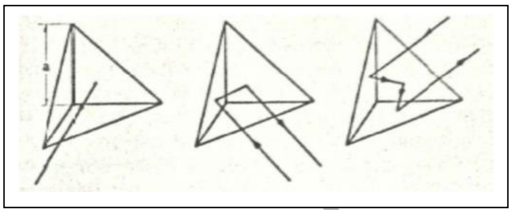
The reflectivity of an AtoN equipped with a radar reflector is essentially determined by three parameters

- reflector type (decisive for the reflection diagram)
- reflector size (decisive for the max. reflection cross section σ)
- reflector height (decisive in connection with the reflection cross section for the attainable range).

4.2 WORKING METHOD

Hier beim einfachen blech anfangen und bis zum Corner-Reflektor beschreiben.

Refection elements are: sheet, crossed plates, corner



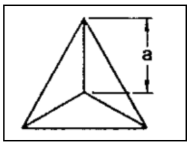
Usually a radar reflector has several metal surfaces arranged at a certain angle to each other, at which a "directed reflection" of the radar waves takes place.

Figure XXX shows the reflection principle using the example of a corner reflector.

The basic principle of a corner reflector is based on the triple mirror. This consists of three reflecting surfaces at an angle of 90 degrees to each other. This arrangement ensures that the incident radiation is returned almost exactly to the sender of the radiation. The reflection effect of these reflectors is physically determined by two factors: The wavelength of the radiation to be reflected and the length of the inner edges of the mirror arrangement. The reflection increases with increasing frequency and increasing edge length.

4.3 RCS

The reflective effect of a triple mirror is usually specified as one surface, whereby the projected or visible surface of a freely suspended sphere with the same reflection is taken as the reference scale.



Under the assumption of some simplifications, which are not described here in detail, the calculation of the reflecting area F is based on the following formula:

F = 4 x Pi x a^4 / ($Lambda^2$ x 3) with:

- Pi = 3.14

- a = inner edge length of the reflector in meters

- Lambda = wavelength of the radiation in meters (Lambda = c/f, f = frequency of the radar radiation, c = speed of light)

Here is an example: A radar reflector with an inner edge length of 42 cm achieves a reflection area of $128m^2$ at a radar frequency of 9.4 GHz (Lambda = 3.19 cm).

Target Enhancement by Radar Reflectors

It was recognised in the early days of radar that some targets (such as wooden boats or buoys) need some form of echo enhancement to ensure reliable detection at an adequate range. Passive radar reflectors are the simplest of the target enhancement techniques available today.

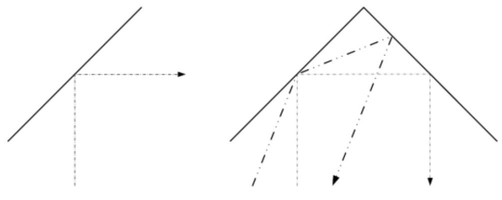


Figure 1: Reflection from a flat plate and a corner reflector

Figure 1 illustrates the basic principle used in the construction of most radar reflectors. Radio waves at the radar frequencies propagate and interact with surrounding objects much like light rays, large4 smooth conducting surfaces acting as 'mirrors'. When a conductive flat surface is viewed obliquely, the incoming radar rays are diverted away from the radar, the rays obeying Snell's law of reflection. If, however, a corner reflector is formed using two flat plates as shown in Figure 1, the rays are directed back to the radar, almost irrespective of the viewing angle. Note that the fact that an object is made of a conductive material does not necessarily mean that it constitutes a good radar target. From radar Figure 1: Reflection from a flat plate and a corner reflector. A simple dihedral corner reflector is adequate on non-floating objects. If the attitude of the target is changing as it moves in a seaway it is necessary to use a trihedral corner. The trihedral corner will ensure that the energy is returned even though the target is moving through a large angle in both the horizontal and vertical planes.

corner reflector: reflector, consisting of flat conducting surfaces intersecting mutually at right angles, that reflects the greater part of the incident waves parallel to their direction of incidence (ISO 8729)

4.4 REFLECTION CHARACTERISTIC OF RADAR REFLECTORS

True 360º coverage in the horizontal plane can be achieved by arranging several corner

reflectors into a cluster. The majority of radar reflectors used in the maritime field are corner clusters [RD2]. Various arrangements are used, typically made up of 5, 6, 8 or 10 corners,

4.5 DEPENDENCE OF THE REFLECTED SIGNAL ON THE RADAR FREQUENCY

The frequency of the radar in use has a marked effect on the amount of signal that is returned from a given sized reflector. Higher frequency or shorter wavelength radars produce much brighter returns. Fortunately, the majority of marine radars operate in the relatively high frequency X or 3 cm band.

4.6 DEFINITION OF RADAR CROSS SECTION (RCS)

BARTON 1 , "Measure of the reflective strength of a target". The E. W. Handbook of U.S. Navy defines, "A measure of the radar reflection characteristics of a target. It is equal to the power reflected back to the radar divided by power density of the wave striking the target. For most targets, the radar cross section is the area of the cross section of the sphere that would reflect the same energy back to the radar if the sphere were substituted. RCS of sphere is independent of frequency if operating in the far field region".

SKOLNIK 2 provides the following short and concise definition, "The radar cross section of a target is the (fictional) area intercepting that amount of power which, when scattered equally in all directions, produces an echo at the radar equal to that from the target".

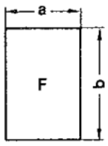
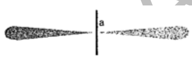
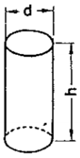
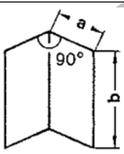
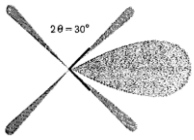
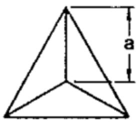
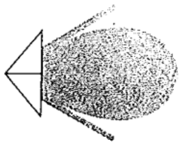
A worldwide standard has been set for making meaningful comparisons of various reflective surfaces: the "effective radar cross-section". This value is useful in stating a "figure of merit" for the performance of radar reflectors. A reflector's performance, the amount of signal that it will reflect, is stated in terms of the diameter of a metal sphere which would produce an equivalent radar response.

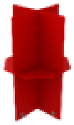
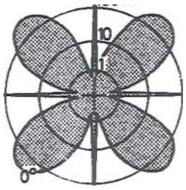
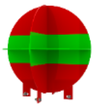
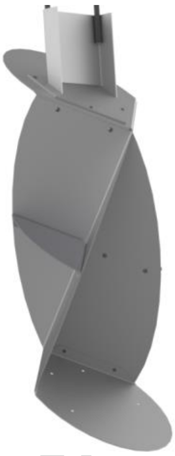
5 TYPICAL DESIGNS

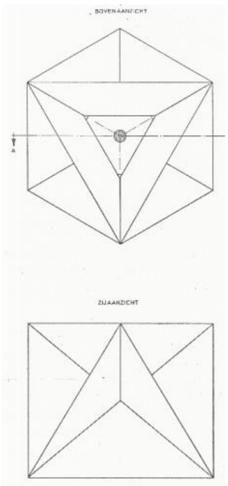
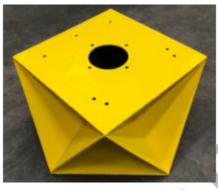
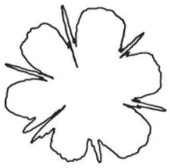
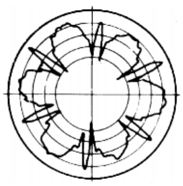
A good radar reflector has a high reflection cross section, a nearly closed reflection pattern and a high mechanical strength.

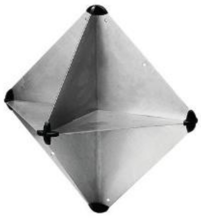
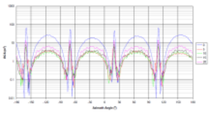
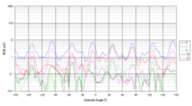
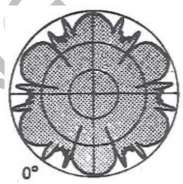
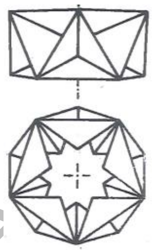
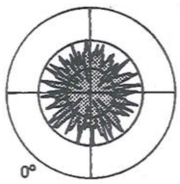
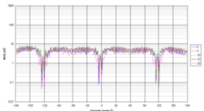
Each of the configurations having somewhat different RCS characteristics. However, the reflector is a passive device, and as such, only returns as much energy as is incident on it. As will be shown later, the maximum RCS of a reflector is proportionate to the square of its effective area, or the fourth power of its side length - so with reflectors size matters. Combination of reflection elements to a radar reflector generate different reflection characteristics.

The following table gives an overview of different radar reflectors and their properties.

name / origin	picture	dimensions	reflection diagram	Max RCS	Purpose
sheet		Width: a Height: b			
cylinder		Ø: d Height: h			
bent sheet metal, 90°		Length: a Width: a Height: b			
Corner reflector		Length: Root2*a Width: a Height: b			
Corner reflector (German administration)					for direct angles of approach (bridges, fixed structures)

Octaheathral reflector, cylindric, (German administration)		Ø: 350mm Height: 600mm		4	for limited angles of approach (buildings , buoys with direction)
Octaheathral reflector, triangle, (German administration)		Ø: 350mm Height: 700mm			
Octaheathral reflector, spherical , (German administration)		Ø: 500mm			
2 corner		Ø: 250mm Height: 700mm		16	Inland waterways, directional
					Bridges, fixed structures

Dutch 6 corner reflector		Ø: Height:			Buoys, bridges, locks, ships
Dutch 8 corner reflector					
english 8 sided reflector Firdell	 	Ø: 575mm / 405 Height: 342 /		20	buoys
12.5" octahedral reflector, commercial (Davis Echomaster)		Ø: 320mm		$12m^2$	

16” octahedral reflector, commercial (Plastimo)		Length: 300mm Width: 300mm Height: 415mm		16	Leisure boats, sailing yacht
tube-type radar reflector, commercial (Plastimo)		Length: 590mm Ø: 100mm		9 m²	
German speckter SR6		Ø: 300mm 390mm 480mm 600mm 900mm		5 14 33 81 411	buoys
10 corner cluster					
Viking Large Tri-Lens		160 x 160 x 80mm		9m²	

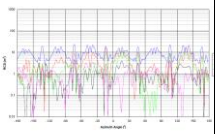
Echomax 230		610 (L) x 248mm (D)		24	

Table....

ISO 8729: 5.2 Reflecting pattern in horizontal plane

5.2.1 *The radar reflector* shall *have a Stated Performance Level of at least 7,5 m2 at X-Band and 0,5 m2 at S-band. The SPL* shall *be maintained over a total angle of at least 280°.* The response shall, at the assessed level for each polar plot:

not have any nulls greater 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.

ALIGN THE FOLLOWING TO BUOYS, see also IALA G1065 (light):

NOTE Typical azimuthal polar diagrams for passive radar reflector at X-band are given in Figures B.1 and B.2.

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.

6 DETECTION RANGE OF RADAR REFLECTORS

6.1 MAXIMUM RANGE UNDER IDEAL CONDITIONS

- Function of radar antenna height, mounting height of the radar reflector, RCS. (Polarization…)
-

6.2 REFLECTOR HEIGHT

- Speckter paper 4.2.3: The final parameter to be considered is the reflector height above sea level. As is well known from visual target detection at long ranges, the target and/or observer heights have to be- increased with increasing range due to the curvature. The range in nautical miles of the optical horizon is given by the formula: R(opt) =2.1 (vHt + .flo) ' :o~ ,-,,_-' "vlhere Ht = target height and • _ ;. __ 0-. _~_p~ = observer height, both in meters This, formula can also be used for a rough estimation of the radar horizon. - The observer and target heights have to be substituted by_. t...h --e- -_r.e_f--lector and antenna heights respectively. It should be noted that this formula results in values for the radar range that are too optimistic under normal atmospheric conditions. For a conservative range estimation only 60 to 90% of the optical range should be used. Rradai> % 0, 6 •• , O. 9 Rapt 1 - '~-;.'.'=-This~considerable reduction in range is caused by the strong interference-effect of the inultipath propagation across the sea:. Under the assumption of a ship I s antenna height between 10 and 20 m, the reflector heights necessary to obtain specified ranges have-been-listed in Table 2. Again, these figures apply to X-band radar only. S-band radars are far less capable of detecting targets near the water surface owing to their longer wave .length. This fact has one important advantage, but at the same time it also has an important disadvantage. The waves of a rough .. sea cause less sea clutter but, on the other hand, the reflector height has to be increased by a factor of 2 to 3 for an equal -probability of detection. Such a substantial increase in -'--reflector-height cannot be implemented. in most cases, especially. when:' small targets like buoys are involved
-
- RESOLUTION MSC.164(78) (adopted on 17May 2004) REVISED PERFORMANCE STANDARDS FOR RADAR REFLECTORS: The radar reflector should have a "Stated Performance Level" measured in square metres radar cross section (m2 RCS) of at least 7.5 m2 in X-band and 0.5 m2 in S-band mounted at a minimum height of 4 m above water level.

The reflection characteristic, i.e. the spatial distribution of the RCS values has to be considered.

Examples of variation of diameter, height, range (ship antenna height assumed to be between 10 and 20 m)

X-band radars (wavelength = 3,2 cm), for S-band radars (wavelength = 10 cm) the RCS drops by a factor of 10.

S-band, reduction in RCS, propagation in s-band, requirements by IMO (MARIO)

RCS max. (m^2)	Typical diameter of the reflector (m)	Height of radar reflector above sea level (m)	Range max. (m)
400	1	3.5 - 4	7
30	0.5	2	4
?			
?			
?			

7 PARAMETERS THAT AFFECT THE RANGE OF RADAR REFLECTORS

7.1 TILT / HEEL ANGLE

The tilt angle is a key element to the performance and should be factored in to the design as this is essential when considering static testing. This will deliver an impression of the dynamic performance.

7.2 SEASTATE/IMPACT OF WEATHER

The impact of sea state is important in the effectiveness of the radar reflector as it can be related to the design and size of the buoy and it relative dynamic performance.

7.3 MULTIPATH

7.4 TOLERANCE REQUIREMENTS / MANUFACTURING ACCURACY

As with all types of cluster reflectors the individual reflecting elements (i.e. the corner reflectors) have to be manufactured to close tolerances, otherwise the reflected wave will diverge from the exact direction back to the illuminating radar. For best results all three plates of each corner reflector must be perfectly flat, and the corner angles must be exactly at right angles. In a production process some deviations are unavoidable and result in certain loss of performance. Unfortunately, the allowable rectangular tolerance and deviations from perfect flatness become smaller as the size of the reflector gets larger. The following angular tolerances should not be exceeded:

reflector diameter	maximum angular tolerance
0,5m	± 1 to 2°
1m	± 0.5 to 1°

reflector diameter	maximum flatness tolerance
0,5m	± XXXXX mm
1m	± XXXXX mm

Even under these conditions a noticeable loss of performance can occur if all tolerances of a corner reflector accumulate (all tolerances of the same sign).

The quality of the mechanical finish is important to the quality of the response from the radar reflector as variation will degrade the effectiveness of the radar reflector.

7.5 SURFACE FINISH

In a marine environment most metals require a surface protection against corrosion. Thin layers' of paint which are directly applied for this purpose to the reflecting surface do not degrade the performance of the radar reflector.

This situation is entirely different if a protective cover is applied. A serious loss in performance occurs if the cover is not properly designed. Important design parameters of the cover are the material and its wall thickness with respect to the frequency band used.

7.6 SHADOWING OF THE RADAR REFLECTOR

If only one plate of a corner reflector is substantially masked by an obstacle, the total corner reflector is rendered ineffective (the radar wave "bounces" three times, once on each plate of the corner reflector, before returning back to the radar). Therefore care should be taken that constructional elements that are mounted in front of the reflector do not cause a serious degradation of the performance. The projected area of these elements should be small compared with the Size of corner reflector.

7.7 IMPACT OF PLASTIC

Impact has only a small detriment to the performance of about ??% This is based upon the measurement

Insert example for German measurement

7.8 IMPACT OF FREQUENCIES

7.9 NT RADAR

8 CONSTRUCTION

From ISO 8729:1

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 and capable of withstanding the environmental conditions specified in 5.3

9 MOUNTING

From ISO 8729:1

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. Manufacturers shall ensure that the method of mounting is adequately described in the manual. Manufacturers shall ensure that the fixing arrangements of the reflector correspond with those described in the manual and are sufficient to mount the reflector in the orientations specified therein

10 TRIALS

Field trials

Examples from at sea trials to be provided.

11 MEASUREMENT

11.1 CONCEPT FOR THE MEASUREMENT OF THE RADAR REFLECTION PROPERTIES

The measurement of radar reflectors should be based on ISO 8729-1 which concerns passive reflectors and gives specifications for the construction, performance, testing, inspection and installation of them. The measuring methods and requirements for the measuring chamber are described in chapter 6.4 of ISO 8729-1.

The reflective performance tests can be conducted in a free-field environment or a fully anechoic chamber. Typically the fully anechoic microwave test chamber is used for carrying out the measurements. Before use, the reflector test range shall be calibrated using a precision sphere of known RCS. 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. The radar reflector shall have a minimum SPL of 7,5 m2 at X-band and 0,5 m2 at S-band.

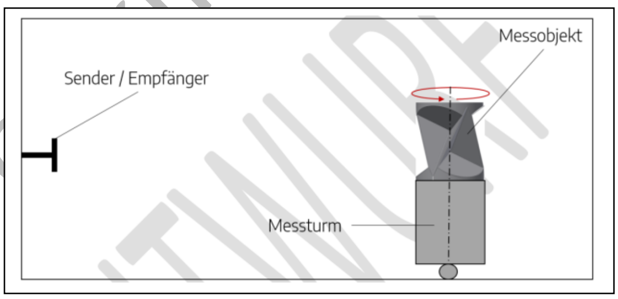
Based on the demands of the ISO 8729-1 a typical test concept could be:

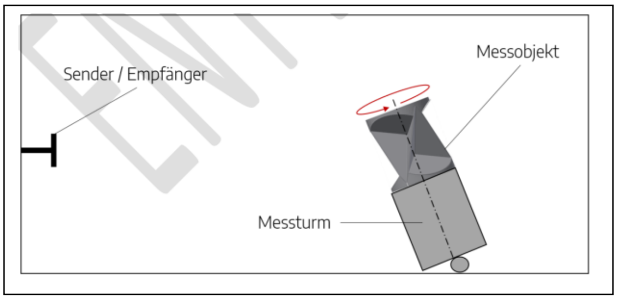
Messparameter	Wert
Messfrequenz	9,410 GHz (X-Band) und 3,050 GHz (S-Band)
Polarisation	Horizontal (HH)
Rotationswinkel	Je 360° (±180°)
Winkelauflösung (Rotation)	0,5°
Neigungs-/Elevationswinkel (nach vorne)	0°, 10°, 20°, 30°

Devices which may have to be provided for realizing the inclinations of the measured objects shall be shielded with appropriate absorbers or shall be made of materials which do not influence the radar reflection characteristics.

11.2 EXAMPLE FOR MEASUREMENT OF A SR6 REFLECTOR

The radar reflectors are mounted on a measuring tower and are measured at 4 different elevation angles (0°, 10°, 20° and 30°). The different elevation angles are realized by tilting the measuring tower forward. At each elevation angle the radar reflectors shall be rotated 360° (around their own vertical axis/tilting tower axis).





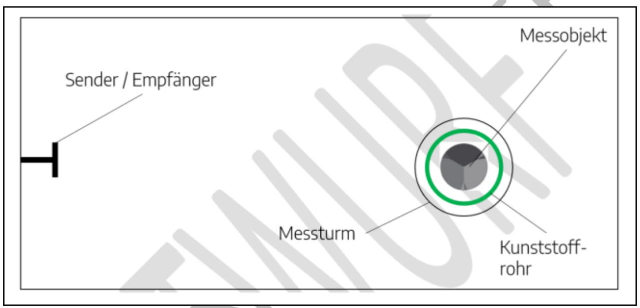
Results:

The difference of Azimuth over Elevation and Elevation over Azimuth responses increases from Elevation zero to ±30°.

11.3 INFLUENCE OF PLASTIC BY INSTALLING THE RADAR REFLECTOR IN A PLASTIC BUOY

11.3.1 MEASUREMENT

In order to find out the impact on the radar reflection characteristics by the installation of a radar reflector in a plastic buoy, the same measurements as in section 11.2 were carried out. The radar reflector was placed in a plastic tube which simulates the buoy body. The plastic tube was made of the same material as the plastic buoy and had the same wall thickness (Clariant Remafin, outer diameter = 400 mm, wall thickness = 12 mm).



The result was, that the transparency of the plastic is good. According to this, the installation of the radar reflector in the plastic buoy under the given conditions (material, paint and wall thickness) is not critical.

11.3.2 VERIFICATION ON SITE

?????

12 SIMULATION

Theoretical predictions are possible with discrepancies between measured and calculations due to mechanical imperfections.

13 GOODS IN INSPECTION ????

14 MAINTENANCE (WITHIN SCOPE??)

14.1 MAINTENANCE FOR OUTSIDE MOUNTED RADAR REFLECTORS

- Cleaning
- Visual inspection: angles, corrosion, rectangularity, mechanical damage
- Renew the coating….Link to maintenance guideline 1077

14.2 MAINTENANCE FOR COVERED RADAR REFLECTORS

- No maintenance required or possible

15 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 and capable of withstanding the environmental conditions.
- Radar reflectors consisting from good electric conductivity materials such as metal. In practice aluminium and steel/stainless steel are typically used.
- Even a very thin layer of metal can make an object strongly radar reflective.
- Usually corner clusters are manufactured from plates of steel or aluminium. But any other material of high electrical conductivity can be employed as well. From a radar point of view only a thin metallic layer is required for a perfect reflection. Thus, a plastic material like GRP with a metallized surface or with a metallized nylon mesh embedded in it yields has similar good results.
-

16 SURFACE PROTECTION

17 GEOMETRY:

18 EFFECT OF THE MANUFACTURING QUALITY, RECTANGULARITY

19 EFFECT OF THE MATERIAL:

20 ENVIRONMENTAL REQUIREMENTS (ISO 8729)

The radar reflector shall comply with all requirements for

– dry heat,

– low temperature,

– vibration,

– rain and spray,

– solar radiation,

– corrosion, and

– compass safe distance

specified in IEC 60945.

21 ACRONYMS

IMO International Maritime Organization (Acronym style)

22 REFERENCES

[1] Abcd

[2] Efgh

ANNEX A EXAMPLE OF AN ANNEX - LANDSCAPE