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EXPERIMENTAL VERIFICATION OF THE NEW IMO RECOMMENDATIONS FOR DETECTION POSSIBILITIES OF SHIP'S RADAR EQUIPMENT

ABSTRACT

Paper presents results of experimental verification of the new IMO performance standards for radar detection possibilities conducted for small sailing vessels using different shipboard navigational radars installed in radar laboratory of Maritime Academy in Gdynia and on ships in 2004 and 2005.

Keywords:
radar, safety.

INTRODUCTION

Proposed revised performance standards for ship radar equipment, accepted later by the Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) in the form of resolution had been presented in two papers during the previous XIVth International Scientific and Technical Conference 'The Role of Navigation in Support of Human Activity on the Sea' in 2004 [1, 2]. There was stressed that one of basic and more difficult questions was definition of recommended minimal radar detection possibilities, mainly for small objects described in table 1 [3].

The IMO Correspondence Group on Radar and members of the Technical Working Group of the IMO Sub-Committee on Safety of Navigation did not define any recommendation for radar detection possibilities in real propagation conditions. They agreed only that performance limitations caused by typical precipitation and sea clutter conditions will result in a reduction of target detection capabilities relative to those defined in table 1. Degradation of detection performance at various ranges and target speeds under the following conditions should be clearly stated in the radar user manual [2]:

- Light rain (4 mm per hour) and heavy rain (16 mm per hour);
- Sea state 2 and sea state 5;
- Combinations of above mentioned conditions.

Additionally it was marked that determination of performance in clutter and specifically range of first detection in the clutter environment, should be tested and assessed against a benchmark target, as specified in the Test Standard.

Table 1. Minimum detection ranges in clutter-free conditions

Reflected object		Detection Range [NM]	
Target description	Height above sea level [m]	X Band	S Band
Small vessel with Radar Reflector meeting IMO Performance Standards[1]	4.0	5.0	3.7
Navigation buoy with corner reflector[2]	3.5	4.9	3.6
Typical Navigation buoy[3]	3.5	4.6	3.0
Small vessel of length 10 m with no radar reflector[4]	2.0	3.4	3.0

Notices:

1. IMO revised performance standards for radar reflectors – Radar Cross Section (RCS) 7.5 m^2 for X band and 0.5 m^2 for S band.
2. The corner reflector (used for measurement), is taken as 10 m^2 for X band and 1.0 m^2 for S band.
3. The typical navigation buoy is taken as 5.0 m^2 for X band and 0.5 m^2 for S band.
4. RCS for 10 m small vessel taken as 2.5 m^2 for X band and 0.25 m^2 for S band.

Due to the above mentioned reasons measurements of the detection distances of small surface objects by contemporaneous ship radar equipment in real weather conditions were conducted in the Department of the Technical Aids to Navigation of the Maritime University in Gdynia and on ships.

SEA MEASUREMENTS IN THE GULF OF GDANSK

Sea trials were conducted in the area of the Gulf of Gdansk and on ships in order to define radar detection and tracking possibilities of small vessels. In the area of the Gulf of Gdansk were realized measurements using two small sailing yachts:

– 'Almak' (9.1 m long with one aluminium mast 11 m high and polyester hull);
– 'Polski Len' – sister vessel to the lost yacht 'Bieszczady' (14 m long with two aluminium masts 15 m high and wooden hull).

Yachts were observed using four different radars installed in the radar laboratory of the Maritime University in Gdynia and another one placed on vessel 'Tukana' owned by the Maritime Office in Gdynia. Scanners of these radars were

installed at the heights of 22 – 23 m above sea level (in the laboratory) and 6.5 m above sea level (on ship). In all cases radars experimental verification of the new IMO recommendations for detection possibilities of ship's radar equipment were maintained and observation performed by experienced personnel (instructors on radar and ARPA courses).

During the trials radar observers knew the approximate position of investigated object and had only to keep radar observation of this one target. Due to that received results may be considered as maximum values of detection distances. For ships' masters and watchkeeping officers conducting routine radar observation during the watch detection distances may be, and even should be, smaller. Yachts were sailing initially without radar corners, later fitted with standard trihedral reflector with 8 corners and length of legs equal to 0.21 m. Reflector was hoisted on the signal halyard below the topmast spreader and its radar cross section (RCS) was 10 m^2. It was only one passive radar reflector approved by Polish Register of Shipping for small sea crafts available at that time on Polish market.

For observations were utilized two radars working in X band with similar parameters of their transceivers. In all measurements older radar – Racal Decca AC 1690 showed echoes from yachts from bigger distances than newer and more modern radar Raytheon Pathfinder MK2. One of reasons of this may be different software, mainly extractor programmes installed in these two radars. Additionally there were used two radars working in the S band: Decca AC 1690 and JRC JAS25.

Weather conditions during two days sea trials were following: wind ENE to SE 2-3m/s and SSE to WNW 3.8 – 8.4 m/s, sea waves with height up to 0.5 m not generating clutters on radar screens in the positions of investigated yachts (distances from scanner positions bigger than 4 nautical miles, initially foggy, later good visibility, sunny and partly cloudy weather. Mean values of measured radar detection distances are presented in table 2.

Table 2. Mean values of measured radar detection distances

Object observed on radar	Detection distances [NM]		
	Radars in the Maritime University		Radar on ship 'Tukana'
	X band	S band	
Yacht 'Almac' without radar corner	5.5	5.6	4.5 – 4.75
Yacht 'Almac' with radar corner approved by PRS	7.0	7.4 – 7.8	4.75
Yacht 'Len Polski' without radar corner	9.4	9.6	5.5
Yacht 'Len Polski' with radar corner approved by PRS	9.4	10	9.9

Radar detection possibility of small objects like yachts depends on the transmitter peak power and antenna one-way power gain and height of its installation. Watchkeeping officers on bigger ships with radars with stronger transmitters and longer scanners located higher above sea level may detect small objects at bigger distances than radar observers on yachts, fishing boats and other small vessels. Alteration of the pulse length influences on the radar visibility of weak echoes from small objects and possibility of their detection very slightly. Decreasing of the radar range will increase possibility of the optical detection of analyzed echoes on radar screens. Experienced radar observer may detect visually weak fluctuating echo visible on the radar screen seldom. This echo will be not automatically acquired and tracked by automatic radar plotting aids (ARPA) and automatic tracking aids (ATA) until it will be not automatically detected in more continuous manner (as minimum during five from ten consecutive scans). Conducted experiment proved that difference between distances of the first visual detection and continuous detection might reach 20 – 40% of the first value.

VERIFICATION OF THE RECEIVED RESULTS

During described measurements were observed losses of echoes from yachts at small distances from the position of radar scanners. There were even situations when in so favorable weather conditions yacht visible visually by observer at sea was not detected by him on radar screen. Due to that observations were continued during the sailing boat race in the Gulf of Gdansk and on ships in different sea areas and weather conditions. During the boat race were observed sailing yachts of different classes on the same already described radars installed in the radar laboratory of the Maritime University in Gdynia and on radar equipment places on yachts. There were received results compatible with these presented in table 2. Some difficulties were noted in detection of radar echoes from small objects inside area of sea clutters. For sea waves up to 0.5 m, even echoes from big sailing yachts participating in the race, were not detected on radar screen at distances smaller than 1 nautical mile. Switching on of long echoes trails made much easier visual detection of radar echoes from small objects inside are of sea clutters.

Additional researches were conducted on sailing vessel ‘Dar Młodzieży’ and on a big tanker ship. Radars Pathfinders delivered by Raytheon were utilized on both vessels. Their scanners were placed on the height of 17 m above sea level (school ship) and on the height, depending on loading condition, between 20 and 30 m above sea level (tanker ship). On the basis of radar observations conducted on these ships

in different sea areas, for different weather conditions and with different small objects (sailing yachts, motor boats, fishing vessels and buoys) was made conclusion that radars working in X and S radio bands detect small objects for sea states up to 4 – 5 in more or less the same manner. S band radar is more useful for detection and observation of this kind of objects during higher sea states only.

Generally, modern ship radars detect small sea objects described in this paper from the distances of about 10 nautical miles. For lower sea states difficulties in radar observation arise for distances between radar scanner and observed object smaller than 2 – 3 nautical miles. For higher sea states these difficulties arise earlier at distances 4 – 6 nautical miles or bigger.

CONCLUSIONS

Following conclusions may be expressed on the basis of conducted radar measurements and observations:

1. According to the theory of radio wave propagation, radar scanner installed on bigger height above sea level enables earlier detection of small objects and increases level of sea clutters impeding or making even impossible detection of echoes from these objects at small distances from scanner position.
2. Even very small objects on the sea surface may be detected by ship radar, but only at small distances from the scanner position (1.0 – 1.5 nautical mile) and when they are outside area of sea clutters.
3. Modern ship radars detect sailing yachts at distances equal to 8 – 12 nautical miles. Initially they are shown as weak fluctuating echoes difficult to detect and identify. As steady repeatable echoes they are shown at distances from scanner position normally equal to about 4 – 6 nautical miles. At moderate sea and at smaller distances equal approximately to 2 – 3 nautical miles, sea clutters mask these echoes. It means that radar experimental verification of the new IMO recommendations for detection possibilities of ship's radar equipment observation of these objects is possible during short period of time when they are at distances 2 – 4 nautical miles from radar scanner (own ship) position only.
4. Installation of passive radar reflector on small vessel improves possibility of its detection by ship radar to a certain degree only and does not impact on this possibility in crucial manner.
5. Radars working in both radio bands (X and S) are approximately useful in the same degree for detection of small sea objects; their usability depends mainly on their technical condition and height of scanner installation.

6. It should be stressed that distance of the first visual detection of echoes from small objects on radar screen is defined subjectively by radar observer and depends on many factors like conditions of observation, level of observer's fatigue, etc.
7. Conducted measurements showed that modern ship radars make possible to detect small sea surface objects from distances bigger than distances recommended by performance standards adopted by the International Maritime Organization (IMO) and required by technical standards of the International Electrotechnical Commission (IEC). Unfortunately these recommendations and standards do not define minimal radar detection possibilities in clutter conditions mainly at small distances from scanner position.

Additionally it should be marked that accuracy of CPA (Closest Point of Approach), TCPA (Time to Closest Point of Approach), true course and true speed calculations performed by automatic radar plotting aids (ARPA) and automatic tracking aids (ATA) for objects with small values of relative speed (relative speed less than 3 knots) is limited in considerable degree.

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