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Verification of the accuracy requirements for relative course and closest point of approach

Wiesław Juszkiewicz

Maritime University of Szczecin
1–2 Wały Chrobrego St., 70-500 Szczecin, Poland, e-mail: w.juszkiewicz@am.szczecin.pl

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Abstract

Closest point of approach (CPA) is a basic factor taken into consideration for risk assessment during the meeting of two ships at sea. Navigators should use radars with automatic target tracking for collision avoidance and should know the accuracy to which radar data are calculated. Basic information about these requirements can be found in IMO resolutions. The currently binding document for devices manufactured after 2008 is IMO Resolution MSC.192(79). But there are two independent requirements for relative motion. One of these refers to relative motion parameters (relative course and speed) and the other one to the value that is the result of this motion (CPA). The other important document is Standard 62388. This specifies the minimum operational and performance requirements, methods of testing and the required test results published by IEC and also refers to radar equipment. However, this standard is not so popular in different publications focusing on radar equipment, so these requirements were not analyzed in the article. The main problem described in this paper refers to the mutual consistency of IMO Resolution requirements. The results of simulations and their analysis are presented.

Introduction

Every year, the equipment used on the bridge gives more possibilities to obtain more accurate and detailed navigational and anti-collision information. But radar (also according to the International Regulations for Preventing Collisions at Sea 1972: COLREG) is still one of the main pieces of technical equipment used by navigators during the watch. So, for the safety of navigation, it is very important to know how accurate the obtained tracked target data are. This is especially important if radar is the main source of observation during restricted visibility. Navigators should know the exact accuracy of the CPA (the closest point of approach) values calculated for tracked targets. These are always the main factors that navigators take into consideration for situation assessment and during anti-collision maneuver calculations (Bole, Dineley & Wall, 2007; Chrzanowski et al., 2010; Stateczny, 2011).

The main recommendation of performance standards for radar equipment is actually contained in IMO Resolution MSC.192(79). These requirements changed in 2008. The main change was an improvement of the CPA accuracy calculation requirements. But the second part of the requirements refers to relative target course, which is obviously connected with CPA value. These demands were changed slightly. So there is a question: How do these requirements correspond to one another? Other doubts arise during situation assessment. Is it possible to fulfill all tracking accuracy requirements in every situation? It should be taken into consideration that tracking has to be provided within 12 NM around the navigating ship. In actual performance, there are no scenarios described for testing tracking accuracy. (Four testing scenarios were described in IMO Resolution A.823(19).) So, should these requirements be fulfilled in every situation?

Some chosen problems of radar performance and tracking accuracy are presented in this article. The discussion about performance standards coherence could lead to knowledge improvement about radar limitations and performance revisions or, more specifically, to explanation necessity. It should be taken in consideration that values of CPA and relative course may be calculated in radar equipment in a different manner, using different algorithms and formulas for CPA on the basis of relative course, relative course on the basis of CPA or independently. For this paper, the first way of CPA calculation was analyzed, and the results of computation were compared with IMO performance.

The IMO performance standards analysis

The revised recommendations on performance standards for radar equipment are contained in IMO Resolution MSC.192(79). The tracking accuracy requirements are described in section 5.25 concerning the tracking and acquisition problems. The main demands are:

- the distance of automatic tracking should cover at least a 12 NM range;
- the automatic tracking accuracy should be reached at a steady target motion;
- the target motion trend should be pointed within 1 min of tracking, and a target's movement should be predicted within 3 min for each acquired target (these time periods are also used at describing tracking accuracy);
- the automatic tracking should show the target motion trend (for ships at true speeds under 30 kn) after 1 min of tracking, and after 3 min should show the predicted target motion at the accuracy described in Table 1.

Table 1. Tracked Target Accuracy (95% probability figures; Resolution MSC.192(79), 2004, MSC 79/23 Add. 2 Annex 34)

Time of steady state	Relative Course	Relative Speed	CPA	Time to CPA	True Course	True Speed
[min]	[deg]	[kn]	[NM]	[min]	[deg]	[kn]
1 min: Trend	11	1.5 or 10% (whichever is greater)	1.0	–	–	–
3 min: Motion	3	0.8 or 1% (whichever is greater)	0.3	0.5	5	0.5 or 1% (whichever is greater)

The accuracies described in Table 1 could be seriously reduced shortly after a navigating ship moves closer to its acquired target.

It should be taken into consideration that Resolution MSC.192(79) has changed the accuracy requirements. Up until 2008, IMO documents described the accuracy demands on the basis of four defined scenarios. These were presented in Appendix 2 of IMO Resolution A.823(19) (Resolution A.823(19), 1995). But now there are no described scenarios in Resolution MSC.192(79). The only remarks that could be seen were that the testing standards should contain detailed target simulation tests as the means to confirm the accuracy at relative speeds of up to 100 kn. Could it be interpreted that the requirements from Table 1 should be fulfilled in all meeting situations? Most navigators could understand it in this way. Navigators usually focus on CPA as the most important factor for situation safety, but what about relative course? Both of these parameters are strictly dependent on each other.

The resolutions comparison leads to the conclusion that the requirements of CPA accuracy in Resolution MSC.192(79) are stricter than in Resolution A.823(19). Acceptable error values were reduced from 1.6–2.0 NM up to 1.0 NM after 1 min of tracking and from 0.5–0.7 NM up to 0.3 NM after 3 min. This is useful information for navigators, but it could be seen that the relative course acceptable errors are almost at the same level. The mean value of the relative course estimation for four scenarios was 11.75° after 1 min of tracking and was reduced to 3.57° after 3 min of tracking.

So that is main question – Is it possible to assume for all navigational scenarios that CPA is calculated based on the known relative course?

Experimental characteristics

What is the essence of the problem driven in this article? Because the two requirements described in Table 1 (columns 2 and 4) relate to the same problem, it could be possible that they do not correspond to each other in all navigational scenarios. Because of the fact that the target tracking process should be carried out within 12 NM, this radar range was the maximum possible simulation field.

For this experiment, two basic terms should be well-defined:

- CPA|CPAlimit – this abbreviation means that CPA was calculated based on the maximum allowed CPA errors (Table 1 column 4);
- CPA|RClimit – this abbreviation means that CPA was calculated based on the maximum allowed relative course errors (Table 1 column 2).

The essence of the problem in the example scenario 2_1 described in Table 2 is shown in Figure 1. It is shown clearly that for the same tracking time and set of IMO requirements, the values of CPA|CPAlimit and CPA|RClimit are different.

Table 2. Test scenarios characteristics – initial data

Scenario No.	Own Ship data		Target data			
	True Course [deg]	True Speed [kn]	True Course [deg]	True Speed [kn]	True Bearing [deg]	Distance to target at acquisition [NM]
1_1	000	20	270	20	045	12/10/8/6
1_2	000	15	270	15	045	12/10/8/6
1_3	000	10	270	10	045	12/10/8/6
2_1	000	20	180	20	000	12/10/8/6
2_2	000	15	180	15	000	12/10/8/6
2_3	000	10	180	10	000	12/10/8/6
3_1	000	20	225	20	022.5	12/10/8/6
3_2	000	15	225	15	022.5	12/10/8/6
3_3	000	10	225	10	022.5	12/10/8/6

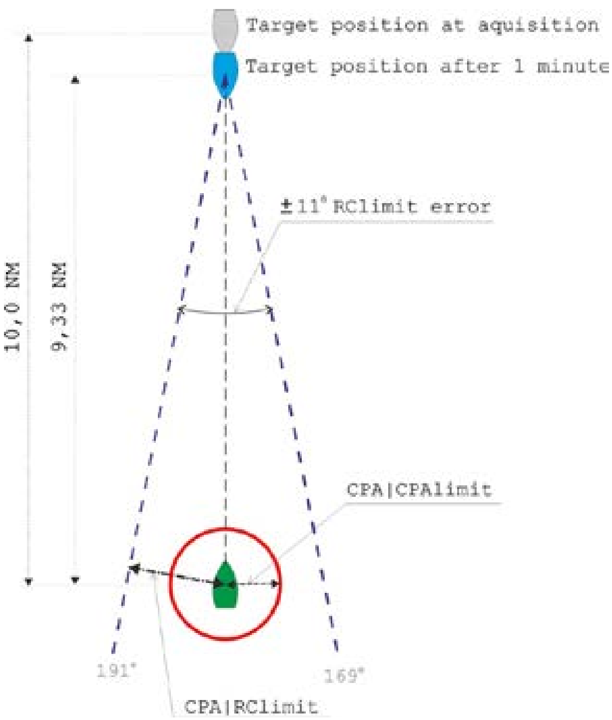

Figure 1. Relation between CPA|CPAlimit and CPA|RClimit values (based on scenario 2_1)

During experiment 3, the typical collision situations between two ships were simulated (CPA = 0). The main unchangeable data during the basic scenarios were: true target (TRGT) and navigating ship (NS) courses and true target bearings. It was assumed that the TRGT and the NS true speeds were always equal. Examples of initial scenario types for the acquisition distance 12 NM and TRGT and NS true speed values are presented in Figure 2.

Additional scenario variants rise by changing the distance to TRGT when the navigator makes an acquisition (12, 10, 8 or 6 NM) and changing the true speeds of both simulated ships (20, 15 or 10 kn). All scenario variants simulated during the experiment are characterized in Table 2. Sub-scenarios of 36 different types were simulated. Every simulation covered 30 min of target tracking.

Results

During all simulations, relative motion and target positions were calculated every 15 s. Assuming a strict connection between relative course and CPA values and acceptable (by IMO) maximum CPA and relative course errors, the possible CPAs at the maximum error values of relative course were calculated during the simulations. Of course, between 1 and 3 min of simulation, the maximum simulated errors

a) b) c)

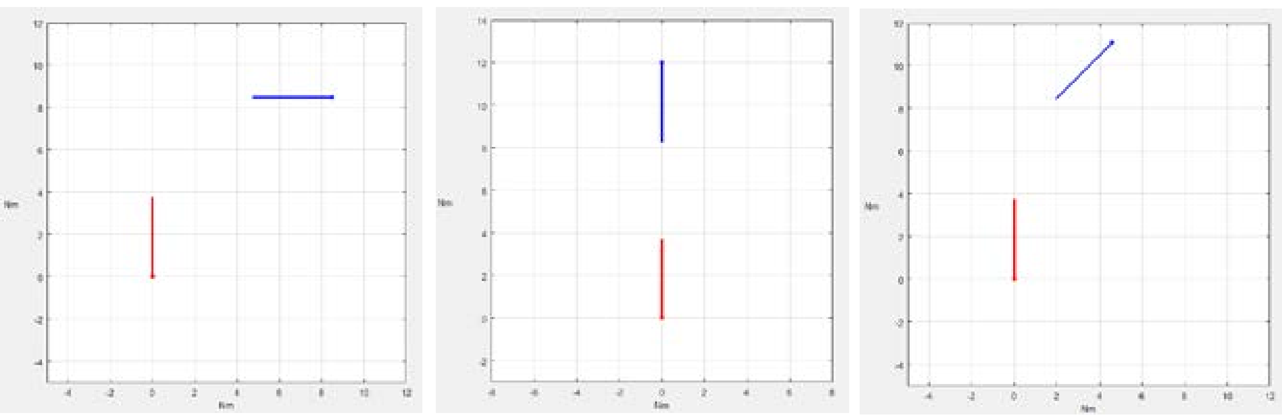

Figure 2. Examples of simulated scenario types: a) Scenario 1_2, acquisition range – 12 NM, b) Scenario 2_2, acquisition range – 12 NM, c) Scenario 3_2, acquisition range – 12 NM (red vector – OS course and speed, blue vector – TRGT data)

were proportionally reduced according to the tracking time. The errors had a fixed value (0.3 NM for CPA error and 3° for relative course error) after 3 min of simulation.

Additionally, for every target position and permissible maximum relative course error (respective to tracking time), the corresponding CPA value was also calculated. These values were compared with permissible maximum CPA errors in order to know when (the time from acquisition) all accuracy data performance had been fulfilled.

An example of the recorded data for scenarios 1_1, 1_3 and 2_1 are presented in Figures 3 to 5. These scenarios differ from one another by their relative speed value. Two of them are related to a crossing situation, but the remaining one refers to the situation where TRGT and NS are on opposite courses at the maximum relative speed simulated during experiment (40 kn).

Blue dots marked on the graphs indicate the moments when the maximum CPA errors calculated for relative target course (with the maximum permissible error level) were lower than the maximum CPA error value specified by IMO in Resolution 192(79) (see Table 1). This means that in this moment, both accuracy demands were the same and both IMO accuracy terms were fulfilled (CPA|CPAlimit = CPA|RClimit).

Discussion

Comparison of all recorded data led to the main conclusion: Taking into account the geometric relationship between relative courses, CPA and maximum permissible errors, all IMO tracking target accuracy requirements cannot be fulfilled within 3 min of tracking stabilization if target acquisition takes place at a distance greater than 6 NM.

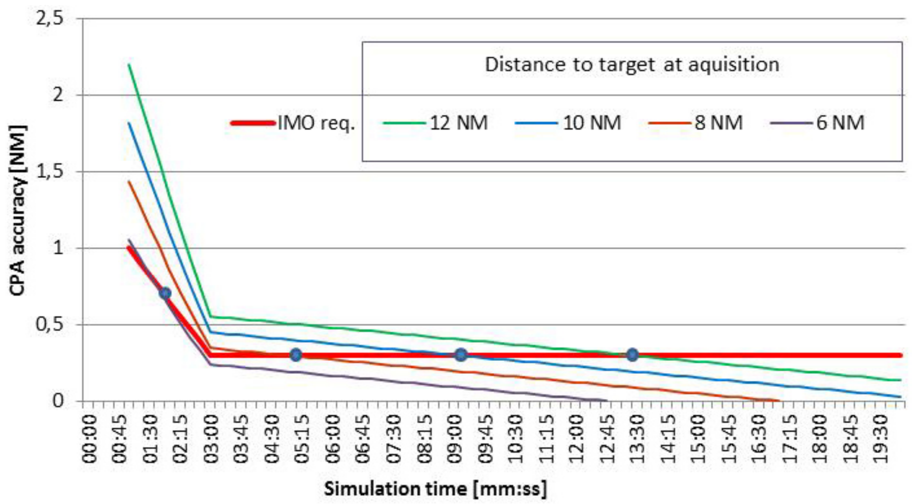

Figure 3. Calculated maximum CPA errors according to tracking target accuracy specified for CPA and relative course – Scenario 1_1 (relative speed: 28.28 kn)

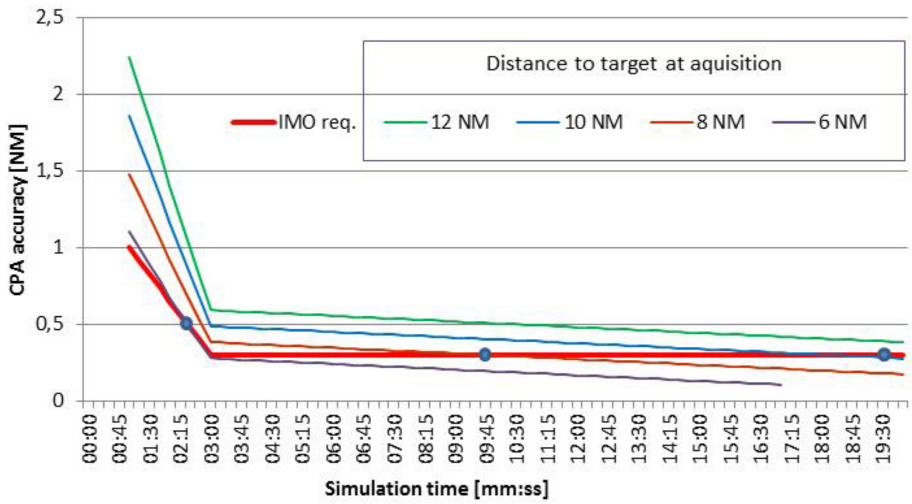

Figure 4. Calculated maximum CPA errors according to tracking target accuracy specified for CPA and relative course – Scenario 1_3 (relative speed: 14.14 kn)

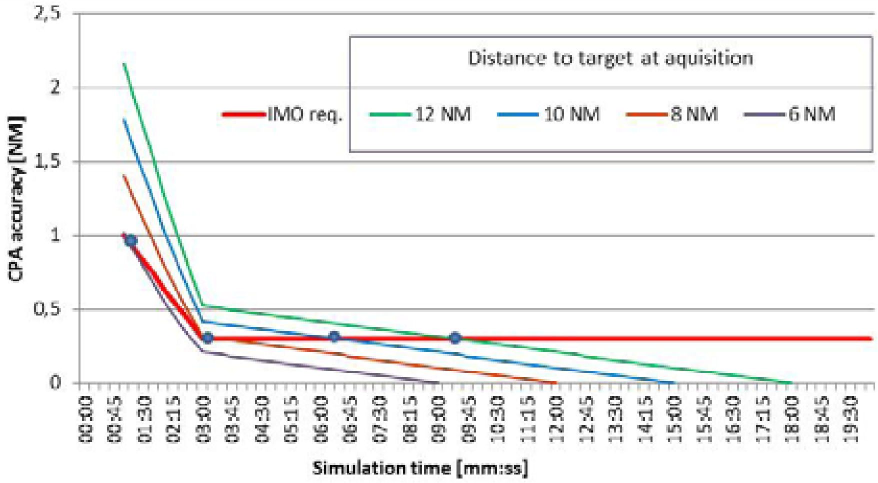

Figure 5. Calculated maximum CPA errors according to tracking target accuracy specified for CPA and relative course – Scenario 2_1 (relative speed: 40.0 kn)

It can be seen that the least restrictive demands refer to the relative course. Of course, the error calculated for the relative course CPA value depends also on the distance between ships. If the distance between ships reduces, the CPA error value calculated on the basis of the relative course error (CPA|RClimit) also decreases.

The CPA|CPAlimit value decreases only between the 1st and 3rd minute of tracking and later stays at the same level throughout the tracking period.

The relationship between time and distance to a target when both discussed IMO requirements are fulfilled (depending on the relative speed value) is presented in Figures 6 and 7. Separate lines are dependent on the distance between ships during acquisition.

The average distance when CPA|RClimit = CPA|CPAlimit was approximately 5.7 NM and was independent of the relative speed value. The distance equate errors of the CPA are lower only in scenarios with target acquisition within a 6 NM range.

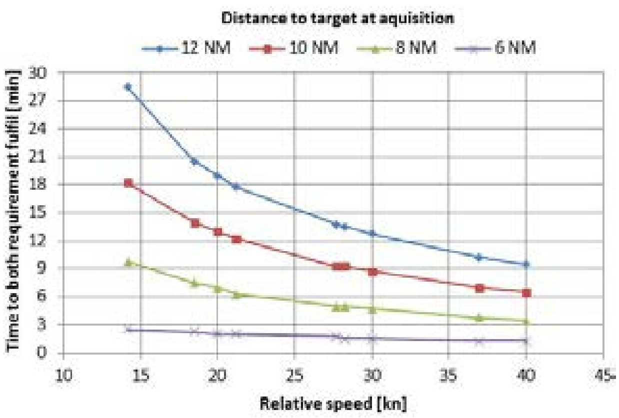

Figure 6. Tracking time when both IMO requirements are fulfilled

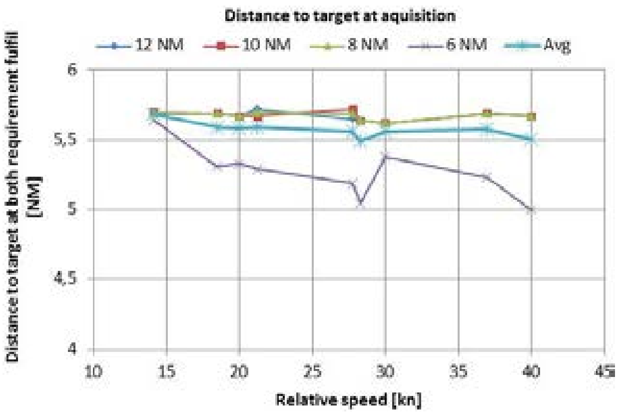

Figure 7. Distance to target when both IMO requirements are fulfilled

This is understandable because during the tracking stabilization period (3 min), the target is passing some distance and apply condition CPA|RClimit = CPA|CPAlimit at a lower range.

Conclusions

On the basis of the described simulations, it could be said that not all IMO radar performances are precisely compatible if a CPA value is calculated on the basis of relative vector and maximum acceptable relative motion errors (described in Resolution MSC.192(79)).

Unfortunately, this is important from the perspective of ship safety values, which are relative motion parameters. Taking into consideration the non-complexity and ease of interpretation, a CPA value should be taken in the first instance for risk assessment. This is very important because of the radar course participants. The participants should know not only the abilities and features of radar but also its disadvantages and limitations. In addition, these limitations should be precisely identified.

The knowledge of possible tracking errors is important for good safety assessment. Another problem is overreliance on radar equipment indications. Therefore, the information should be cleared and properly verified. This will be very important in the next IMO radar performance verification. These doubts should be checked and all demands should be correctly and comprehensively described along with information on the types of CPA and the accuracy of relative course computation algorithms.

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