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Analysis of the form of presentation of graphic-tracked target data – sectors of dangerous courses

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Abstract

At present, providing a clear presentation of the navigational situation around a navigator's own ship (OS) is one of the most important issues facing device manufacturers. Integration of navigational devices on the bridge has made it possible to transfer information and present it in the form chosen by the navigator screen. However, this may cause a decrease in the clarity of information and hamper its interpretation. The ability to select the best information, and that which is most needed at a given moment, depends on navigator proficiency. Vectors are still the basic form of the graphic presentation of radar-tracked object data. However, the ability to track more objects at the same time in crowded areas results in a decrease in readability and can cause errors. This article introduces the possibility of presenting information about collision danger in the form of Dangerous Courses Sectors (DCS) together with an analysis of changes in these during typical ship encounter situations. DCS are calculated on the base of Dangerous Passing Areas (DPA) as bearings on the marginal points of these areas.

Introduction

According to basic principles and practice, radar equipment should be the basic navigational equipment used to obtain information about dangerous traffic situations and to plan anti-collision maneuvers. Radar equipment is necessary to obtain both sea and ground radar picture stabilization (IMO, 1995; IMO, 2004; Convention, 2009). For this reason, the navigator must always take into consideration the actual operating parameters during a situation assessment. This is very important because, in the event of strong currents, the difference in the ground and water presentation can be significant. It can lead to an incorrect situation assessment and anti-collision action measures which are ineffective and which breach COLREG regulation.

The situation could be complicated by a possible mixing of the types of simultaneously presented target information (radar-tracked and AIS targets). This can lead to wrong decisions being taken. Consequently, when analyzing and planning anti-collision maneuvers, water radar picture stabilization should be used to ensure the highest accuracy and efficiency (Juszkiewicz, 2016; Juszkiewicz & Nowy, 2016).

Detailed regulations concerning the technical requirements for radar equipment are contained primarily in the SOLAS Convention and IMO Resolutions A.422(XI), A.823(19) and MSC.192(79) (IMO, 1979; IMO, 1995; IMO, 2004; Convention, 2009).

The possibility of increasing tracking to up to 40 objects simultaneously represents real progress in the development of radar equipment. However, it should be borne in mind that the interpretation of the vector form of such information, especially in areas where navigation is difficult, is more time-consuming and can create problems for less experienced navigators. This can be seen when radar training is conducted in simulators. However, at present it is the main, and only required, way of presenting radar-tracked target data in graphic form. Other graphic forms are acceptable but much less common. An analysis of the possibilities of other graphic forms was presented in (Bole, Dineley & Wall, 2005; Galor, 2016; Juszkiewicz 2016).

Planning for anti-collision manoeuvers in the use of Sectors of Dangerous Courses (SDC) functions may be simpler because the navigator can display information about the tracked targets at one location near the vector of their own ship (OS).

Additional parameters that may limit the displayed information may be, for example, the distance to the tracked targets or the Time to Closest Point of Approach (TCPA). All advantages and limitations of graphically presenting target data in this way should be taken into consideration. On the one hand, it is certainly possible to easily determine the required change in course of the navigator's OS. Difficulty occurs when it is necessary to change speed. It is also necessary to take into account the COLREG rules and the fact that the magnitude and position of dangerous courses sectors (DCS) will change with distances to the target changes.

DCS are defined on the basis of the relative positions of ships, their speed relationships, and the Closest Point of Approach safety limit (CPA_{limit}).

Defining the limits of Dangerous Passing Areas

As already mentioned, the basis for defining the SDC is the proper determination of the limits of Dangerous Passing Areas (DPA) as the DPA should be understood as marked on the radar screen area, for which $CPA \leq CPA_{limit}$. This means that a safe passing distance (set by the navigator) will not be maintained between the OS and target (TRGT).

If the factor C expresses the relation of the TRGT and OS speed:

$$C = \frac{V_{TRGT}}{V_{OS}} \tag{1}$$

where:

C – the ratio of the TRGT and OS speed;
V_{TRGT} – TRGT true speed;
V_{OS} – OS true speed.

Depending on the C value, three basic situations can be distinguished:

- $C > 1$ – it is possible to calculate one, two, or no DPA (depending on the relative positions of the TRGT and OS);
- $C = 1$ – it is possible to calculate only one DPA, provided that the angle between the true target course and the TRGT-OS bearing is less than 90°;
- $C < 1$ – it is always possible to calculate only one DPA.

The following assumptions for DPA border drawing should be introduced:

- OS true speed V_{OS} = const.;
- TRGT true speed V_{TRGT} = const.;
- TRGT true course KR_{TRGT} = const.;
- TRGT position (BRG, Dist);
- CPA_{limit} value.

To achieve this, the common points of two circles should be calculated:

- the ring of OS positions after t (fixed position of the circle center, the variable radius of the circle);
- the ring of CPA_{limit} radius value and circle center in TRGT position after t (the variable position of the circle center, the fixed value of the circle radius).

This situation is illustrated in Figure 1.

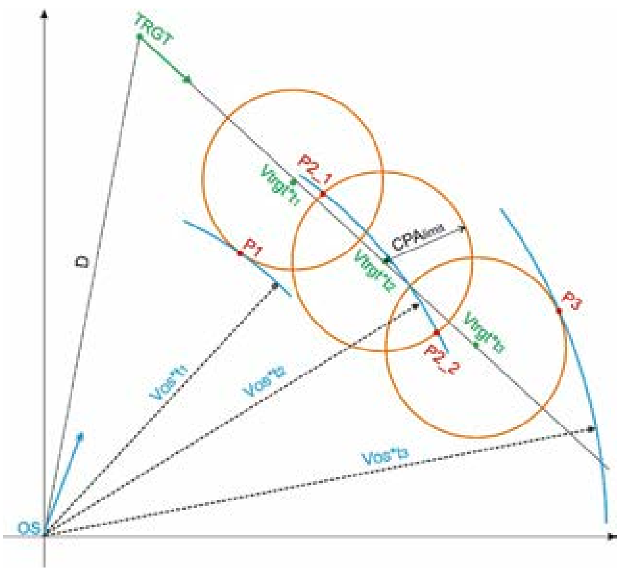

Figure 1. The principle of the calculation of DPA border points (North-Up and TM presentation)

In Figure 1, the green points are TRGT positions after t_1, t_2, and t_3 periods. Orange circles indicate CPA_{limit} distance from TRGT positions. In these moments, OS could reach the blue rings (respectively $V_{OS} \cdot t_1$, $V_{OS} \cdot t_2$, and $V_{OS} \cdot t_3$). The beginning (point P1) and end (point P3) of the DPA drawing are the moments of pre-defined circle tangency. Points P2_1 and P2_2 are calculated when pre-defined circles are crossing.

Further characteristic moments of calculated border points of DPA are shown in Figures 2a–e.

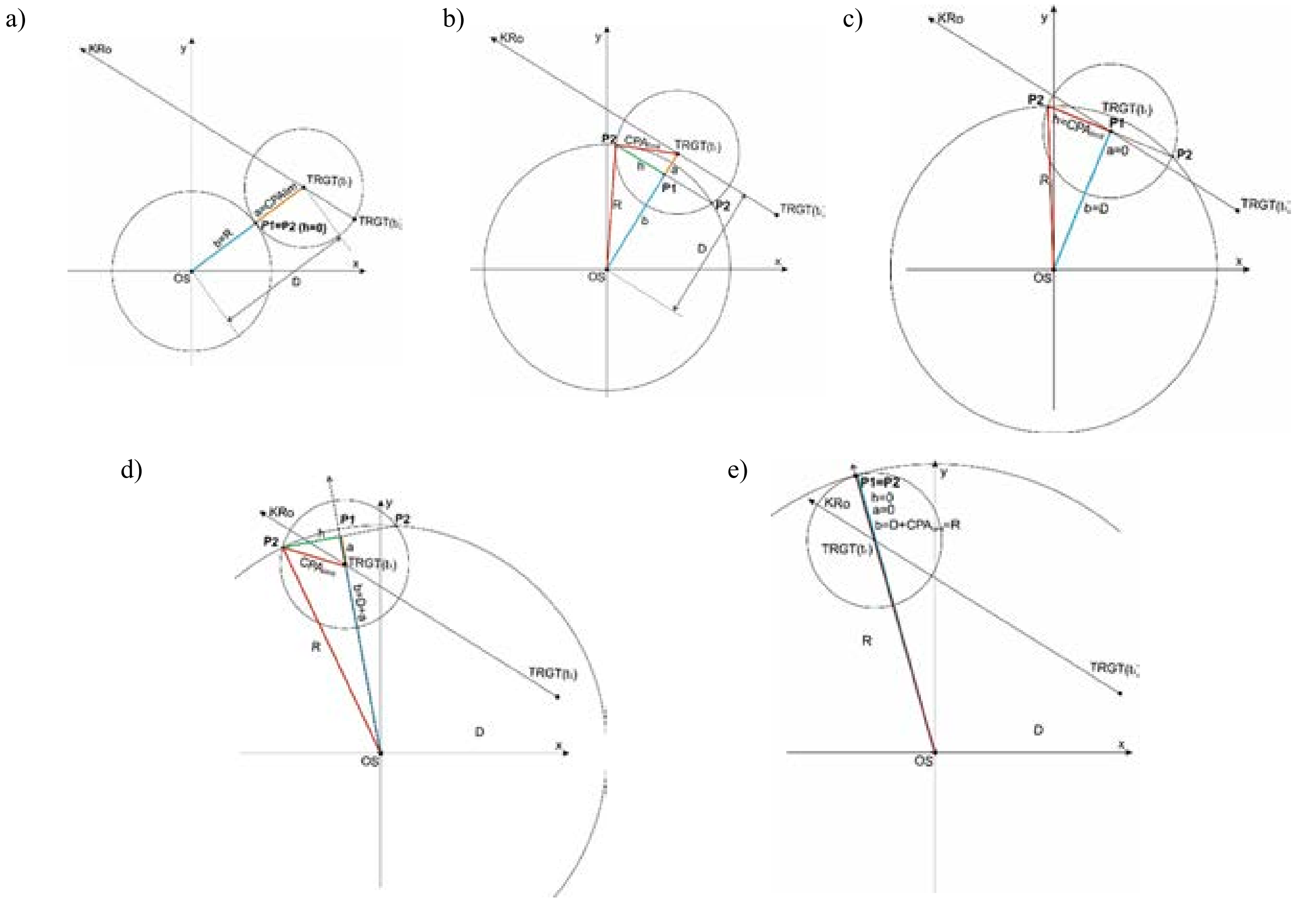

Figure 2. Subsequent phases of the calculation of DPA border points (North-Up and TM presentation): a) the first point of circle tangency situation ($D = R + \text{CPA}_{\text{limit}}$); b) two intersection points in the first period ($\alpha \le 90°$); c) two intersection points where $\alpha = 90°$; d) two intersection points in the last period $\alpha > 90°$); e) the final point of circle tangency situation ($R = D + \text{CPA}_{\text{limit}}$); α – the angle between the segment joining the OS and TRGT positions and the segment joining the TRGT position and the point of intersection of circles (P2); R – the radius of possible OS positions after t_1; D – distance between OS and TRGT position in t_1; a – distance between P1 and TRGT positions; b – distance between OS and P1 positions; and KRo – target true course

The condition for the first DPA boundary point calculation is the tangent of a circle with a radius $\text{CPA}_{\text{limit}}$ with a circle defined by the OS positions that it can reach after time t_1 (Figure 2a). Continuing to move the forecasted position over time enables the calculation of a pair of intersection points (Figures 2b, 2c). Intersection points are calculated according to dependencies presented in formulas (2a) and (3)–(7). When the angle α is greater than 90° the (2b) formula should be used at the beginning of the calculation.

$$a = \frac{\text{CPA}_{\text{limit}}^2 - R^2 + D^2}{2D} \tag{2a}$$

$$a = \frac{R^2 - \text{CPA}_{\text{limit}}^2 - D^2}{2D} \tag{2b}$$

$$h = \sqrt{\text{CPA}_{\text{limit}}^2 - a^2} \tag{3}$$

$$P1x = x_{\text{TRGT}} + \frac{a\left(x_{\text{OS}} - x_{\text{TRGT}}\right)}{D} \tag{4}$$

$$P1y = y_{\text{TRGT}} + \frac{a\left(y_{\text{OS}} - y_{\text{TRGT}}\right)}{D} \tag{5}$$

Circles' crossing points coordinates are:

$$P2x = P1x \pm \frac{h\left(y_{\text{OS}} - y_{\text{TRGT}}\right)}{D} \tag{6}$$

$$P2y = P1y \mp \frac{h\left(x_{\text{OS}} - x_{\text{TRGT}}\right)}{D} \tag{7}$$

where:

x_{TRGT}, y_{TRGT} – predicted TRGT position coordinates after t_1;
x_{OS}, y_{OS} – OS position coordinates;
$P1x$, $P1y$ – P1 coordinates;
$P2x$, $P2y$ – P2 coordinates.

Sectors of SDC determination

In a situation where the DPA boundaries are known to delimit dangerous sectors, two border points for each area which define an angle of view of the DPA from the OS position must be found. The

SDC is displayed at a distance equal to the actual OS vector length with a red arc. Examples of the presentation of DPA and SDC for selected meeting situations are presented in Figures 3–5.

After SDCs are computed for all tracked objects meeting the criteria chosen by the navigator (e.g., actual TRGT distance), all DCS that do not meet safety criteria (CPA ≤ CPA_{limit}) can be displayed in one place on the screen. This presentation should facilitate the interpretation of the OS collision situation and make a decision to undertake an anti-collision maneuver easier.

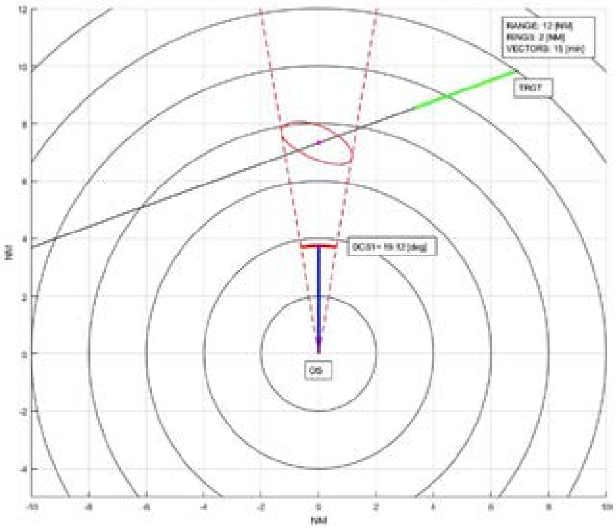

Figure 3. An example of an encounter situation with one DPA, PPC, and SDC (*C* = 1) (North-Up and TM presentation)

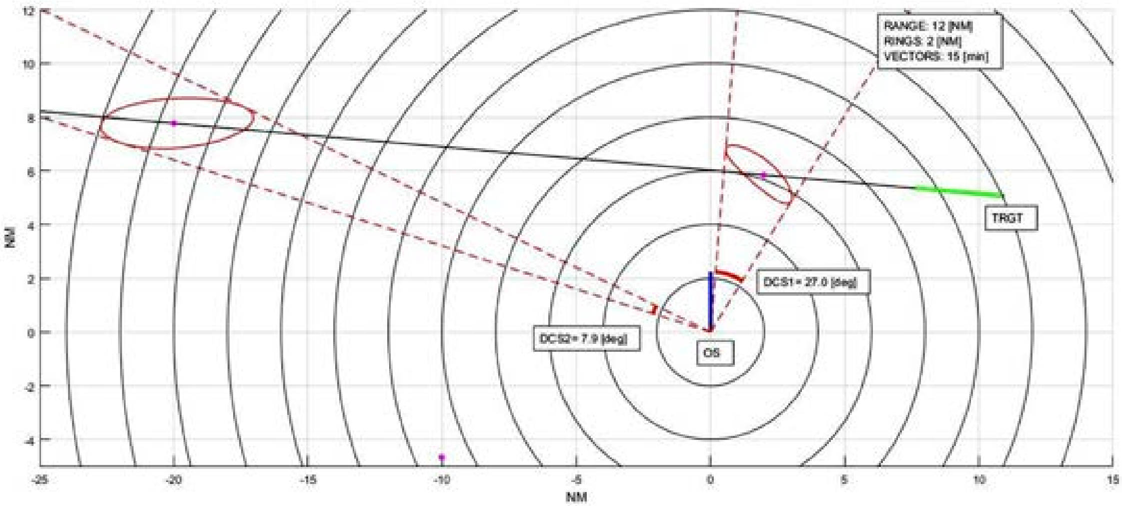

Figure 4. An example of an encounter situation with two DPAs, PPCs, and SDCs (*C* > 1) (North-Up and TM presentation)

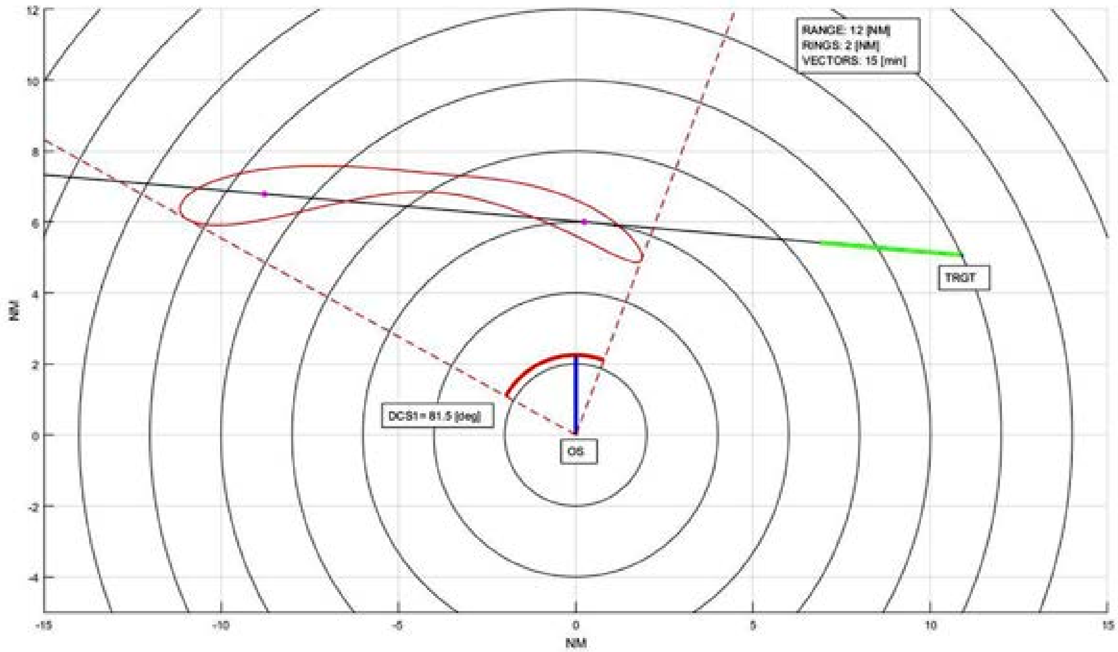

Figure 5. An example of an encounter situation with two PPCs inside one DPA and one SDC (*C* > 1) (North-Up and TM presentation)

The simulated encounter situation characteristic

For SDC changes analysis according to the TRGT distance, the following three typical encounter situations in different variants of starting position were simulated: vessels on opposite courses; crossing courses situation at an angle of 135°; and crossing courses situation at an angle of 90°. The simulated scenarios are described in Table 1.

Table 1. Initial scenario data

Scenario	OS Data: True course [deg]	OS Data: True speed [kn]	TRGT Data: Distance [NM]	Bearing [deg]	True course [deg]	True speed [kn]	CPA [NM]	TCPA [min]
1A				000			0.0	24
1B	000	15.0	12.0	005	180	15.0	1.0	24
1C				010			2.1	24
2A				045			0.0	33
2B	000	15.0	12.0	050	270	15.0	1.0	33
2C				055			2.1	33
2D				040			1.0	33
3A				022.5			0.0	25
3B				027.5			1.0	25
3C	000	15.0	12.0	032.5	225	15.0	2.1	25
3D				017.5			1.0	25
3E				012.5			2.1	25

A safe passage distance value of CPA_{limit} = 1.0 NM has been established.

The changes introduced to initial position allow the simulation of different situations with CPA values between 0 and 2.1 NM.

Analysis of SDC value changes for typical ship encounter situations

During the simulations, the location of the calculated hazardous areas was calculated at 1 minute intervals. At these moments, the boundaries of these areas, and the angles of the dangerous sectors, were determined.

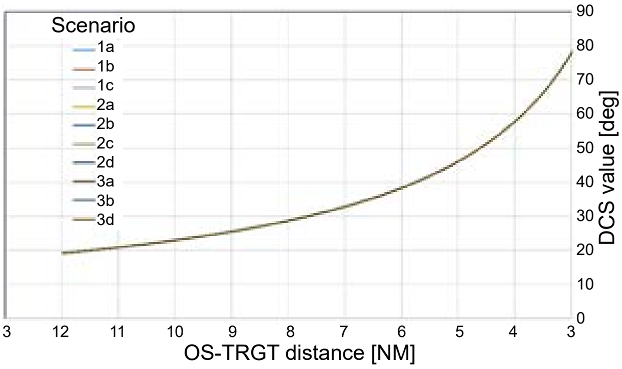

Figure 6. The change of the SDC value at OS-TRGT distance decreasing

a) b)

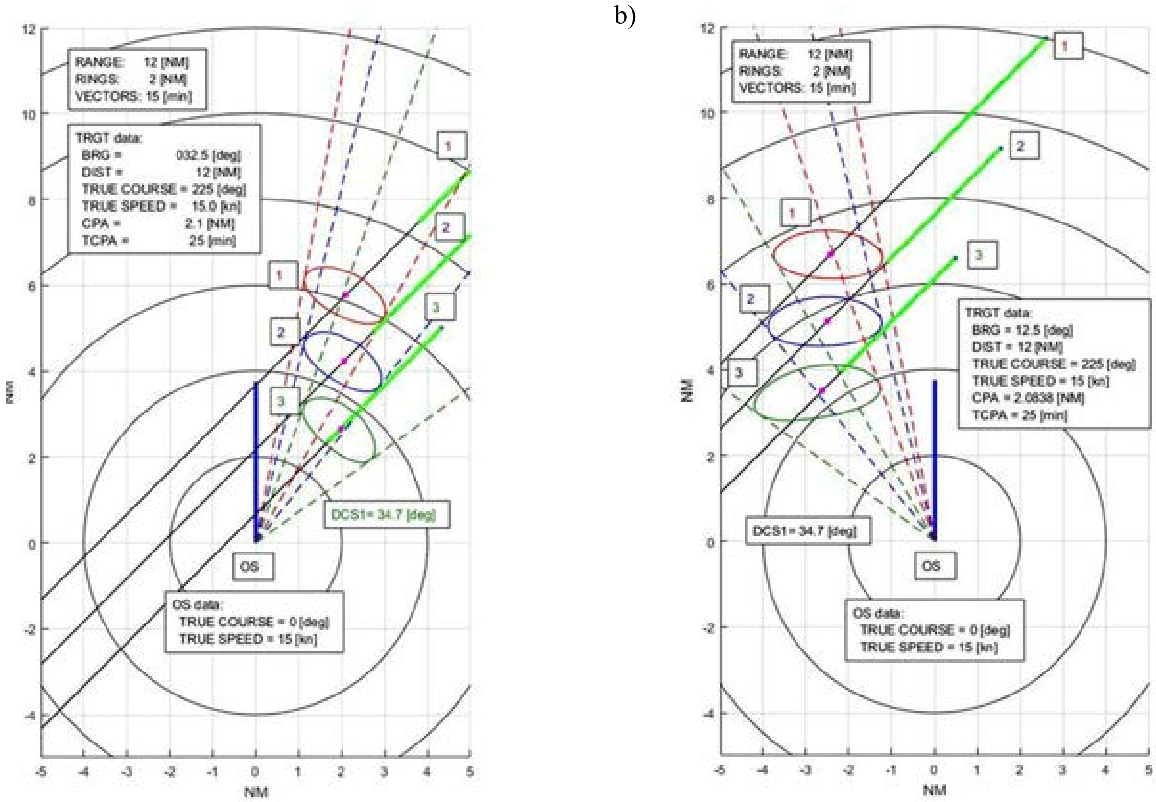

Figure 7. The change of DPA position and SDC border bearings with OS-TRGT distance decrease (North-Up, RM with True Vectors presentation): a) scenario 3C; b) scenario 3E

The recorded SDC value when TRGT was approaching (in all simulations) changed similarly from approx. 19.1° at a distance of 12 NM to approx. 80.4° at a distance of 3 NM. The same shape in the SDC changes curve was obtained in practically all scenarios.

The recorded results are shown in Figure 6.

Of course, a simple conclusion that sectors will always change in the same way cannot be drawn. Two situations illustrate this simply in Figure 7.

Conclusions

A method of calculation and SDC possibilities have been presented in the paper.

An interesting alternative to the traditional vector presentation is another method of graphic presentation in SDC form. While the first solution (vectors) requires a large amount of graphics to be displayed on the radar screen, which may make it difficult to observe objects (especially in areas with high traffic density), the use of the SDC does not have this disadvantage. Sectors naturally integrate information about multiple targets and allow it to be displayed near the OS position.

In this way, OS course changes which are not permitted and which do not ensure that the planned safe passing distance will be reached are marked.

Another parameter allowing the better alignment of information may be, for example, a tracked target distance limit for which such information will be calculated and taken into consideration. This could reduce that part of the information which is not important, and facilitate the decision-making process. This should provide an indication of targets for which the navigator will make decisions about anti-collision manoeuvers. Such segregation of targets is naturally carried out by navigators, and is particularly relevant for navigation in areas with intensive traffic.

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