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# Ability to test shipboard automatic identification system instability and inaccuracy on simulation devices

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**Key words:** automatic identification system, automatic radar plotting aid, closest point of approach, time needed to reach the closest point of approach, accuracy, stability of indication

**Abstract**

According to the International Maritime Organisation (IMO) recommendation, when the target data from the automatic identification system (AIS) and radar tracking are both available and the association criteria are fulfilled such that the AIS and radar information are considered for one physical target, then as a default condition of radar equipment, the AIS target symbol and the alphanumerical AIS target data, including information on the closest point of approach (CPA) and time needed to reach the CPA (TCPA) should be automatically selected and displayed as this is more accurate than radar tracking data as the current values of true and relative vectors of a manoeuvring object can be presented without time delay which is characteristic for radar tracking. Research conducted at sea on two ships using real navigational equipment has shown that sometimes onboard AIS presents CPA of other vessels equipped with this device as unstable and inaccurate as the automatic radar plotting aid (ARPA). The source of these instabilities and inaccuracies is to be discovered and thus implemented into radar-navigational simulators used for radar training at operational and management levels.

This article briefly describes the encountered inaccuracy and instability of the values of the CPA of the encountered vessel presented by AIS, on current shipboard systems, and the possibilities of their demonstration on simulation devices.

## Introduction

The automatic identification system (AIS) is an important and useful tool in enhancing situational awareness of traffic and may be used to assist in collision avoidance decision-making. Due to that, International Maritime Organisation (IMO) Resolution MSC.192(79) "Adoption of the revised performance standards for radar equipment" adopted on 6th December 2004 recommends that radar equipment installed on sea-going vessels according to the International Convention for the Safety of Life at Sea (SOLAS) requirements on or after 1 July 2008 shall present graphically and digitally the information received by the shipborne AIS. It should be possible to select any tracked radar or AIS target for the alphanumeric display of its current data: range, bearing, predicted distance at which a target will pass own ship (closest point of approach – CPA), the time needed to reach CPA (TCPA), true course and true speed. If the target data from AIS and radar tracking are both available and if the association criteria (e.g. position, motion) are fulfilled such that the AIS and radar information is considered as related to one physical target, then as a default radar condition, the activated AIS target symbol and the alphanumeric AIS target data should be automatically selected and displayed. The user should have the option to change the default condition to the display of tracked radar targets and should be permitted to select either radar tracking or AIS alphanumeric data (IMO, 2004).

Irrespective of the above recommendations for radar equipment, the IMO adopted, 11 years later on 2nd December 2015, the Resolution A.1106(29) "Revised guidelines for the onboard operational use of shipboard automatic identification systems (AIS)" containing a clear statement that the potential of AIS as an assistance for anti-collision device is recognized and AIS may be recommended as such a device in due time. This resolution emphasized that the user should not rely on AIS as the sole information system, but should make use of all available safety-relevant information and that data provided by AIS may not give a complete and correct picture of the situation around the ship and should be appreciated as supplementary to that derived from visual observation and navigational systems, including radar and radar tracking aids. In particular, the introducing of AIS has no impact on Rule 19 "Conduct of vessels in restricted visibility" of the International Regulations for Preventing Collisions at Sea (COLREG) and interpretation of its recommendations. AIS is only an additional source of information which supports radar and radar tracking aids by assisting in the identification of radar targets and their navigational status, presentation of targets heading, immediate identification of performed manoeuvres and more accurate presentation of the targets vectors. (IMO, 2015).

IMO refers to the possibility of using AIS for anti-collision purposes carefully due to the limitations of the AIS technique. Resolution A.1106(29) emphasizes that AIS is not currently, and will not be in the near future, installed on all sea surface objects including those that can be detected by radar. Additionally, it might be switched off on all ships when the master, on his professional judgement, believes that the continuous operation of AIS might compromise the security of his ship, as the system works in a semiautomatic manner and transmits data introduced automatically or manually without checking its quality, reality and accuracy.

The basic parameter needed to assess the risk of collision with another vessel is CPA. AIS calculates its value on the basis of information on the current values of the course over ground, speed over ground and geographical position of the own ship and opposite vessels indicated by the Differential Global Navigation Satellite System (D)GNSS receivers connected to the onboard AISs. The (D)GNSS receiver indications are more accurate than values of the mentioned parameters calculated by tracking devices based on radar measurements and devoid of a time delay characteristic of radar tracking. The issues that need to be investigated are:

- the accuracy and stability as a function of time of the AIS indications of CPA calculated from the momentary values of the actual positions and true vectors of the own and opposite ships, particularly in bad weather conditions when vessels equipped with AIS strongly yaw and change instantaneous speed values; and
- the possibility of demonstrating this accuracy and stability of AIS indications on simulation devices used in the training and examination of ships' captains, watch keeping officers and pilots.

Information on these topics is not presented in the available professional literature.

## Measurements at sea

To find the answer to the first question presented in the introduction, measurements were carried out on two ships: the bulk carrier "Magdalena Oldendorff" (106 884 GT) and the liquefied petroleum gas (LPG) carrier "Pampero" (46 789 GT), using the following systems installed on these vessels, for AIS the JHS-183 and for radar, the JMA series produced by Japan Radio Company (JRC). The mentioned vessels are presented in Figures 1 and 2.


**Figure 1. Bulk carrier "Magdalena Oldendorff" (Vessel Finder, 2017a)**

**Figure 2. LPG carrier "Pampero" (Vessel Finder, 2017b)**

As shown in Figures 3, 4 and 5, the results of the conducted tests proved that, as stated in the Resolution A.1106(29), AIS presents an often more accurate and stable true vector and CPA of the observed vessel than the automatic radar plotting aid (ARPA). During tests the results of which are shown in the Figures 3–5, bulk carrier (40 500 GT) was observed from LPG carrier "Pampero". Both ships were proceeding with steady courses and speeds, the wind was 4–5° in Beaufort scale, the sea state was 3° in Douglas scale (Wesołowski, 2016). It should be emphasized that the presented meeting situation is an example of a situation in which ARPA indicated the value of CPA and true vector of the other vessel with errors greater than their limit values set out in the IMO resolution. The cause of such large errors is not known (readings from AIS indicate that the opposing vessel was not yawing).

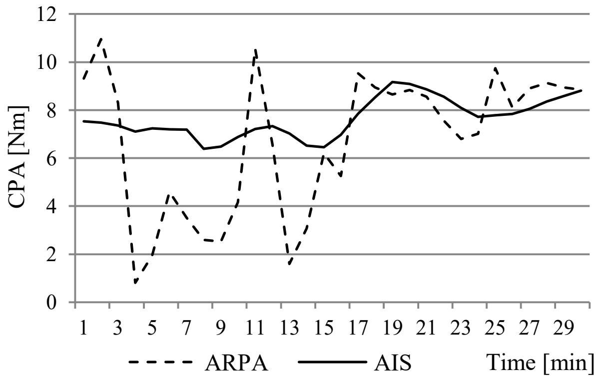


**Figure 3. Information on the CPA of the bulk carrier (40 500 GT) presented by AIS and ARPA installed on the LPG carrier "Pampero". Both ships were proceeding with steady courses and speeds in sea state 3 (Wesołowski, 2016)**

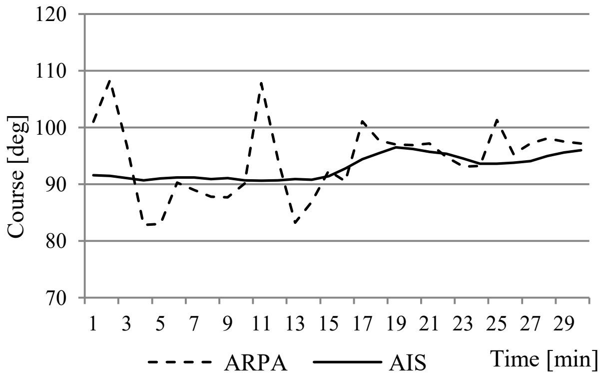


**Figure 4. Information on the true course of the bulk carrier (40 500 GT) presented by AIS and ARPA installed on the LPG carrier "Pampero". Both ships were proceeding with steady courses and speeds in sea state 3 (Wesołowski, 2016)**

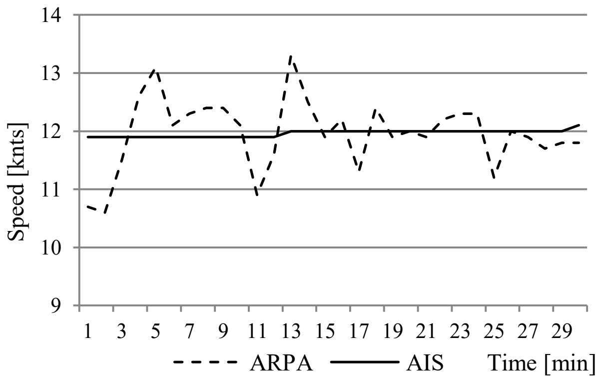


**Figure 5. Information on the true speed of the bulk carrier (40 500 GT) presented by AIS and ARPA installed on the LPG carrier "Pampero". Both ships were proceeding with steady courses and speeds in sea state 3 (Wesołowski, 2016)**

But sometimes accuracy and stability of these parameters indicated by AIS were on the same level or even worse than the accuracy and stability of data presented by radar tracking devices. An example of the low stability and accuracy of CPA indications by AIS and ARPA is presented in Figure 6. There was an observed bulk carrier (38 767 GT), both ships were proceeding on parallel courses keeping both steady courses and speeds. Hydro-meteorological conditions during the measurements were the following: wind 8° in Beaufort scale, sea state 7° in Douglas scale, high swell causing the own ship's rolling up to 15°and no precipitation (Wilczyński, 2015). As shown in Figures 7 and 8, the reason for the low stability of the CPA indication can be a small stable of indications, as a function of time, of the true course and true speed of the observed ship.

More detailed information on the results of the studies described above is provided in an article

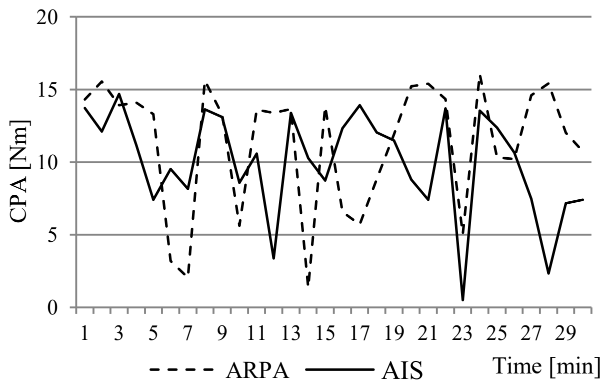


**Figure 6. Information on the CPA of the bulk carrier (38 767 GT) presented by AIS and ARPA installed on the bulk carrier "Magdalena Oldendorff". Both ships were proceeding with steady courses and speeds in sea state 7 (Wilczyński, 2015)**

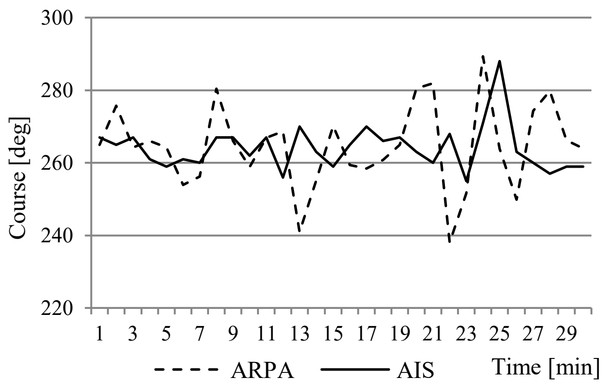


**Figure 7. Information on the true course of the bulk carrier (38 767 GT) presented by AIS and ARPA installed on the bulk carrier "Magdalena Oldendorff". Both ships were proceeding with steady courses and speeds in sea state 7 (Wilczyński, 2015)**

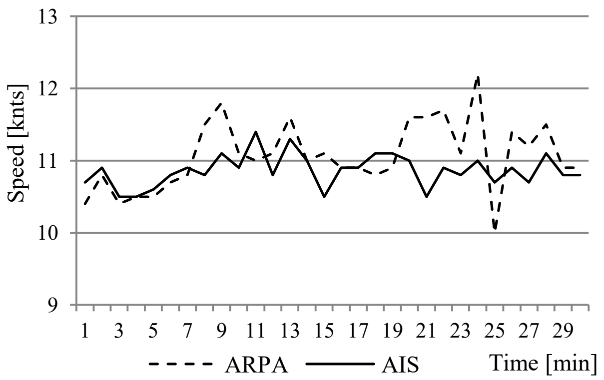


**Figure 8. Information on the true speed of the bulk carrier (38 767 GT) presented by AIS and ARPA installed on the bulk carrier "Magdalena Oldendorff". Both ships were proceeding with steady courses and speeds in sea state 7 (Wilczyński, 2015)**

published in the International Journal on Marine Navigation and Safety of Sea Transportation (Wawruch, 2016). Tests were carried out in order to check whether when data from AIS and radar tracking are both available, and the association criteria are fulfilled, the person in command of the ship (captain or watch keeping officer) may rely on instantaneous readings of the CPA values of other vessels available from AIS only. These measurements were pilot-based and are continued on other ships. The amount of data collected is too small to define statistical relationships and make any final conclusions based on them. In addition, the tests were performed using several types of radars and ARPA and one type of AIS purchased from one manufacturer only. This manufacturer (JRC) is popular and its equipment is installed on many vessels, but it is difficult to ascertain the extent to which conclusions based on these measurements are representative for third-party devices.

The most important issue requiring further investigation is the accuracy of the CPA information presented by the shipboard AIS, especially in unfavourable hydro-meteorological conditions. Tests carried out so far have shown that it should be not recommended to rely on instantaneous readings of the CPA value presented by AIS. Just like for radar equipment, it should be recommended to carry out systematic observation of the AIS dynamic data indication. Due to the significance of this issue, it is important to check the possibility of presenting possible errors and instability of CPA values shown by shipboard AIS on so-called full mission, bridge, and radar-navigational simulators. Simulators of these types are used for practical training and examination of masters, watch keeping officers and pilots of sea-going ships for their ability to keep the watch, assess the risk of collision and execute an anti-collision manoeuvres. The ability to simulate the AIS instability during this training and exams is therefore of major importance for the safety of navigation.

## Tests conducted on simulators

Older types of radar-navigational simulators (like NAVSIM 90) were fitted with real radar and ARPA display units (indicators) connected to the computer (central processing unit) sending them input signals. They were excellent at demonstrating radar and ARPA accuracies, time delay in detecting tracked targets manoeuvres and influence of the own ship's manoeuvres, and the effect of hydro-meteorological condition on the accuracy of radar tracking. But they were not fitted with AIS and its indications could be simulated by transmission to the training bridges the current values of the target bearing, distance, true course, true speed, CPA and TCPA generated by the central processor (simulator) only. For this reason, the AIS indications were devoid of any errors and were useful for demonstration of the possible inaccuracies and time delay of radar tracking data only. These simulators are not useful for training in the use of AIS as a technical means of observation and as an additional source of data facilitating assessment of the traffic situation. These remarks confirmed results of the tests realized on the training bridge equipped with the real ARPA Atlas Elektronik 8600 (AK 8600) on NAVSIM 90 simulator. The tests were carried out with 12 series of measurements described in Table 1 using 4 different vessel models: a loaded very large crude carrier (VLCC), a bulk carrier, a container ship and a small coastal vessel with displacement respectively: 270 000, 73 113, 42 245 and 1200 m$^3$. There were recorded, for the same time moments, values of the CPA, true course and true speed of the opposite ship (ship B) indicated by ARPA (AK 8600) installed on the training bridge (ship A) and the central unit (simulating data from AIS on ship B). According to the IMO recommendation, before the research was commenced, the opposing vessel was tracked by ARPA for 5 minutes. During this time, both ships did not make any manoeuvres and were proceeding with steady courses and speeds. In all simulated meeting situations existed a risk of collision, and in most cases, there was a close-quarters situation. The setting was an open sea area and gusty wind (direction 045°, mean speed 10.3 m/s corresponding to 5° in Beaufort scale). The state of the sea was calculated automatically by the simulator as a function of the set wind

**Table 1. Description of the meeting situation in the particular measurement sessions**

| No. | Meeting situation | Ship A – initial Course [deg] | Ship A – initial Speed [knots] | Ship B – initial Course [deg] | Ship B – initial Speed [knots] | Manoeuvre |
|---|---|---|---|---|---|---|
| 1 | 1 | 270 | 24.0 | 000 | 9.8 | Ship B – course alteration 50° to starboard |
| 2 | 1 | 270 | 24.0 | 000 | 9.8 | Ship B – stop engine |
| 3 | 1 | 270 | 24.0 | 000 | 24.0 | Both ships – emergency stop |
| 4 | 1 | 270 | 24.0 | 000 | 24.0 | Ship B – emergency stop |
| 5 | 1 | 270 | 24.0 | 000 | 24.0 | Both ships – course alteration 50° to starboard |
| 6 | 2 | 000 | 24.0 | 000 | 9.8 | No manoeuvres |
| 7 | 2 | 000 | 24.0 | 000 | 12.8 | Ship B – course alteration 35° to starboard |
| 8 | 3 | 180 | 24.0 | 000 | 24.0 | Ship A – course alteration 50° to starboard |
| 9 | 3 | 180 | 24,0 | 000 | 24,0 | Ship B – course alteration to starboard and stop engine |
| 10 | 3 | 180 | 24.0 | 000 | 15.0 | Both ships – course alteration 50° to starboard |
| 11 | 3 | 180 | 24.0 | 000 | 15.0 | Ship B – emergency stop, ship A – course alteration |
| 12 | 3 | 180 | 24.0 | 000 | 15.0 | Ship B – emergency stop |

value. The manoeuvres performed complied with the relevant COLREG rules.

In description of the meeting situation presented in Table 1, the following signs were used: 1 – crossing courses, 2 – overtaking and 3 – contrary courses.

Figures 9–11 present sample graphs showing CPA indicated by ARPA and simulated AIS as a function of time. Due to the lack of instability of the CPA value indicated by AIS, they show only graphs for the period of time immediately before, during and after the manoeuvre. As expected they demonstrate errors and time delays of ARPA indications in relation to the data presented by AIS only.

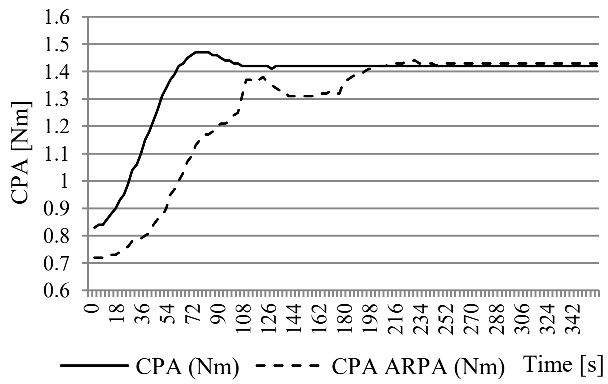


**Figure 9. Values of CPA indicated by ARPA (CPA ARPA) and simulated AIS (CPA) as the function of time in the measurement session 1**

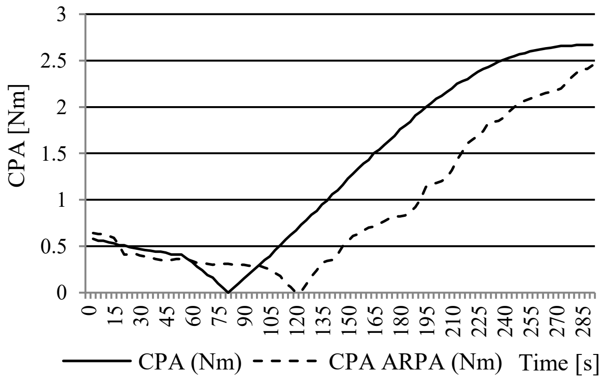


**Figure 10. Values of CPA indicated by ARPA (CPA ARPA) and simulated AIS (CPA) as the function of time in the measurement session 4**

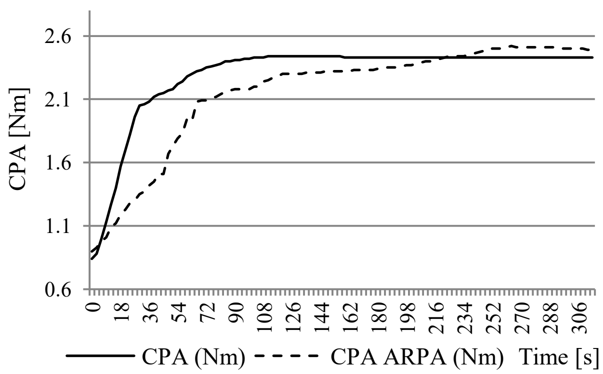


**Figure 11. Values of CPA indicated by ARPA (CPA ARPA) and simulated AIS (CPA) as the function of time in the measurement session 10**

A detailed description of the tests conducted on the NAVSIM-90 simulator was presented at the conference LogiTrans in 2017 (Wawruch, 2017).

Modern simulator training bridges are fitted with LCD monitors simulating operation of the navigational equipment display units of several manufacturers selected by the simulator supplier. AIS devices are operated on these bridges via radar and Electronic Chart Display and Information System (ECDIS), which also display data transmitted by AIS installed on other training bridges (so-called own ships) and vessels operated by instructors working on the simulator central console (so-called extraneous ships). In the case of extraneous ships, the data sent by the AIS is generated by the central processor and can be recorded manually either on the training bridges or on an instructor console. An example of a device with the above-mentioned capabilities is the Polaris simulator. During the studies conducted on this simulator, own ship (container vessel) was following a course in open sea with heading 000° and speed 12 knots and tracking using ARPA and a Polaris bulk carrier running in the opposite direction with a speed of 17 knots. The gusty wind (direction 045°, mean speed 19 m/s corresponding to 8° in Beaufort scale) was switched on causing yawing of both ships within an angle of 5° and rolling up to 10°. The programmed wind force was approximately the same as during the ship's measurements, the results of which are shown in Figures 6–8. Like in the NAVSIM 90 simulator, the state of the sea was calculated automatically by the processor as a function of the set wind value. The tracked vessel altered its course 30° to starboard side to increase the passing distance from 0.5 NM to 1.3 NM. Figures 12–14 present values of CPA, true course and true speed of the opposite ship indicated by ARPA and AIS in the function of time for that test. As with the figures presenting the results of the tests conducted on the NAVSIM 90 simulator, due to the lack of noticeable instabilities of the CPA values indicated by AIS and ARPA, Figures 12–14 show only graphs for period of time immediately before, during and after the manoeuvre.

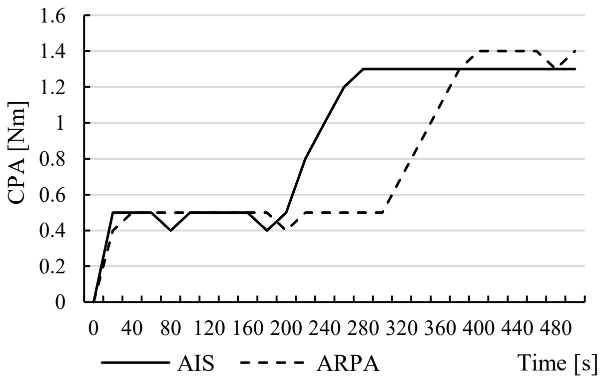


**Figure 12. Values of CPA indicated by ARPA and AIS as a function of time for the test conducted on the Polaris simulator**

Presented in Figures 13 and 14 graphs of the true course and true speed show the instantaneous values of these parameters for the time of registration indicated by the gyrocompass and the log installed on the tracked vessel.

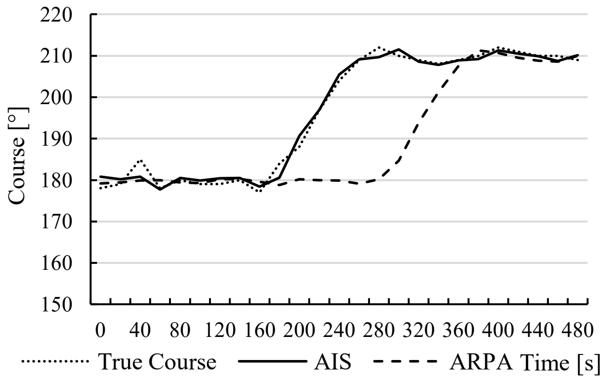


**Figure 13. Values of true course indicated by ARPA and AIS as a function of time for the test conducted on the Polaris simulator**

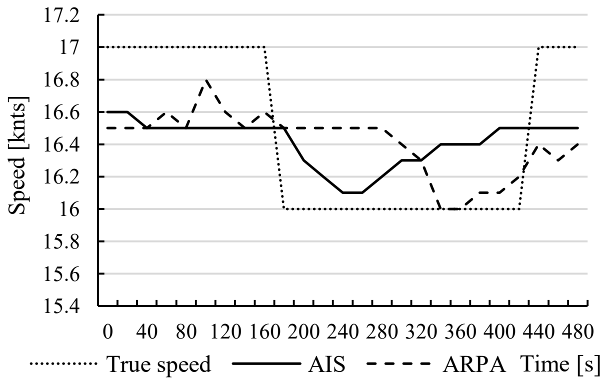


**Figure 14. Values of true speed indicated by ARPA and AIS as a function of time for the test conducted on the Polaris simulator**

## Conclusions

The number of tests, described in this paper, that were conducted on ships at sea is too small to formulate general conclusions about the accuracy and stability of the opposite vessel CPA indication by AIS and accuracy of its calculations by ARPA, but they allow the formulation of the following initial conclusions:

1. Onboard AIS, like radar tracking aids (ARPA and automatic tracking aid (ATA)), may display unstable and inaccurate CPA values of the opposite vessels, especially under unfavourable hydro-meteorological conditions. Further recordings in real conditions are necessary to find the statistical performance of AIS.
2. Due to the possible instabilities and inaccuracies mentioned in the first conclusion, a systematic observation of the CPA value of the opposite vessel indicated by both AIS and ARPA (ATA) should be recommended.

3. There is no possibility to present the inaccuracy and instability of the CPA indication by onboard AIS on simulators of the old types produced prior to the date of the introduction of AIS onboard sea going vessels and the date of entry into force of IMO Resolution MSC.192(79).
4. There are difficulties in simulating the aforementioned inaccuracy and instability of indication on modern simulation devices equipped with LCD monitors simulating the operation of navigational equipment of several manufacturers.
5. The manufacturers of simulation devices should take note of the problems identified in this conclusion.

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