TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 12
Number 4
December 2018
DOI: 10.12716/1001.12.04.04

Comaparative Study of the Accuracy of AIS and ARPA Indications. Part 2. Accuracy of the Opposite Vessel True Course and True Speed Indication

R. Wawruch
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: The article presents analysis of the automatic radar plotting aid (ARPA) and automatic identification system (AIS) indications reliability performed on the base of the results of measurements conducted on merchant vessels at sea. In the first part of the article titled "Comparative study of the accuracy of AIS and ARPA indications. Part 1. Accuracy of the CPA indications" are described: vessels on which the tests were carried out, AIS and radar equipment installed on them, observed meeting situations and accuracy of the CPA indication. In this article are discussed, for the same meeting situations, accuracy of the information on true course and true speed of the opposite vessel presented by ARPA and AIS and correlation between this accuracies and errors of the CPA indication.

1 INTRODUCTION

As emphasized in part 1 of the article titled "Comparative study of the accuracy of AIS and ARPA indications. Part 1. Accuracy of the CPA indications" published in The International Journal on Marine Navigation and Safety of Sea Transportation "TransNav", Vol. 12, No 3 [1], according to the recommendations of the Resolutions: MSC.192(79) "Adoption of the revised performance standards for radar equipment" adopted by International Maritime Organization (IMO) on 6th of December 2004 and A.1106(29) „Revised guidelines for the operational use of shipborne automatic identification systems (AIS)" adopted by the same organization on 2nd of December 2015, AIS may be used to assist in collision avoidance decision-making process as an additional source of information which supports radar and radar tracking aids, by assisting in [2,3]:

- Identification of targets by name, call sign, ship type and a navigational status;
- Presentation of targets heading;
- Immediate identification of manoeuvres performed by targets; and
- More accurate presentation of the targets courses and speeds over ground and rate of turn.

If the target data from radar tracking and AIS are both available and their association criteria are fulfilled, then as a default condition of radar equipment installed on sea going vessels on or after 1st of July 2008, the AIS target symbol and the alphanumerical AIS target data should be automatically selected and displayed only [2]. This means that if the association criteria are fulfilled, the radar display unit does not show in the default mode of work the data calculated by the radar tracking systems (ARPA od ATA).

IEC Standard 61993-2 on AIS required that on board AIS shall calculate and display value of the closest point of approach (CPA) with the accuracy not inferior to those adopted for radar equipment by IEC in the Standard 62388 on shipborne radar and by IMO in the Resolution MSC.192(79) [4,5]. According to that

requirements, accuracy of radar tracking and CPA indication by AIS shall be as described in Table 1 presented in the first part of this article and repeated there only [1,2,3,4].

On board AIS transmits automatically the actual values of the true course and true speed of the ship on which it is installed, received from the connected to it GNSS receiver, currently mainly the GPS or DGPS receiver. Due to that listed IMO recommendations and IEC standards contain requirements regarding the accuracy of the presentation of these two parameters by ARPA only, not by AIS.

The analyses described in this paper have been performed to verify that ARPA indications of tracked vessel true course and true speed in real sea conditions meet the specified accuracy requirements and to clarify the reasons for the errors in the correct CPA values presentation by both ARPA and AIS. They were carried out as a part of the statutory research No. 440 conducted at the Navigation Department of the Maritime University in Gdynia.

2 DESCRIPTION OF THE MEASUREMENTS

The measurements were performed in real (not simulated) conditions during the sea voyages of three merchant ships described in [5]:
- Bulk carrier "Magdalena Odendorff" (gross tonnage 106884);
- LPG tanker "Pampero" (gross tonnage 46789); and
- Multipurpose vessel "ESL Africa" (gross tonnage 11864).

The ships, their AIS and radar equipment used during research as well as observed meeting situations are also described in the first part of the article [5].

As already mentioned, on board AIS retransmits only data on the true course and true speed received from the GNSS receiver connected to it, so international standards and recommendations do not specify with what accuracy these data should be transmitted and then presented by AIS on the other ship. Nevertheless, for each series of measurements, the mean values and standard deviations of the true motion vector parameters were calculated to verify their stability potentially affecting the accuracy of the radar tracking and the calculation of the CPA value by ARPA and AIS.

The presented analysis was done for 55 meeting situations listed in the table 3 in the first part of the article [5]. As noted in this article, in all tests, observed vessel fitted with AIS was tracked by ARPA for at least 5 minutes before the beginning of registration and own and opposite ships were proceeding with steady courses and speeds during this time and later during the registration. There were recorded, simultaneously every 30 seconds, all elements of a radar report about the vessel being observed and tracked displayed by ARPA and AIS.

3 DISCUSSION OF TESTS RESULTS AND CONCLUSIONS

The exact numerical values of the average true courses and average true speeds of the vessels observed and tracked during the individual measurement series and doubled values of their standard deviations are presented in Table 5 published in Proceedings from the 19th International Radar Symposium (IRS) [6]. Table 2 summarizes this information and presents the number of meeting situations where true course and true speed indication errors (ARPA) or dispersion (AIS) were greater than their allowable values for a probability equal to 95%.

Table 1. Tracked target accuracy according to the IEC Standard 62388 (95% probability figures) [4]

Time of steady state [min]	Relative course [°]	Relative speed [kn / m/s]	CPA [M / km]	TCPA [min]	True course [°]	True speed [kn / m/s]
1 min: trend	11	1.5 / 0.8 or 10% (whichever is greater)	1.0 / 1.85	-	-	-
3 min: motion	3	0.8 / 0.4 or 1% (whichever is greater)	0.3 / 0.56	0.5	5	0.5 / 0.3 or 1% (whichever is greater)

Table 2. The number of meeting situations where true course and true speed indications errors (ARPA) or dispersion (AIS) were greater than their allowable values for a probability equal to 95%

Type of meeting situation	Number of meeting situations						
	Total	With error greater than acceptable					
		ARPA			AIS		
		TC+TSp	TC	TSp	TC+TSp	TC	TSp
Parallel courses - overtaking	23	4	3	6	-	4	-
Reciprocal courses	17	2	3	5	-	-	-
Crossing courses	15	6	-	5	-	3	-
Total	55	12	6	16	-	7	-

Abbreviations used in Table 2 means:
TC+TSp - true course and true speed;
TC - true speed; and
TSp - true speed.

Results of the measurements of the accuracy of ARPA and AIS indications presented in Table 5 in Proceedings from 19th IRS (the accuracy of the presentation of true motion parameters) [6] and in Table 4 in the first part of this article (the accuracy of the closest point of approach (CPA) presentation) [1] are summarized in Table 3. This table shows whether or not the accuracy requirements have been met by values of the true course, true speed and CPA of opposite ship displayed by the on board ARPA and AIS. Information that the presented data does not meet the accuracy requirements is marked in bold and underlined. The last column indicates the state of the sea during the particular series of measurements expressed in degrees of the Douglas scale.

AIS presented in all meeting situations mean value of the opposite ship's true speed with the satisfactory accuracy (with doubled value of the standard deviation less than 0.5 knots or 1% of the speed). It means that the instability during measurements of the instantaneous values of the speed of observed and tracked ships should not affect the accuracy of their CPA calculation. Values of the current true course indicated by AIS had unacceptable errors (the variation bigger than 5°) in 7 meeting situations for 55 tested. For all these 7 situations ARPA had problems with the true course calculation too. Generally, ARPA presented true motion parameters (true course, or true speed, or true course and true speed) with errors greater than acceptable in 34 meeting situations for 55 tested (61% of all situations). No relationship was found between the magnitude of errors in the determination of true motion vector and CPA and the type of meeting situation and the state of sea.

The measurements show that both ARPA and AIS can indicate the CPA value of the radar tracked vessel fitted with AIS with accuracy smaller than that required by the regulations. Analysis of the tests results does not clearly explain the causes of these errors. Interesting are the results of measurements No 5, in which was tracked, at sea state 5°, overtaken cargo ship "Cristopher" proceeding on parallel course at the distances 1.8-1.6 M (3.3-3.0 km) with the speed of 15.1 knots (7.8 m/s). Both ARPA and AIS indicated the true parameters of its motion with the required accuracy. The accuracy requirements also met the CPA value shown by ARPA. The unacceptable error had only CPA indicated by the AIS (Figures 1, 2 and 3).

Table 3. Compliance with accuracy requirements for a probability equal to 95%

Number of meeting situation	Compliance with accuracy requirements True course ARPA	AIS	True speed ARPA	AIS	CPA ARPA	AIS	State of the seas
Parallel courses - overtaking							
1	Yes	Yes	Yes	Yes	Yes	Yes	2
2	Yes	Yes	Yes	Yes	Yes	Yes	4
3	**No**	Yes	Yes	Yes	**No**	**No**	5
4	**No**	**No**	**No**	Yes	**No**	**No**	3
5	Yes	Yes	Yes	Yes	Yes	**No**	5
6	Yes	Yes	Yes	Yes	Yes	Yes	4
7	**No**	**No**	Yes	Yes	**No**	**No**	1
8	Yes	Yes	**No**	Yes	**No**	**No**	3
9	**No**	Yes	**No**	Yes	**No**	**No**	3
10	Yes	Yes	Yes	Yes	**No**	**No**	4
11	Yes	Yes	**No**	Yes	**No**	**No**	2
12	Yes	Yes	**No**	Yes	**No**	**No**	6
13	Yes	Yes	**No**	Yes	Yes	Yes	3
14	No	Yes	Yes	Yes	Yes	Yes	2
15	Yes	Yes	Yes	Yes	**No**	Yes	3
16	**No**	**No**	**No**	Yes	**No**	**No**	4
17	Yes	Yes	Yes	Yes	Yes	Yes	1
18	Yes	Yes	Yes	Yes	**No**	**No**	3
19	Yes	Yes	Yes	Yes	Yes	Yes	2
20	Yes	Yes	Yes	Yes	Yes	Yes	4
21	**No**	**No**	**No**	Yes	**No**	**No**	7
22	Yes	Yes	**No**	Yes	**No**	**No**	1
23	Yes	Yes	**No**	Yes	**No**	**No**	3
Reciprocal courses							
24	**No**	Yes	**No**	Yes	**No**	Yes	4
25	Yes	Yes	**No**	Yes	Yes	Yes	4
26	Yes	Yes	**No**	Yes	**No**	Yes	6
27	**No**	Yes	**No**	Yes	**No**	Yes	1
28	**No**	Yes	Yes	Yes	**No**	Yes	5
29	Yes	Yes	**No**	Yes	Yes	Yes	2
30	Yes	Yes	**No**	Yes	Yes	Yes	3
31	**No**	Yes	Yes	Yes	**No**	Yes	2
32	Yes	Yes	Yes	Yes	Yes	Yes	3
33	Yes	Yes	Yes	Yes	Yes	Yes	5
34	Yes	Yes	Yes	Yes	Yes	Yes	1
35	Yes	Yes	**No**	Yes	**No**	**No**	4
36	Yes	Yes	Yes	Yes	Yes	Yes	5
37	Yes	Yes	Yes	Yes	**No**	**No**	2
38	Yes	Yes	Yes	Yes	**No**	Yes	2
39	**No**	Yes	Yes	Yes	**No**	Yes	3
40	Yes	Yes	Yes	Yes	Yes	Yes	4
Crossing courses							
41	Yes	Yes	**No**	Yes	**No**	**No**	4
42	Yes	Yes	Yes	Yes	Yes	Yes	3
43	**No**	**No**	**No**	Yes	**No**	**No**	5
44	Yes	Yes	Yes	Yes	Yes	Yes	4
45	Yes	Yes	**No**	Yes	Yes	Yes	4
46	**No**	Yes	**No**	Yes	**No**	**No**	5
47	**No**	Yes	**No**	Yes	**No**	Yes	2
48	Yes	Yes	Yes	Yes	Yes	Yes	3
49	**No**	Yes	**No**	Yes	**No**	Yes	2
50	Yes	Yes	**No**	Yes	**No**	**No**	2
51	**No**	Yes	**No**	Yes	**No**	Yes	5
52	Yes	**No**	Yes	Yes	Yes	Yes	7
53	Yes	Yes	**No**	Yes	Yes	Yes	7 sw
54	Yes	Yes	**No**	Yes	**No**	**No**	2
55	**No**	**No**	**No**	Yes	Yes	Yes	3

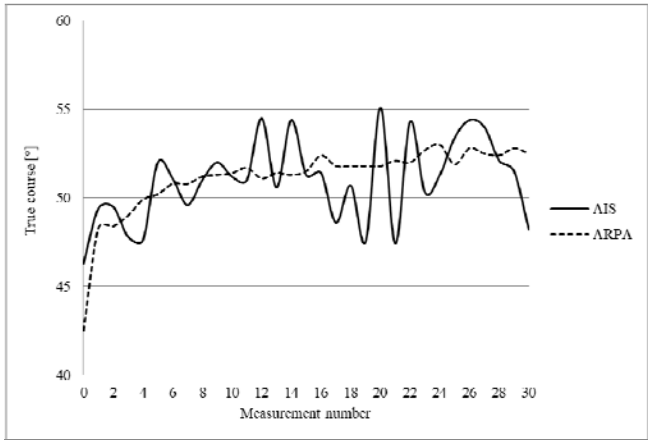

Figure 1. True course values of the ship "Christopher" (meeting situation 5) presented by ARPA and AIS [7]

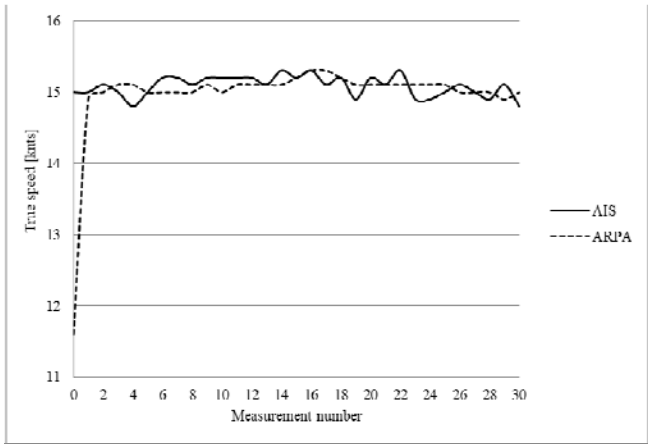

Figure 2. True speed values of the ship "Christopher" (meeting situation 5) presented by ARPA and AIS [7]

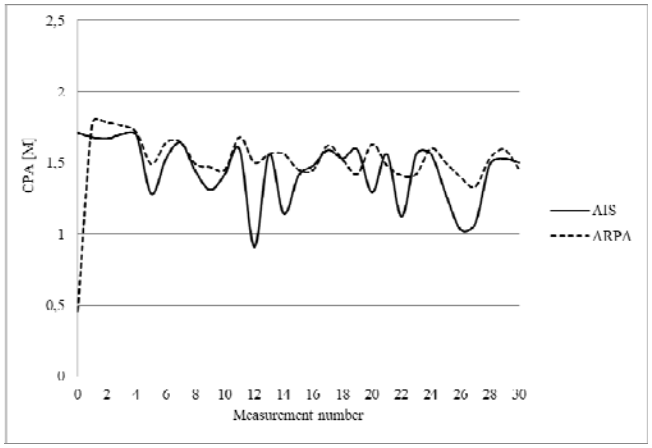

Figure 3. CPA values of the ship "Christopher" (meeting situation 5) presented by ARPA and AIS [7]

Another interesting example are the results of measurements No 22, in which was tracked, at sea state 1°, overtaken cargo ship "Union Ranger" proceeding on parallel course at the distances 18.7-18.4 M (34.6-34.1 km) with the speed of 11.7 knots (6.0 m/s). AIS indicated the true parameters of its motion with the required accuracy. The accuracy requirements also met the true course value shown by ARPA. The unacceptable error had CPA indicated both by the ARPA and AIS (Figures 4, 5 and 6).

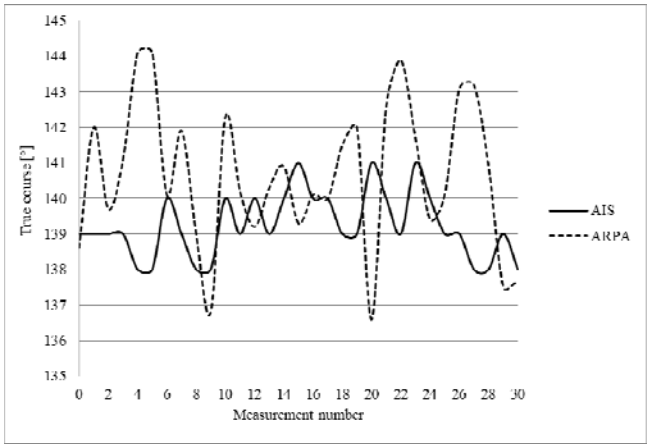

Figure 4. True course values of the ship "Union Ranger" (meeting situation 22) presented by ARPA and AIS [7]

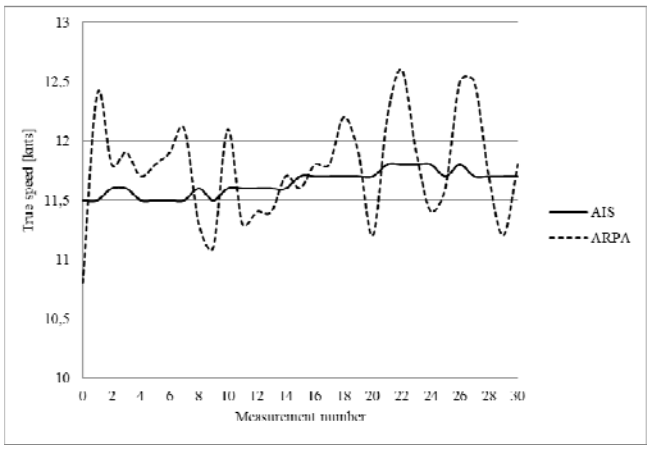

Figure 5. True speed values of the ship "Union Ranger" (meeting situation 22) presented by ARPA and AIS [7]

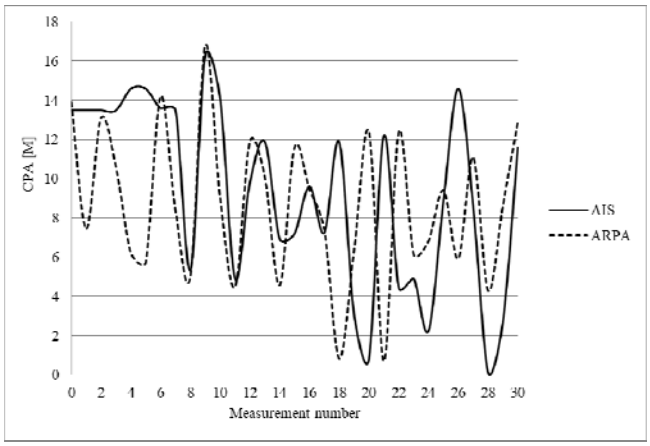

Figure 6. CPA values of the ship "Union Ranger" (meeting situation 22) presented by ARPA and AIS [7]

Figures 7-9 show, for example, the values of the true course, true speed and CPA as a function of the measurement time for the measurement series No. 1, in which all parameters were presented with the required accuracy both by AIS and by ARPA. There was tracked, at sea state 2°, cargo ship "Alexandra" proceeding on parallel course at the distances 2.5-2.2 M (4.6-4.1 km) with the speed of 17.9 knots (9.0 m/s).

1

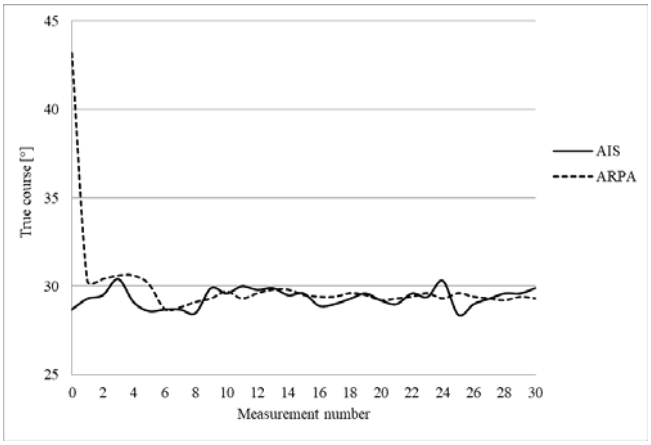

Figure 7. True course values of the ship "Alexandra" (meeting situation 1) presented by ARPA and AIS [7]

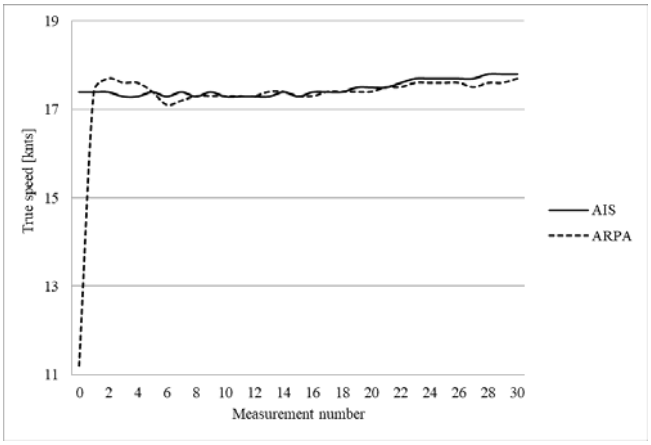

Figure 8. True speed values of the ship "Alexandra" (meeting situation 1) presented by ARPA and AIS [7]

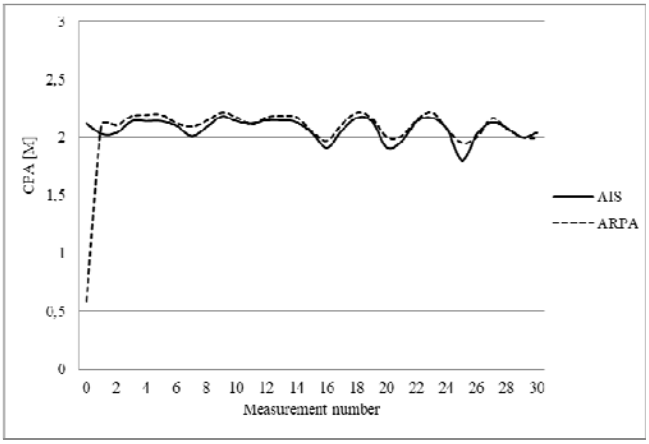

Figure 9. CPA values of the ship "Alexandra" (meeting situation 1) presented by ARPA and AIS [7]

An example of one of the three situations in which all parameters, with the exception of the true speed indicated by AIS, were presented with too large errors was the meeting situation 16. There was tracked, at sea state 4°, cargo ship "Ocean Trader" proceeding at the distances 19.8-19.6 M (36.7-36.3 km) with the speed of 11.1 knots (5.7 m/s). Graphs for this meeting situation are presented in Figures 10, 11 and 12.

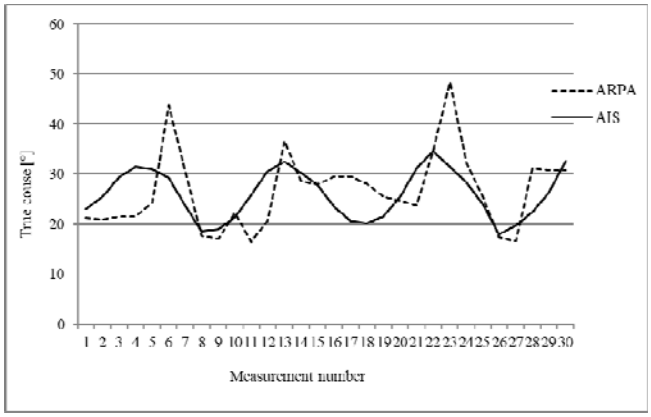

Figure 10. True course values of the ship "Ocean Trader" (meeting situation 16) presented by ARPA and AIS [8]

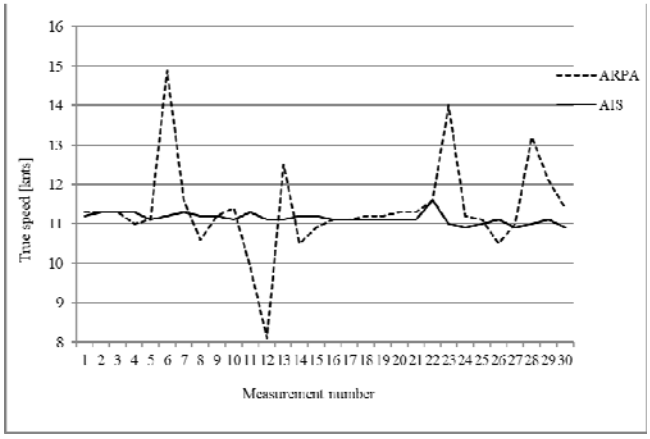

Figure 11. True speed values of the ship "Ocean Trader" (meeting situation 16) presented by ARPA and AIS [8]

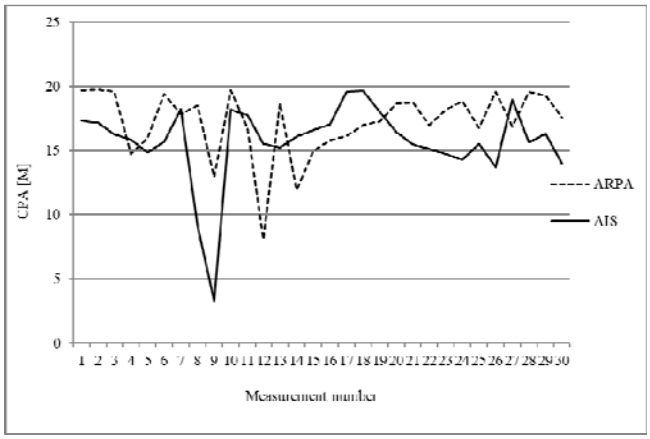

Figure 12. CPA values of the ship "Ocean Trader" (meeting situation 16) presented by ARPA and AIS [8]

The number of described in this paper measurements carried out on merchant ships at sea and the number of tested equipment of different manufacturers are too small to formulate on their basis general conclusions about the stability of the opposite vessel true course and true speed indications by AIS and accuracies of their calculations by ARPA and correlation between these stability and accuracy of the CPA indications by ARPA and AIS, but they allow for the following initial conclusions:

1 As expected, AIS is really a much more accurate source of information about the opposite vessel true motion vector than ARPA.

2 No clear relationship was found between the accuracy and stability of the opposite vessel true motion vector indication and the accuracy of its CPA value displayed both by ARPA and AIS. AIS displayed observed vessel true vector with too low stability in 7 meeting situations and its CPA with unacceptable error in 21 situations (for a total of 55 investigated meeting situations).

REFERENCES

[1] R. Wawruch, *"Comparative study of the accuracy of AIS and ARPA indications. Part 1. Accuracy of the CPA indications"*, The International Journal on Marine Navigation and Safety of Sea Transportation "TransNav", Vol. 12, No 3, September 2018, pp. 439-443.

[2] Resolution MSC.192(79) *"Adoption of the revised performance standards for radar equipment"*, IMO, London 2004.

[3] Resolution A.1106(29) *"Revised guidelines for the operational use of shipborne automatic identification systems (AIS)"*, IMO, London 2015.

[4] IEC Standard 61993-2 ED3 *"Maritime navigation and radiocommunication equipment and systems – Automatic identification systems (AIS) – Part 2: Class A shipborne equipment of the automatic identification system (AIS) – Operational and performance requirements, methods of test and required test results"*, IEC, Geneva 2017.

[5] IEC 62388 *"Maritime navigation and radiocommunication equipment and systems – Ship-borne radar – Performance requirements, methods of testing and required test results"*, IEC, Geneva 2012.

[6] R. Wawruch, *"Tests of the Accuracy of Indications by ARPA and AIS of the Opposite Vessel True Course, True Speed and CPA"*, The 19th International Radar Symposium "IRS 2018", June 20-22, 2018, Bonn, 2018, Proceedings, DGON, Bonn 2018 (CD).

[7] M. Kalamon, *"AIS jako dodatkowy środek obserwacji i oceny ryzyka zderzenia"*, *engineering thesis,* Gdynia Maritime University, Gdynia 2017.

[8] M. Wilczyński, *"Analiza porównawcza dokładności śledzenia systemów AIS i ARPA"*, *engineering thesis,* Gdynia Maritime University, Gdynia 2015.