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The Integrity of Information Received by Means of AIS During Anti-collision Manoeuvring

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ABSTRACT: Radar and ARPA feature certain efficacy limitations due to weather conditions and target manoeuvres. Therefore, it appears rational to supplement the information derived from radar with additional information. A system which is claimed to be tailored to perform this task is AIS delivering proper information automatically and continuously. However, in certain users opinion, integrity of AIS data is still insufficient. In this paper, discussion concerning incompleteness and integrity of this type of data is presented. To prove effectiveness of AIS dynamic data in collision avoidance, detailed investigations have been conducted. Analysed data originate from the Gulf of Gdansk, dating back to the years 2006-2012. According to the research results, there are exceptional situations, when the information coming from the sensors cooperating with AIS is incomplete. This problem concerns information related to HDG and ROT, especially, when the vessels are not "on the way".

1 BACKGROUND

The Automatic Identification System (AIS) is in fact the system for broadcasting specific information concerning the ship to other ships and shore stations. In general it consists of:

- Group of constant data, e.g. the name of ship and Call sign;
- Group of dynamic data, e.g. position, heading and speed of the ship;
- Group of information concerning the trip i.e. port of destination and ETA.

Information provided by AIS are extremely useful for automatic tracking systems, vessel traffic services. In addition it makes bridge watchkeeping duties more comfortable. According to many expertises, since its introduction in 2004, the system has played an important role in improving safety at sea. The introduction of the system into shipping industry has been oriented mainly on VTS and monitoring of the traffic on busy waters. However, other aspects of maritime security in vicinity of different threats, e.g. with the piracy or for environments are equally important.

It seems evident that the system plays a vital role in search operations on the sea as the source of the information with regard to the position of victims, but the practice proved that AIS could be very useful also in search and rescue operations as a tool for resource coordination. In this context, it is proper to remember that the system assures the communication not only between ships, but also with aircrafts. In addition, recent years revealed how useful can be AIS-data registered in the system of shore-base stations for accidents investigations, since it provides accurate information concerning positions, headings, courses, rates-of-turn and speeds of all participants of accident, exactly coordinated in relation to the time.

Innovative, and to some extent not founded by the architects of the system, is the use of AIS position data in different geographic information systems available on the Internet.

This use, as opposed to abovementioned examples, wakes however certain provisions either on the part of IMO or usual users, as the potential threat for international maritime transport.

2 COLLISION AVOIDANCE

One of the most important field of application of AIS data planned on the beginning stage of the system was collisions avoidance, especially between large vessels at sea that are not within range of shore-based systems. However this use is still marginal and controversial. It results from the fact that AIS transponder is typically connected to the bridge equipment and is gathering data from a Global Navigation Satellite System (GNSS) receiver, gyrocompass or heading indicator device and a rate of turn indicator. Such set of information is sufficient for the planning of avoidance maneuvers. Additionally, data delivered by AIS prove to be more exact and more recent than these, which is collected by means of ARPA. This is especially important when ships are not keeping the heading or speed. In such situation, data provided by ARPA are not sufficiently reliable. Conversely, due to significant limitations, AIS cannot be recognized as the main tool for the collision avoidance. Primary limitation is the fact that not all vessels are equipped with AIS devices. In addition, the constraints of VHF radio communications play an important role, but the most troublesome is the common opinion of the mariners with regard to the system and the insufficient confidence to the AIS information. It is a fact that the system was introduced hurriedly and first years of its use resulted in many examples of its incorrect operation. Common use of AIS caused the opinion on the imperfections of the system, related to the lack of transmission or the transfer of not integrated information, emerged. However some signs of improvement of the situation can be found in the analysis of accessibility of one of base stations situated at the Polish shore [Felski, Jaskólski EJN].

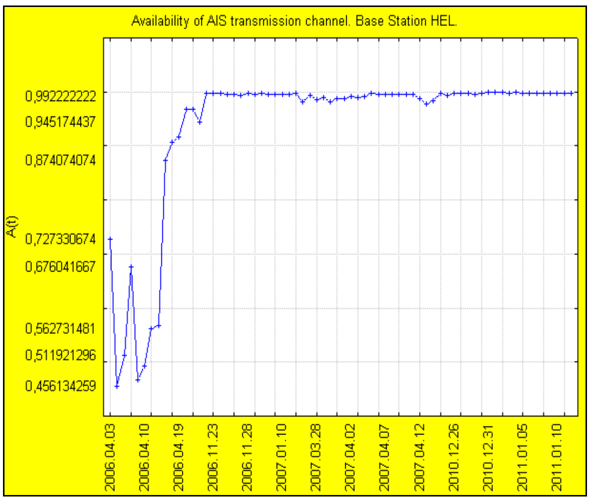

Figure 1. Availability of AIS transmission channel. Base Station HEL. [own study]

As an example of users opinion concerning the AIS, this information can be used in the results of opinion poll conducted by the authors of this paper in November 2011 on the group of deck officers with a professional experience from 5 to 15 years on their position. The question was: "what kind of information delivered by AIS can be useful for collision avoidance?" All participants of the investigation pointed the ship name as the most useful information for this task. It seems that among investigated officers the prevailing method of the avoidance of collisions is by means of explanations of mutual intentions by radio. In such case, AIS delivers the important information about the name of the ship, what gives no radaar, and is indispensable for establishing the communication via VHF. Suprisingly, only 70-80% investigated staff members perceive advantages from gaining of the information broadcasted by nearby ship concerning its heading and speed.

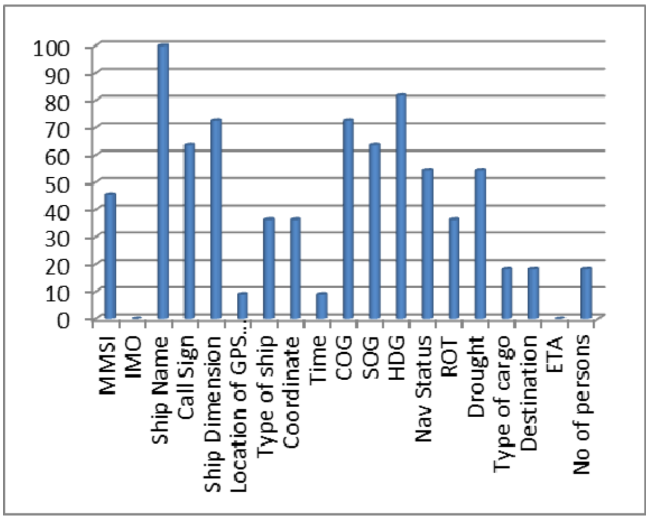

Figure 2. Usefulness of AIS information [own study]

Overall studies on the incompleteness and integrity of AIS information published to date are generally linked to message No. 5 (Static & voyage related data). This problem was also analysed by [Harati-Mokhtari A. et all, 2007a] and [Bailey N., 2005], [Drozd W., et all, 2007], [Harati-Mokhtari A. et all, 2007b], [Hori A., et all, 2009]. However, literature studies revealed that there is no publications concerning quality of the dynamic information, particularly the one that is important in the analysis of anti-collision manoeuvring.

This paper is limited to presenting the results of the integrity of AIS dynamic information. An assessment of the integrity was performed on the basis of AIS signals recorded in the years 2006, 2007, 2010, 2011, 2012. This enabled a demonstration of the variability of the measured navigation characteristics.

3 DEFINITION OF INTEGRITY

In respect to maritime navigation, the integrity is widely referenced to the radio navigation system. It appeared in 2001, when (Federal Radio navigation Systems, 2001) defined it as a system ability to timely inform deck officers about the AIS unfitness for its use in the navigation process. Since 2005, (Federal Radionavigation Plan, 2005) the term is defined as a measure of confidence in the accuracy of the information provided by the system. The same document adds that integrity implies the ability of radionavigation system for the timely alerting the user when the system should not be used for navigation.

Perceiving AIS as a navigation system is debatable. This is essentially a radio broadcast channel. For this reason, it does not provide information about its improper work.

The authors consider the integrity as a measure of confidence in derived information and the degree of correctness of received AIS messages. This measure will be expressed by statistical methods.

4 DATASETS AND RESEARCH AREA

The studies of AIS integrity were performed on the basis of recorded messages in txt files. The study was conducted in the Gulf of Gdansk. Each information recorded to a file is treated as a series. Analyzes used only 24-hour recordings, which were made on the basis of statistical analysis for every 7 days. Data were recorded from 4 April 2006 to 08 January 2012 (selected 54 weeks - 378 days). Assessment of the dynamic information integrity may be carried in a message group 1, 2 and 3. Message No. 1 provides information concerning the status navigation, position, SOG, COG, ROT, HDG. Summary of the range of valid data and the value indicating incomplete data are shown in Table 1.

Table 1. Summary of ranges of correct and incorrect data in the message No. 1 [ITU R.M.1371, 1998]

Components of dynamic data	Correct value	Incorrect value
LONGITUDE	±180	181
LATITUDE	±90	91
SOG	[0, 1022]	1023
COG	[0, 3599]	3600
TRUE HEADING	[0, 359]	511
RATE OF TURN	±127	128

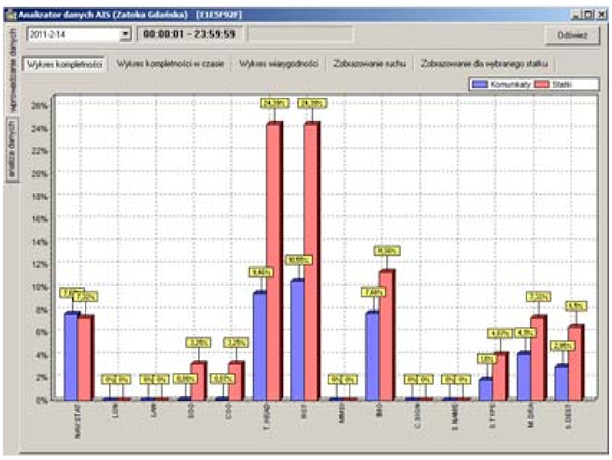

Figure 3. Graph of AIS dynamic information integrity during 24 hours [own study]

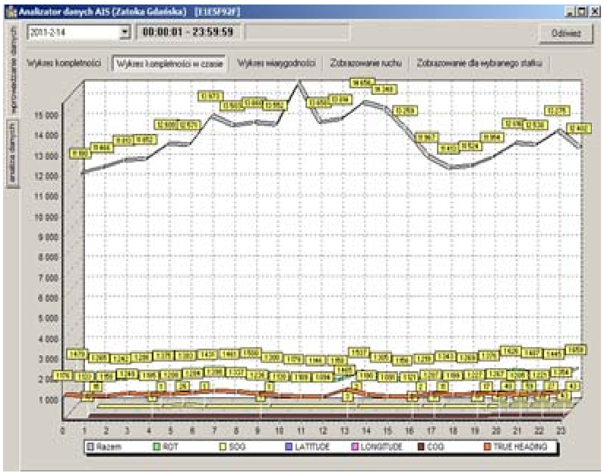

Figure 4. Graph of AIS dynamic information integrity during 1 hour [own study]

On the basis of research criterion authors have developed a research tool to evaluate the integrity of dynamic information. The results from a single session are shown in Figure 3 and Figure 4.

The authors suggested two research approaches to conduct a study of AIS information integrity. It was a "criterion of lines", referring to the number of lines of information transmitted and the "criterion of ships" corresponding information for the state of incorrectness.

5 STATISTICAL SUMMARY OF RESULTS

According to the methodology, the following components of Position Report were evaluated:
- true heading;
- rate of turn;
- position;
- speed over ground;
- course over ground.

5.1 *Integrity of true heading*

The analysis of study results leads to the conclusion that the integrity of HDG is below requirements in each of the 7-day test series. This is a problem for "criterion of vessels" and "criterion of lines". Maximum factors are: 0,86 (ships) and 0,92 (lines).

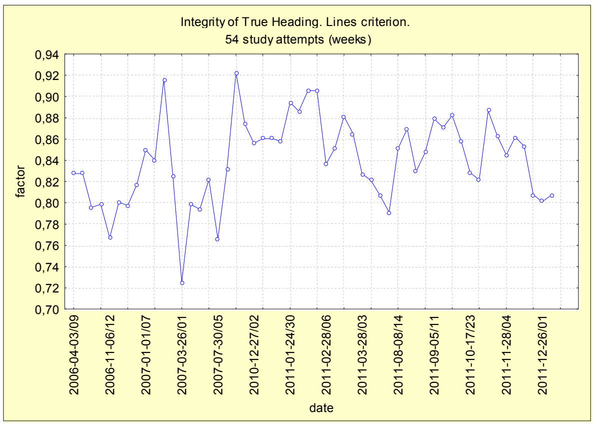

Figure 3. Graph of the integrity of True Heading, „criterion of lines" [own study]

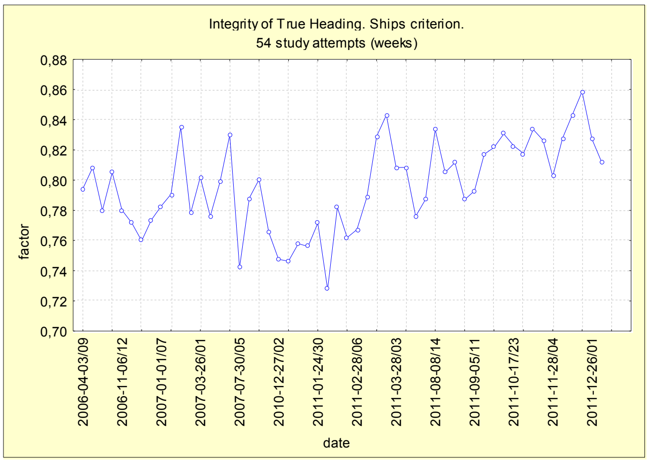

Figure 4. Graph of the integrity of True Heading, „criterion of ships" [own study]

Detailed analysis of the information excluded from further study the information transmitted by ships standing in port and at anchor if the SOG was less than 4 knots. Results of the study are presented below (Fig 5, Fig 6) through the filtering data used for integrity analysis.

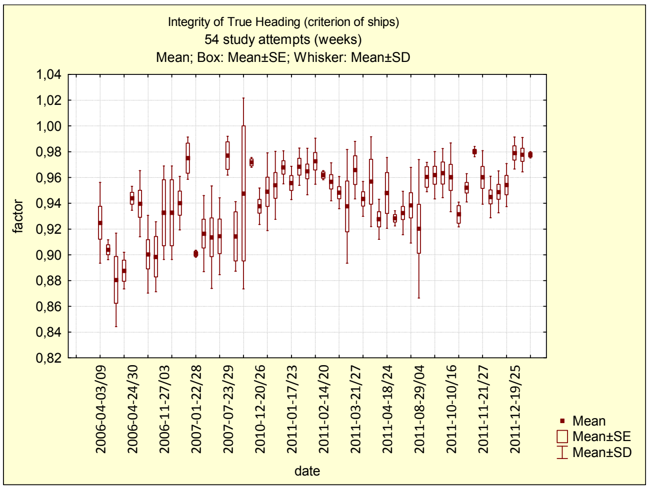

Figure 5. Integrity of True Heading after filtration process , „criterion of ships" [own study]

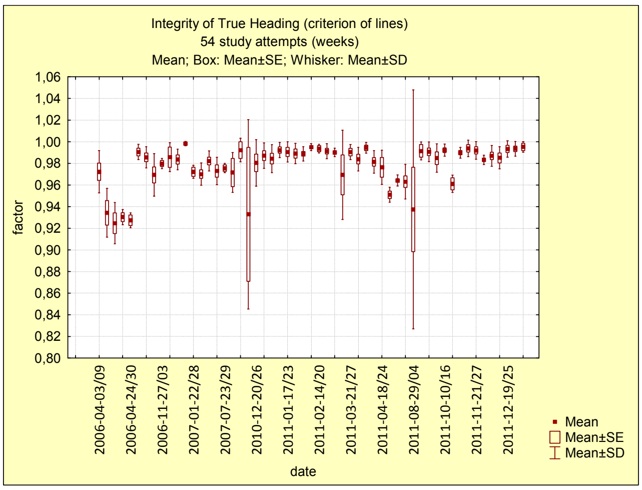

Figure 6. Integrity of True Heading after filtration process , „criterion of lines" [own study]

During research, it was observed that lower coefficients were observed for the "criterion of ships".

5.2 *Integrity of rate of turn*

The maximum value of the integrity coefficient of the series amounted to 0.880 for "criterion of vessels" and 0.930 for "criterion of lines". This problem has been presented, *inter alia*, by (Banyś P., et. all, 2012), where the research was conducted in approaches to the port of Rostock, and on the Balitc Sea between Arkona and Treleborg. The investigation results were presented at European Navigation Conference 2012. In this case, the coefficient on the ROT integrity in the harbour area was at the level of 0.716. In the coastal area, correctness was at the level of 0.948. Preliminary results of ROT integrity were presented below.

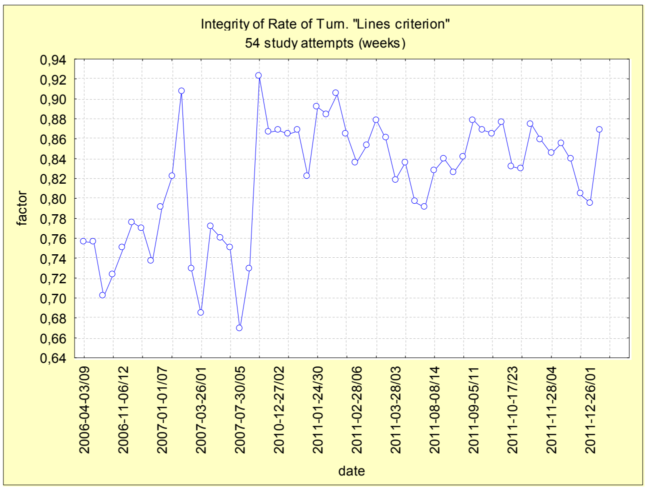

Figure 7. Graph of the ROT integrity, „criterion of lines" [own study]

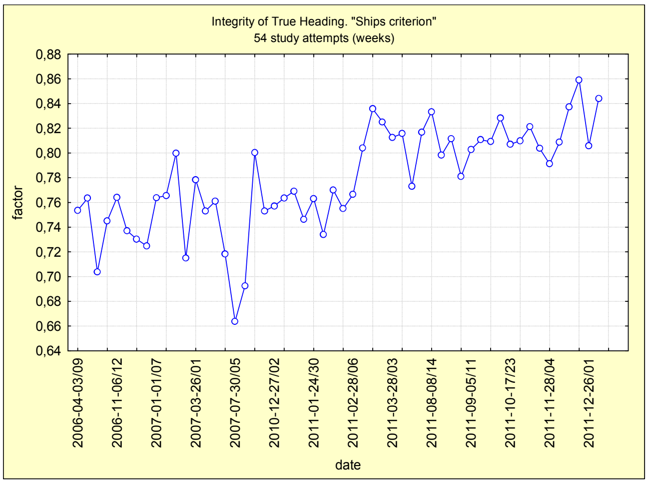

Figure 8. Graph of the ROT integrity, „criterion of ships" [own study]

Detailed analysis of the information were excluded from further examination of the information transmitted by ships standing in port and at anchor if the SOG was less than 4 knots. Below the results of the study, obtained through the filtering data used for integrity analysis, are presented (mean values, standard deviations and standard errors).

On the basis of the integrity graph of information concerning ROT (Fig. 9, Fig. 10), the improvement of information quality has been observed for the session of December 2010. Up to December of 2010 the results take much larger values of standard deviations and standard errors of parameters.

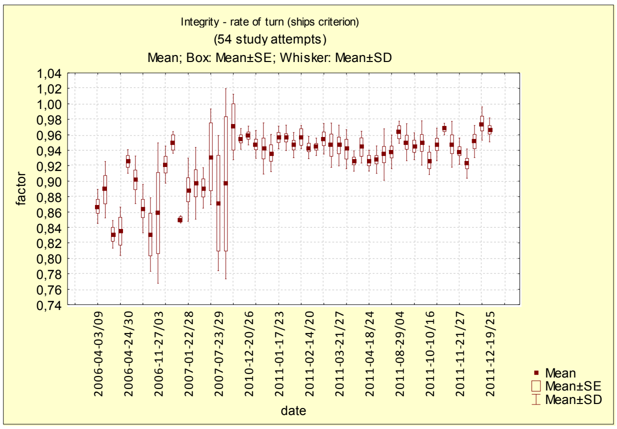

Figure 9. Graph of the integrity ROT after filtration process, „criterion of lines”[own study]

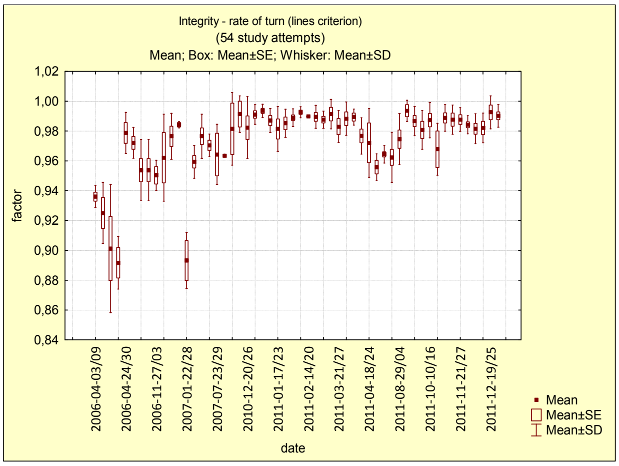

Figure 10. Graph of the integrity ROT after filtration process, „criterion of ships”[own study]

5.3 *Integrity of geographical position*

The results of integrity of information for the geographical position are shown below.

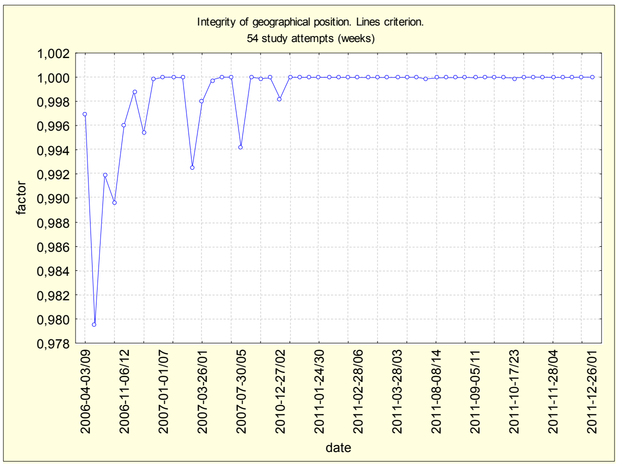

Figure 11. Graph of the integrity position, „criterion of lines” [own study]

The results for "criterion of lines" and "criterion of ships" indicate a high coefficient for position integrity. The increase in completeness of geographical position can be observed from December 2010.

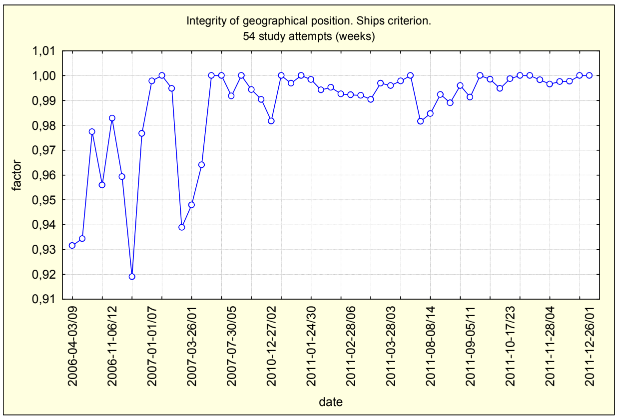

Figure 12. Graph of the integrity geographical position, „criterion of ships” [own study]

5.4 *Integrity of speed over ground & course over ground*

Preliminary results of SOG and COG integrity were presented below (Figure 13, Figure 14).

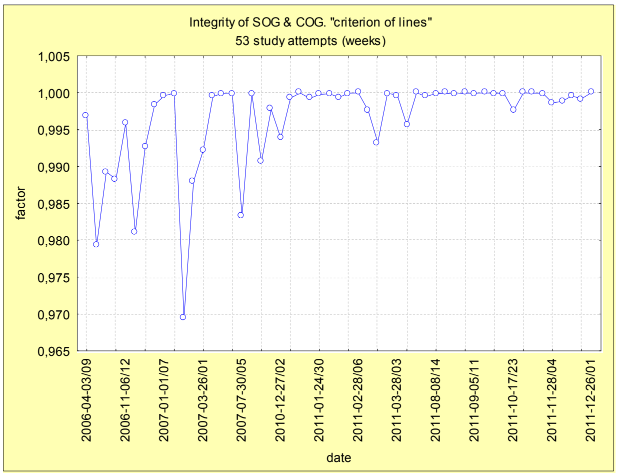

Figure 13. Graph of the SOG and COG integrity „criterion of lines” [own study]

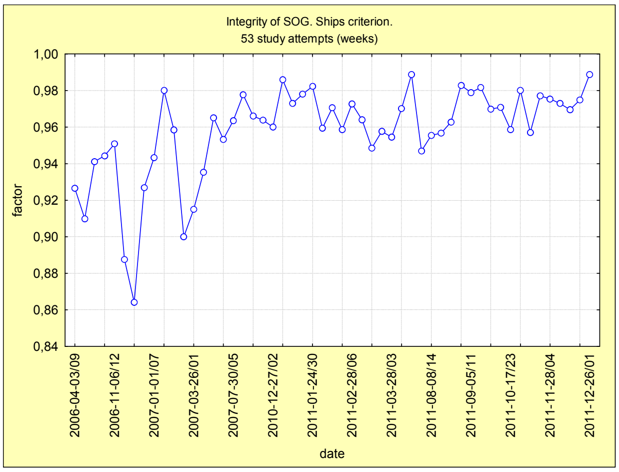

Figure 14. Graph of the SOG and COG correctness „criterion of ships” [own study]

According to the research results concerning the SOG and COG integrity, since December 2010 the increase of coefficients was observed.

6 SUMMARY

This paper presents the results of AIS integrity dynamic data. The research studies of dynamic data integrity provides information with regard to abilities of the AIS information to supplement radar and ARPA information. The results of a measurement experiment indicate a high level of dynamic data integrity. The smallest value of variable integrity concerns ROT (0.9755). The highest value of the coefficient applies to geographical position (0.9986). The accuracy of the parameters is associated with accurate indications of GNSS receivers and gyro-compasses. The results of AIS integrity information are presented in table 2.

Table 2. The results of AIS integrity information [own study]

Variable	X*	δ**	X_{max}***	X_{min}****
Integrity of heading– “criterion of lines”	0,9783	0,0118	0,9921	0,9378
Integrity of heading – “criterion of ships”	0,9436	0,0214	0,9675	0,9122
Integrity of ROT – “criterion of lines”	0,9755	0,0125	0,9894	0,9379
Integrity of ROT – “criterion of ships”	0,9316	0,0246	0,9552	0,8911
Integrity of position – “criterion of lines”	0,9986	0,0011	0,9996	0,8649
Integrity of position - “criterion of ships”	0,9867	0,0074	0,9953	0,9765
Integrity of SOG & COG - criterion of lines”	0,9964	0,0028	0,9993	0,9724
Integrity of SOG & COG - “criterion of ships”	0,9576	0,0149	0,9775	0,9390

*X – mean, **δ – standard deviation,*** X_{max}- maximum value, ****X_{min} - minimum value

According to research presented in the table 2, the most reliable variables is: position – “the criterion of lines” (0.9986), “the criterion of ships” (0.9867), whereas the lowest rate was obtained for integrity of ROT – “criterion of ships” (0.9316). More than 84.98% of the communications came from vessels moving at a speed of less than 1 knot in the harbour area for 15.84% of all messages with unreliable information on the true heading. This state is represented by 80.17% of vessels transmitting incomplete information in the harbour area with SOG less than 1 knot to 20.49% of all vessels in the Gulf of Gdansk transmitting incompleted true heading. It was found that 17.3% of all messages with incomplete ROT comes from 85.67% of ships, to the maximum. The speed was less than 1 knot and they were located in the harbour area. This state is represented by 77.56% of the vessels. They meet the previously specifed criteria for the position and velocity of 21.74% of all vessels transmitting unreliable messages on ROT in the Gulf of Gdansk. Graphical presentation of the studies has been illustrated in Figure 11. During the studies of dynamic information (HDG & ROT), when SOG was less than 4 knots, the information from the harbours area have been omitted. The number of vessels transmitting unreliable messages is not equal to the number of unreliable messages. It results from the time interval of transmitted data by the on-board AIS.

These differences can be observed in Table 2 and in Figure 11 These factors present a synthetic summary of the integrity of investigated variables.

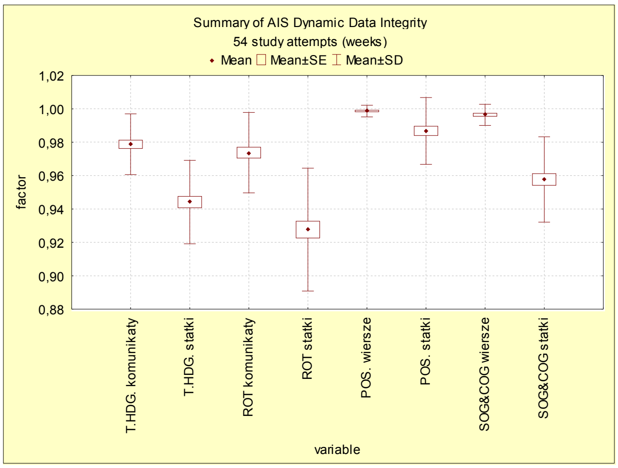

Figure 11. Summary of the results for the selected components of The Integrity Position Report (selected variables) [own study]
*T.HDG komunikaty – True Heading “criterion of lines”, T.HDG statki - True Heading “criterion of ships”, ROT komunikaty – Rate Of Turn ”criterion of lines”, ROT statki – Rate Of Turn “criterion of ships”, POS wiersze - Geographical Position “criterion of lines”, POS statki - Geographical Position “criterion of ships”, SOG&COG wiersze – Speed Over Ground & Course Over Ground “criterion lines, and ships”.

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