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The Assessment of Drafting Ship Movement Parameters Using Radar and the Automatic Identification System

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ABSTRACT: This article presents the movement vector research conducted in the radar laboratory of Gdynia Maritime University and during vessel cruises. The precision of designating the vessels' location, course, speed and CPA were researched using on-baord radars and AIS data. It is concluded that the precision of designating the researched parameters is greater than the International Maritime Organization requires.

1 INTRODUCTION

At the beginning of the 21st century a major shift occurred in the field of naval navigation. The navigator was now in possession of data pertaining to ships in their vicinity which was previously unavailable. Utilizing the Automatic Identification System ships transmit their name, size, etc. as well as current navigational readings. This opens new possibilities of situation assessment and allows for direct radio communications. One can obtain more precise data about other vessels than the one given by an on-board radar, but, at the same time, they can be blocked or incorrect. As a result of that, the comparative research of result precision between ship radar and the Automatic Identification System was undertaken. It was conducted within Gdańsk Bay using radars installed in AM laboratories and on-board commercial vessels.

2 TRACKING PRECISION REQUIREMENTS

On the 6th of December 2004 the Maritime Safety Committee adopted a new resolution entitled Adoption of the Revised Performance Standards for Radar Equipment[2, which pertains to the radar equipment installed on-board sea vessels starting on 1st July 2008. This document states the requirements for radar tracking devices and the precision with which object parameters must be presented during acquisition and tracking. The International Electrotechnical Union presented a norm which precisely states in what way this equipment must be tested. It is the IEC 60872-1 norm: Maritime navigation and radio-communication equipment and systems – Part 1: Shipborne radar - Automatic Radar Plotting Aids- Performance requirements. Methods of testing and required test results[1].

Automatic tracking is based on the relative radar echo position measurement and inner vessel movement parameters. Other available sources of information may be used as a support in the process of automatic tracking. Echoes clearly visible for 5 out of 10 concurrent cycles of antenna rotation, or a period equal to that, should be tracked. For vessels travelling with real speeds up to 30 knots, the tracking device should give results with error margins not greater than those given in table 1 (with 95% probability):

Table 1. Tracking device precision (for 95% probability)[2]

Time of set tracking process	Relative course	Relative speed	Closest point of approach	Time of closest point of approach	Real course	Real speed
Minutes	Degrees	Knots	Nautical mile	Minutes	Degrees	Knots
1	11	1.5 or 10% [1]	1.0	-	-	-
3	3	0.8 or 1%[1]	0.3	0.5	5	0.5 or 1%[1]

- relative movement tendencies of the echo in one minute tracking intervals,
- movement parameters of the echo in three minute tracking intervals.
- The tracking process is set when own vessel and the tracked object do not manoeuvre and the precisions are as follows:
- radar measurements are within 2o and 50m or +/- 1% observational range (bigger margin of error decides),
- the information about movement parameters is less sufficient than that recommended by IMO in resolutions.

Device testing leading to vessel installation is performed on a simulator, which allows the introduction of echoes with the required parameters. Those parameters are kept with precision, so the object movement conditions are stable and unchanged in stable environmental conditions

3 VESSEL MOVEMENT VECTOR TESTING IN GDAŃSK BAY

Systematic surveillance of vessel movement in Gdańsk Bay is performed using equipment installed in the radar laboratory. Data given by the radars is compared with data given by the Automatic Identification System, through which vessels send current navigational parameters obtained from their equipment. In addition, vessels move within Gdańsk Bay on designated waterways and thus their real courses are known. Measurement conditions are better than on open sea because the ships' own movement does not play a role.

The Automatic Identification System delivers data from ship equipment, and allows for source information gathering, the same information the ship's officer obtains. This is the best source of data, however not always. We can switch the AIS off when it endangers our safety. It being deactivated means the vessel is no longer visible within the system. We obtain one-time data from a given device (GPS receiver, gyrocompass) in regular intervals dependent on the ship's speed. However, the radio transmission is not always received and our actions can cause the data sent to be invalid. That is why the main information source for manoeuvre planning is the radar. In the AIS system the position of the receiver antenna is transmitted, while the echo is created where the microwave signal is reflected (the hull or other elements of the vessels construction) and such a signal is prolonged with the radars transmitted signal and widened by the radar antenna radiation angle. That is why the shift between both positions will occur. Due to the fact that the data is calculated from subsequent positions, differences in other parameters will occur, that is the course of the tracked vessel, its CPA and TCPA speed. Measurements are recorded every minute. Every vessel is usually surveilled for a period of several minutes to one hour.[3]

Radars with the X Raytheon Mk2 i NSC34, and Decca AC 1659 spectrums were used in the laboratory. Both Raytheon radars worked with one transmitter, but the same signal which can be seen on the diagram, was calculated differently due to different software.

On Gdańsk Bay about 100 vessel cruises were recorded. The radar measures the distance and direction of the echo. The CPA, the time it has achieved, as well as the course and speed of the vessel are calculated based on the following measurements. Distance measurements in the 10 Nm range are 95% probable to within a circle of 0.03 Nm in diameter. The distances between radar echo position and that obtained through AIS are within a 0.03 to 0.06 Nm range. The values are within the width range of 0.5o (from 0.2o to 0.7o). Devices from different producers calculate those parameters differently. The ARPA by Raytheon always shows a greater distance than that showed on ECDIS 300 by Transas, most often by 0,04 Mm.

The AIS sends temporary values of the course, which were earlier obtained from the memory buffer of the device. The tracking system in the radar calculates it on the basis of concurrent measurements of distance and direction. The course presented by different devices can differ up to a couple degrees. The lowest fluctuations can be found in the AIS systems. The highest in the Decca systems, and a bit lower in Raytheon. This is the result of different tracking algorithms.[5]

For radar surveillance performance it is essential to designate a course and speed of another vessel and the closest point of approach and time of its achievement. The distance and direction measurement depends on the radar's precision and in practice, due to the fact that tracked vessels give a strong reflected signal, these measurements are more precise than the norms require. The rest of the data is averaged from concurrent measurements and depending on the algorithms assumed, the calculations may give different results. Data obtained from different devices differs form one another. At sea the vessel is always under the influence of different ever-changing forces, that's why its speed and course is constantly but ever-slightly changing. The radar signal is also changing due to condition changes and the changes of surface calculations of tracked objects. This means that the concurrent radar signals illuminate different parts of the vessel and as such the parameters obtained differ. [4]

The CPA calculations performed based on data received from the AIS show almost double the errors than when calculated using ARPA equipment. It is the result of the fact that ARPA averages data of constant surveillance and AIS are discreet values. The average CPA errors calculated by the radar were below 0.1 Nm, and those from the AIS were on the level of 0.15Nm. All results were within the norms, which state the precision must be under 0.3 Nm. Time for TCPA was not calculated.

As an example. the course (pic. 2) and speed (pic.3) of one vessel registered in typical weather conditions are shown. It was an LPG tanker 99m in length and 20m in width with 4954 tonnage – pic.1. It was travelling on the waters of Gdańsk Bay towards the North Port. During the measurement there was a west wind with the force of 4B. The M/V GAS FLAWLESS measurement session was 60 minutes.

Figure 1. M/V GAS FLAWLESS

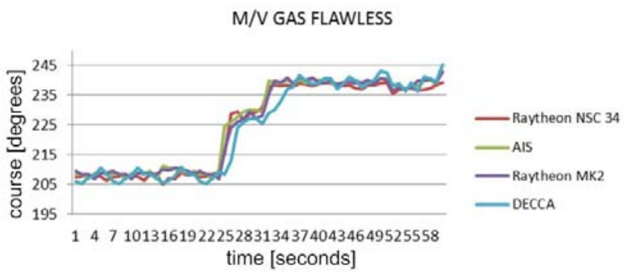

Figure 2. Course diagram for M/V GAS FLAWLESS

During the measurement session the object was on a constant course up until minute 22. Between minutes 22 and 33 the M/V GAS FLAWLESS manoeuvred changing course from 206/207 starting to 227/228 and finally finishing with a course of about 240 degrees. All measurement equipment readings were almost identical, with the exception of DECCA, which recorded bigger changes in course with a delay. A the beginning of the measurement the difference was about 1,5 degrees. In the following minutes the difference is about 1 degree. After the manoeuvre the radars show a greater fluctuation in the calculated course. The measurements ended when the radar signal began to vanish.

The vessel travels with a constant speed of 13,1 kn between minutes 1 and 26 and then reduces the speed between minutes 27 and 45 to a value of 9,5 kn. In the following minutes the vessel travelled at a constant speed as measured by Raytheon and VTS. The difference in speed between vessel and shore radar is insignificant.

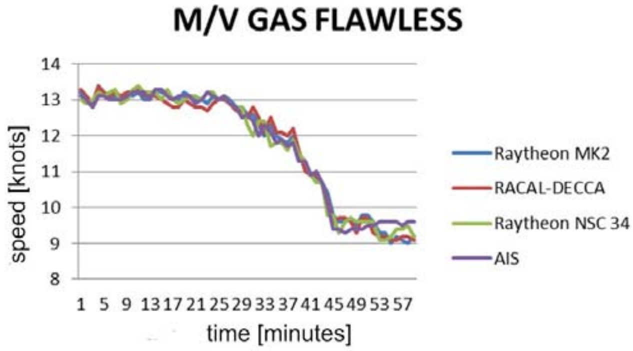

Figure 3. Speed diagram M/V GAS FLAWLESS

The momentary speed values of the vessel received from the AIS and calculated by the radars differ by less than 0,5 kn and show similar tendencies, which means that they rise or fall in in the same periods. It shows that the speed changes were not created by accidental errors and are a result of slight changes in speed caused by waves, wind and are connected with the ship steering precision. Usually the DECCA radar gives a slightly higher speed readings than Raytheon.

4 RESEARCH ON BOARD A VESSEL

Radar surveillance performed during ship movement is burdened by input data about own course and speed. If the ship travels in a stable manner and the influence of wave and wind is minimal, the influence is not important, and it is additionally lowered by radar data filtration. Those can, however, play a greater role in calculating data for AIS systems, because momentary ship data is being transmitted and compared to own vector designated in a different time period. [6] The measurements were also performed during research cruises, where about 20 vessels were recorded. In this report one of them was recorded, that of MV Nicola. It is a general cargo ship with gross tonnage of 9611 t. The Sperry Marine BridgeMmaster E 340 radar worked within the X spectrum. The presented research was conducted on 9th October 2015 on the Pacific Ocean. The meteorological conditions were as follows: sea status 4, wind in Beaufort scale 5, wind direction SW, dead wave 1.7 m SW.

Figure 4. Orion data

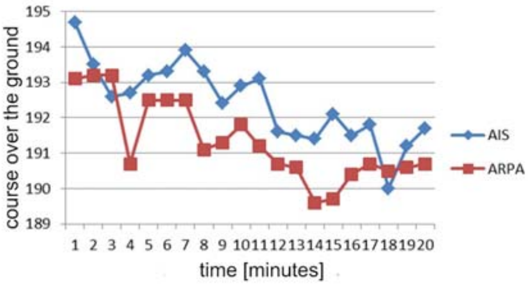

Figure 5. The registered course of the vessel.

At the beginning of the measurement the difference is about 1,5 degrees. In the following minutes the difference is about 1 degree. From minute 5 to 7 of the surveillance, as calculated by ARPA, the course is unchanged, than it is slightly lowered. According to the AIS, the vessel's course is slightly fluctuating, and the systems' readings are higher than those of the radar. Average errors in both devices' readings are about 1 degree.

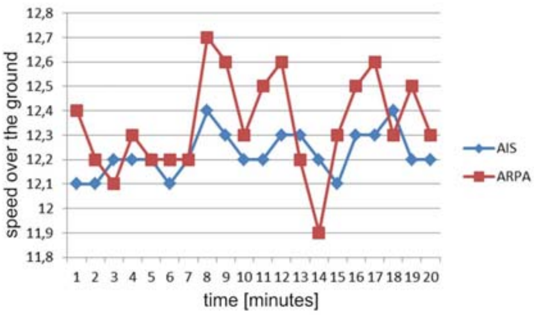

Figure 6. Registered speed of the registered vessel.

During the surveillance the research vessels kept a constant speed. The values obtained using the AIS show only slight fluctuations, their average being just 0.1 kn. Speed calculations performed using a radar show much bigger changes, and their average is twice of those by the AIS, at the same time still being very small and not over 1 kn. The radar-signalled changes of the tracked echoes' speed are possibly a result of echo signal fluctuation.

5 CONCLUSION

The data obtained by the AIS give the navigator new possibilities. It offers not only movement data on other vessels with much higher precision and shorter delay than in the case of the radar, but also enables direct information exchange.

On the basis of the performed observations, one can state that the measurements of distance using radar are performed with high precision. The calculations of ship distance performed with the AIS (from the difference in GPS position of own and alien vessel) are also precise. The differences in measurements between both systems are constant during all operations, which proves that they are caused by different software and different measurement methods. The course calculated by ARPA is done by subsequent measurements of distance. The echo's speed is calculated with precision and each measurement series shows the stability of this measurement. The ship's course is designated with less precision and shows fluctuations in the range of a few degrees. The radar signal is calculated differently by different devices and higher fluctuations are shown by ARPA Raytheon than the ECDIS connected with such radar, and the Raytheon is quicker to detect the echo's change course manoeuvre.

The research shows that none of the navigational devices gives full certainty as far as the presented data is concerned. The differences between readings of distance, position, speed and especially course of the echoes show that navigation utilizing only one device can be risky. However, each of the discussed systems presents valuable data for the navigator. Comparing readings from different sources is conducive to safe cruises, that is why bridges on many modern vessels are equipped with all the devices mentioned above.

All the obtained results, both laboratory and on board, are in line with the MSC.192(79) resolution. Measurements at sea have a slightly lower precision than those registered in a laboratory, which is the result of delays in the gyrocompass's transmission of course change. This influence is marginal, because the research was done on-board a large vessel with good hydro-meteorological conditions. During a storm, when the ships works on waves the readings of the movement vector and CPA will be less precise.

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