TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 8
Number 3
September 2014

DOI: 10.12716/1001.08.03.02

Influence of Automatic Identification System on Safety of Navigation at Sea

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ABSTRACT: Detection of small crafts/targets, in particular, sailing yachts with the ship's radar is not always possible. Radar reflectors are used to improve their detection. The AIS (Automatic Identification System) transmits position in WGS84 geodesy system, motion vector and identification signals of a vessel to other ships and VTS (Vessel Traffic Services) centers. This system significantly increases the possibility to detect small crafts.
The paper presents results of comparative study of using information from the Automatic Identification System and from radar to determine the accuracy of tracking the position and motion vector of ships in the Gulf of Gdansk. Possibilities and limitations of the AIS are also presented.

1 INTRODUCTION

Maritime transport is an important branch of global economy. It also creates a high risk of environmental pollution because a ship can carry at one time even more than a hundred thousand tons of hazardous goods. Therefore, there are a lot of measures undertaken to prevent ecological disaster caused by ships. A large ship, because of the huge inertia, must start a maneuver a few miles in advance, whereas a small sailing yacht will perform any maneuver in place; still it depends on the wind force. Therefore, the safety of small crafts often depends on their detection by other vessels. The officer on the bridge (at a height of 10 to 30 m) is usually alone and apart from observing the vicinity at the same time he/she operates a lot of other equipment. A yacht can hardly be seen and it much depends on its lights. The basis of the observation is to monitor a radar image. Basic radar operates in a range scale of 3 cm and the vessels of more than 3 000, in addition, can have radar operated in a range scale of 10 cm. The latter detects small crafts at shorter ranges but it is more resistant to hydro-meteorological disturbances.

2 RADAR DETECTION OF YACHT ECHOES

We have been carrying out radar observations of small crafts in the Maritime University for many years. The observations show that the possibility of detection of reflected signals from these targets is limited. The interference of radar signal from the sea surface to the direct signal causes fluctuations and echo dropouts, and scattered from the sea surface echo signal masks all the other echoes around their own position. Depending on the height of the antenna and the state of the sea this range can reach up to 4 nautical miles. Precipitation may mask the echo in the whole range of observation. Interference can be minimized by using a software analyzing visual signals, or improving the reflective properties of the observed objects, for example. by the use of radar

reflectors. Figure 1 shows, the calculated by CARPET 2, the probability of detection a yacht by a ship's radar as a function of distance from the antenna. The zones of attenuation of the signal are visible [12].

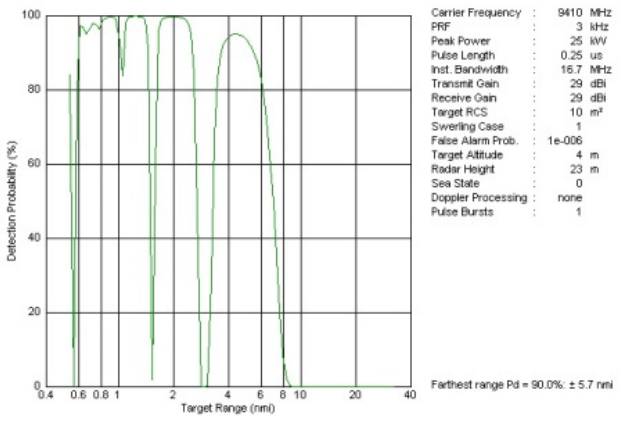

Figure 1. Probability of detection of a yacht [8]

We carried out research into the impact of different types of radar reflectors on the detectability of a yacht in the Gulf of Gdansk. Radars installed in the Gdynia Maritime University, on ships of the Maritime Office and those working in the Vessel Traffic Service VTS Gdańsk Bay were used for this purpose. This corresponds to typical situations encountered at sea. The reflecting properties of an object are defined as effective reflection surface. It is the surface of a metal plate giving the same degree the reflected signal as a real object. This parameter depends on the shape, dimensions and type of material. Typical effective areas of a small craft are less than 50 m^2 and of vessels they are a few thousand square meters. Metal elements of the deck equipment play a crucial role for a yacht. A standard reflector, approved by PRS (Polski Rejestr Statków), improves the detection range of a yacht by about 20%, while other reflectors have a minimal impact on tracing of echoes of small objects. Shore based radars, working in traffic control system, have higher performance and the examined crafts were detected by them in the entire area [11]. It has been found that radar operating in the X band in the same conditions is slightly less resistant to hydro-meteorological disturbances than S-band radar, however, due to the wider radiation pattern in the horizontal plane the motion vector defined by the S-band radar is less precise. Accuracy of determining the motion vector depends on the speed of the echo (for speeds below 1.5 m/s ARPA (Automatic Radar Plotting Aids) cannot determine a motion vector) and on computational algorithms. On the basis of the same radar signal, the calculated parameters of movement of echoes may indicate different values on radar and on ECDIS (Electronic Chart Display and Information System) screens (e.g. course differs up to several tens of degrees). Figure 2 illustrates courses of a vessel. Based on numerous observations, it was found that a radar detects a small target at a distance of about 5 - 8 nautical miles but its echo on the radar screen is a very small, what is more, the operator is not likely to notice it because of background noise. Usually small object radar echo is lost in clutters of the sea surface at distances of less than 2 NM. The possibility of observing movement of small crafts using ship's radar is often very limited [10]. These observations were confirmed during cruises on ships. It was found that the vessels have limited opportunities to detect small crafts at sea. Materials from these studies were used to raise IMO (International Maritime Organization) interest in this problem. (IMO as a specialized United Nations agency dealing with maritime issues only).

3 AUTOMATIC IDENTIFICATION SYSTEM - AIS

Automatic Identification System - AIS uses data transmissions in the VHF. AIS devices operate with a time division multiple access TDMA using for transmission two AIS1 frequencies 161.975 MHz (channel 87B) and AIS2 equal to 162.025 MHz (channel 88B), which makes it possible to send about 4000 and 2000 reports per minute. The on board device automatically sends data regarding position and motion vector from GPS navigation receiver, the gyrocompass and log course, speed through the water and the identification data. Time interval between transmissions depends on the speed of the vessel. [9] AIS was introduced by the end of 2004 for vessels employed in international shipping and on ships taking only domestic voyages on July 1 in 2008. Since 2010 fishing vessels have had such equipment and leisure - sport crafts are also planned to be fitted alike. Fitting vessels with AIS equipment has changed the work on the bridge. Navigator gained information about other ships, which have so far not been available to him. The system allows insight into the instruments of another vessel. Until then, positions, courses and speeds were determined on the basis of radar observation or estimated on the basis of visual observation. Measuring the distance by radar enables to get the measurement accuracy of approx. 250 m, when echo of the other ship shows up on the screen, while GPS allows you to obtain this position at 20 m [10].

Another bit of important information is warning about another ship maneuver. ARPA helps to detect another ship in less than 1 min whereas it is very difficult to detect the target by observing the image of the radar. The AIS sends the current data every 2-3 s during the maneuver. The maneuver is defined as the change in the course of 5°/30s. When a ship keeps a constant course, the frequency of sending dynamic data was chosen so that the distance between the actual position of the ship and the obtained from the system does not exceed 50 m. The AIS provides information at a much greater distance than radar or visual observation, but it is not so important.

4 USE OF AUTOMATIC IDENTIFICATION SYSTEM

Another very important issue related to the introduction of the AIS is the registration of vessel traffic by services on land which, among other things, demands more diligent work from watchkeeping officers. It allows monitoring traffic and supports the rescue operations. However, sending data to all in a radius of 50km can be dangerous (activities of pirates), so the ship has the right to turn off this

device. The ship's crew knowingly, or more often not, can falsify the data sent by the device, because despite of the supply of very important and more accurate data the AIS is not used as observation means. If the targets located by radar and the AIS are sufficiently close to each other, the provisions of the IMO recommends the use of data from the AIS. An experiment carried out by the author does not confirm that. AIS measurement was first used during testing the range of radars operating in Vessel Traffic VTS Gulf of Gdansk [13]. Positions in World Geodetic System-1984 from the GPS receiver were recorded on the 'Zodiac' ship and then were given to AIS device.

The World Geodetic System 1984 (WGS84) datum is the nominal datum used by GPS [16]. It is based on the WGS84 ellipsoid which only exhibits a small difference in the flattening parameter compared to the GRS80 and therefore both ellipsoids can be assumed identical for most practical purposes. The WGS84 datum has been refined several times to be closely aligned with the International Terrestrial Reference Frame - ITRF in order to prevent degradation of the GPS broadcast ephemerides due to plate tectonics. The ITRF is the most precise earth-centred earth-fixed terrestrial datum currently available, realised by an extensive global network of accurate coordinates based on the Geodetic Reference System 1980 (GRS80) ellipsoid and derived from geodetic observations using GPS, Very Long Baseline Interferometry, Satellite Laser Ranging, Lunar Laser Ranging and Doppler Orbitography and Radiopositioning Integrated by Satellite. The ITRF is a dynamic datum and changes according to temporal variations of coordinates and their velocities due to the effects of crustal motion, earth orientation, polar motion and other geophysical phenomena such as earthquakes and volcanic activity. The ITRF is still refine to ensure that the change between successive realisations in the order of 1–2 cm. Similar redefinition of World Geodetic System, known as WGS84 (G1150), was implemented in GPS week 1150 (20 January 2002). After this alignment with the ITRF2000, it was shown that the WGS84 coincides with the ITRF within a few centimeters at the global level [15]. For all mapping and charting purposes with accuracy requirements at the 10 cm level, the WGS84 and the most current ITRF can therefore be assumed identical [16] then GPS measurements could be realized in this system.

It turned out that the AIS device retrieves the data of the ship equipment to the buffer memory and sends them according to the schedule of the system. As a result, it was found that the errors of the system are greater than those implied by the assumptions.

Further research showed that the Gulf of Gdansk dynamic data are received less frequently than it results from the assumptions of the system. The differences between the position of the vessel perceived by means of AIS and that recorded on board the ship reached 250 m [2]. There are usually about 100 vessels in the Gulf of Gdansk covered by the AIS, mainly at anchor (sending dynamic data every 3 minutes). One problem is static data sent every six minutes as they can occupy more than one frame. The author registered similar problems in other European waters during the voyages on board the tall ship 'Dar Młodzieży'. There were few ships on the waters covered by the research within VHF communication, so there could be no problem with the lack of free frames. Fewer transmissions were received than expected [1]. The AIS device does not signal if the data are sent, so it is not possible to state if the system allocates frames for transmission or not, or whether as a result of interference they are not received. The author also registered information received from the AIS on board a ship at anchor. Data are provided by AIS every 3 minutes, which is enough to know how many ships are at anchorage, but their current status cannot be defined basing on them, or whether by the action of wind the ship is swinging or dragging anchor [3]. The frequency of broadcasts by ships at anchor should be at least 10 times more, but this may block the system in areas of very high traffic (e.g. Singapore). The solution may be decreasing the strength of the signal or adjusting the frequency of broadcasts by traffic control in the area. Since 2001, the author has been carrying out a comparative study of the use of information from the Automatic Identification System and from radar to determine the accuracy of tracking the position and motion vector of ships in the Gulf of Gdansk. These studies confirm that the AIS system enables quicker access to information about the ship's maneuver and usually enables to determine the motion vector of another vessel more accurately. However, cases were recorded when the AIS indications were subject to errors, for example shifting of the positions by several cables. Such errors can be identified by traffic control systems but on board the ship is not always possible [7].

The possibility of introducing compulsory AIS equipment of Class B on board leisure and sport crafts is currently being considered. The development of new modulation of signals (CSTDMA) for the equipment means that it does not overload the network system [5]. According to the simulation research, even very large number of small crafts (over 1000) in one sea area will not block the system. It is very important to increase safety of small crafts because they are often not visible at sea and are not detected by ship's radar, and their maneuverability is dependent on the direction and force of the wind [12].

The chance of detecting targets using radar depends on their reflective properties which in the case of small crafts are insufficient. While using the Automatic Identification System the conditions of propagation in the VHF band and the parameters of the devices have impact on the detectability therefore this system allows the detection of small crafts at sea regardless of the hydro-meteorological conditions.

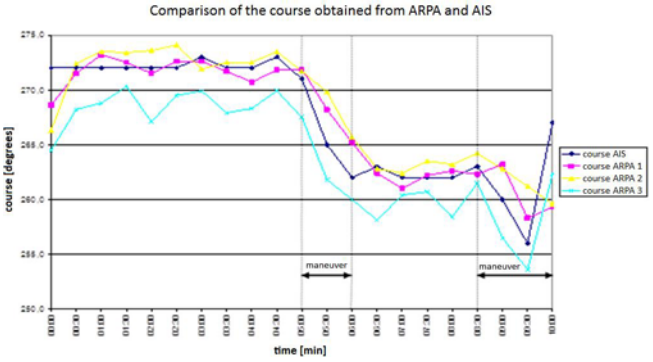

Figure 2. Courses obtained from ARPA and AIS

Figure 2 shows course of a ship sailing to the port in Gdansk registered with the AIS device and calculated by the radar tracking systems. The radar signal comes from a single block of transmitter – receiver and was calculated by the new NSC34 Raytheon, older version MK2, by ECDIS system and Transas 3000 [14]. The least accurate data were obtained from the electronic chart system. The main problem is not that the data are different but that the navigator receives various data to be analyzed.

The introduction of the ships AIS equipment allows the navigator to obtain new information about the vessels in the vicinity. Previously, this information was provided by a lookout, visual observation dependent on lighting and visibility conditions and was assisted by acoustic signals. The introduction of radar made it possible to assess the risk of collision and traffic parameters of other vessels also during limited visibility. However, the observation of about 20 km around the vessel on a small screen and the limitations of the device itself can produce traffic data with limited accuracy. Radar allows detecting another vessel from a distance of 10 - 20 km and then determining its position with an accuracy of about 200m. Courses and speed of other vessels are calculated on the basis of changes in the position during subsequent observation and knowledge of own course and speed. Therefore, changes in the course of another vessel can be detected by radar with a delay – in the AIS system these data are transmitted directly from the ship's equipment so the data are available on other ships with a minimum delay of several seconds, while the ARPA should, on the basis of radar observations, detect the maneuver within one minute. Other data are also available, such as the name of the vessel, IMO and MMSI numbers, dimensions, port of destination. The AIS allows sending short text message to a ship selected from the list and knowing its name, communication using VHF radio can be established. The system of automatic identification of vessels made some data that were previously unavailable, available and increased their accuracy. However, there are also disadvantages and limitations of the system. We have no control whether the received data are true. Not always the cooperation of the vessel's equipment with the devices of AIS is correct or certain actions can cause falsification of the transmitted data.

This system changed the possibilities of obtaining data on other ships in maritime transport. The data should be accurate and up to date, because they come directly from the ship's equipment. However, they are stored in a buffer of the device and they are sent with some delay. Not all transmissions are received (or maybe they are not sent at all?), neither is known their reliability. They can be falsified intentionally or inadvertently.

A vessel is equipped with a SART transponder (Search and Rescue Transponder) that allows locating the distress position of a survivor. Once activated, after receiving a signal from shipboard radar, the device sends a response, which is displayed on the radar screen as a special echo. Since 2010 the AIS transponder has been an equivalent to a radar transponder as it sends its number and position from the built-in GPS receiver.

This device is more resistant to interference than the ones working in radar band. A special symbol is reserved for it but older devices do not know this signal. In this situation there is no guarantee that the crew will identify the signal of the distress position [4]. Figure 3 shows the signals of a SART buoy.

Figure 3. Signals of the AIS transponder

5 CONCLUSIONS

The AIS, as each of the electronic systems used at sea, has many limitations, knowledge of which is necessary for its proper usage. In particular, the user of the AIS should bear in mind the following:

- Data obtained from the AIS device are as accurate as accurate and correct were the data entered into the system. In particular, the data entered into the AIS device manually should be interpreted with great caution.
- Not all ships are equipped with the AIS or it can be switched off. In particular, non-conventional vessels, such as sport, leisure, fishing boats and warships need not be, and for various reasons, are often not, equipped with the AIS.
- It should be taken into account that not all installations are properly made and the device can be turned on /operational when transmitting the data may be against safety regulations.
- Operation of the AIS is based on the use of VHF band and is subject to the same limitations as any other system operating in this band.

In summary, the AIS system is a useful and modern tool that is still being developed and used in more and more numerous applications, a tool, which used in the right way, can contribute to a significant increase in the safety of passengers, crew, cargo and ships, as well as the marine environment.

The research has shown that observation of small crafts such as yachts, fishing boats is significantly restricted. The detection of such objects is possible, mainly in addition sea clutters area, and their radar echoes are small and difficult to notice. Radar observation is supported by the data from Automatic Identification System- the AIS and visual observation –a lookout. The AIS is the system that allows detecting small crafts from a proper distance, regardless of the hydro-meteorological conditions.

The training of ship's crews and programs of study should incorporate information on new technologies and system functions especially those connected with the safety of navigation and saving life at sea. This can be done effectively by entering such information into the program of individual rescue techniques trainings, as each crew member undergoes this course every 5 years.

For these reasons, small crafts during sea passages should mandatory be equipped in a Class B of the AIS device. This will allow for their detection, positioning and tracking regardless of the hydro-meteorological conditions and significantly will increase the safety of

millions of small crafts sailing at seas and oceans all over the world.

The satellite navigational systems (GPS Navstar, GLONASS) give possibility of objects continuous coordinates calculate. Additionally differential or Sbasse methods enable getting better accuracy of positions. Radio transmission of object positions in World Geodesy System WGS84 helps to presents them on the chart to steer safety navigation.

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