Verification of automatic drift calculation accuracy using an automatic radar plotting aid

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Abstract
One consideration required in the resolution concerning radar and automatic radar plotting aid (ARPA) equipment is the possibility of an automatic drift calculation being realized in the base of fixed target tracking. This information is very important to providing safe navigation, especially in restricted areas. This paper presents an analysis of the present regulations contained in IMO resolutions and the results of an experiment conducted in the ARPA simulator. The aim of the simulations was to verify the reliability of the information presented on the ARPA display and to determine the accuracy of the automatic drift calculation implemented in the simulator.

Analysis of requirements for the radar and ARPA mode of stabilization

Basic regulations governing the use of radar equipment installed on vessels (including automatic radar plotting aids) focus on both the proper training of navigators and technical requirements of equipment. The second group of requirements can be found mainly in Chapter V of the 1974 SOLAS Convention (with amendments coming into force in subsequent editions of the Convention) and the IMO Resolutions (depending on the date of installation of the radar equipment on board, either Resolution A.422(XI), A.823(19) or MSC.192(79) should be taken into consideration). The need to adapt legal provisions is related to, among other things, the appearance of new bridge navigation devices/systems cooperating with radar as an integrated bridge system (AIS, ECDIS, and VDR) and technological progress allowing for increases in the capabilities and accuracy.

One of the important functions that the navigator must take into account when selecting and interpreting navigation information about the situation around their ship is the type of radar mode stabilization. It is worth considering how technical requirements concerning this function change during the operation of radar equipment on board and what impact the drift automatic calculation can have on a correct assessment of the situation.

The first IMO Resolution A.422(XI), which sets out the requirements for automatic radar plotting aids (ARPA), does not contain direct requirements for both types of stabilization (sea and ground). Requirements for speed indicators, which are designed to provide information about the ship's speed through the water, can only be found in this resolution. Resolution A.422(XI), however, concerns devices that were introduced gradually on the bridge as mandatory equipment. During this period, the radar device most often worked individually and connecting to other navigation devices and working with them as integrated was possible but not required (IMO Resolution A.422(XI), 1979).

Changes to requirements for radar image stabilization mode occurred with the publication of IMO

Resolution A.823(19). Since 1997, each ARPA (according to par. 3.11) should be capable of sea and ground stabilization and the type of input and stabilization in use should be displayed. Radars were still required to provide information about the ship's own speed through the water. Log and speed indicators providing inputs to ARPA equipment should be capable of providing the ship's speed through the water in the fore and aft direction (IMO Resolution A.823(19), 1995).

The ground stabilized input may be provided from the log, from an electronic position-fixing system, if the speed measurement accuracy is in accordance with the requirements of resolution A.824(19), or from tracked stationary targets. Such a formulation of requirements could suggest that it would be enough to provide one of these methods to meet the requirements of the resolution. Therefore, due to the widespread display on a radar's GPS information or even the need to provide such a signal for their proper operation, automatic radar plotting aid without a fixed object tracking used to calculate the drift is met (IMO Resolution A.823(19), 1995). In addition, the resolution also contains definitions referring to a type of stabilization (p. 33 and 34) and highlights the need to distinguish actual ground and sea course and speed.

Another resolution, MSC.192(79), which adopts for equipment installed after 01.07.2008, also brought some changes in the requirements for the type of stabilization. These requirements have been placed in various locations of the resolution, which does not have a positive impact on their readability. General requirements, in accordance with Resolution A.823(19), are in par. 5.22 (requirement to provide two modes of stabilization) and the necessity to

ensure ground stabilization based on a fixed object tracking and proper identification of such echoes' results directly to par. 5.25.4.8 associated with the possibilities of tracking process. At this point, it is explicitly stated that this function should be available on each radar with automatic radar plotting aid (IMO Resolution MSC.192(79), 2004).

Due to the lack of specific guidelines for the accuracy of the automatic calculation of drift and its impact on tracked object and own ship information, a question arises: to what extent and when can the navigator trust the information presented on the display?

Simulator

The experiment was conducted in a NORCONTROL NMS-90 MK II simulator. The simulator consists of three training stations and the instructor station. Each of the stations is equipped with a maneuvering console and radar equipment with automatic plotting aid. Due to limited availability of radars equipped with automatic calculation of drift, only two stations were used during the experiment. Images of the training stations are shown in Figure 1.

The instructor station allows the instructor to perform a preparation of exercise courses, supervising of running exercises, initiating alarms, and all the principal tasks needed for the training on simulation systems as well as recording and playing exercises that are carried out. The instructor station includes a means of controlling and displaying information for each of the Own Ships (OS) in respect to environmental conditions including sea state, tidal and current information, wind speed, direction, etc.
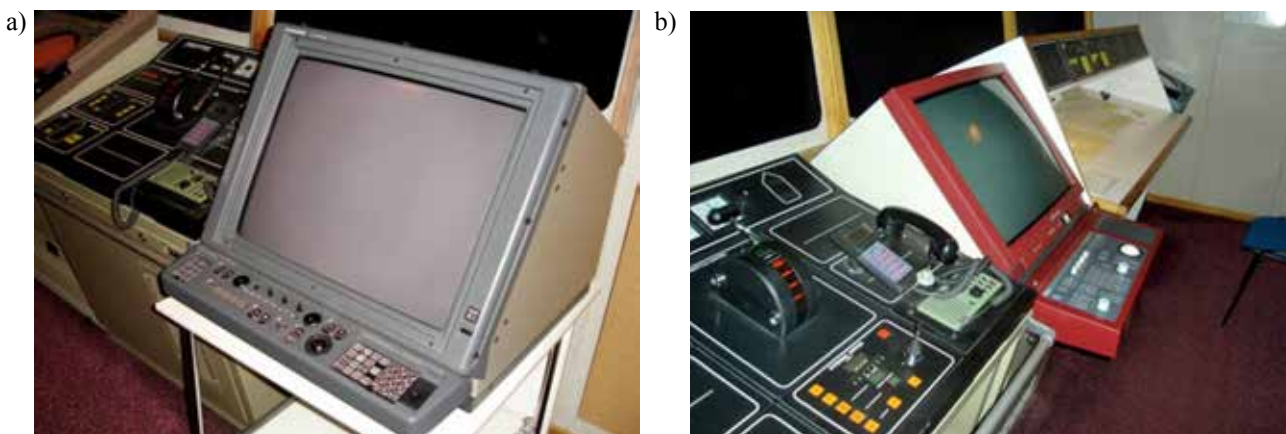

Figure 1. Training stations in radar simulator: a) station No. 1 equipped with 2805 Furuno ARPA, b) station No. 2 equipped with 9800 Atlas ARPA

Figure 2. Instructor console, NMS-90 simulator

The simulator meets all the requirements of Section AI/12 of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW78/95), for both general and additional radar and ARPA simulators (Wawruch, 2005, p. 7). Radar and ARPA courses for operational and management levels can be performed.

Research scenario

During the experiment, three research scenarios were carried out. Simulated current parameters are the main difference. Simulated scenarios were as follows:

- Scenario 1 – current 3 knots, direction 090°;
- Scenario 2 – current 3 knots, direction 180°;
- Scenario 3 – lack of current.

Scenario three was the basis for the comparison of registered estimation results.

In addition, for each scenario, two variants of ship type were taken into account. Two mathematical models of ships were used: bulk carrier and container ship. This allowed for the differentiation of maneuver speeds and determined the impact of the ship's speed on the accuracy of current parameters calculation (Table 1).

Table 1. Characteristics of mathematical models of ships used during the experiment (Norcontrol Simulation NMS-90)

Ship's model	Length [m]	Width [m]	Draught [m]	DWT [T]	RPM [FA]	Speed (FA) [kn]
Bulk carrier	174	31.1	12.0	54 600	125	14.8
Container	194.5	30.5	11.2	37 636	88	23.8

The experiment was carried out using two different types of radars: Furuno ARPA 2805 and Atlas Elektronik ARPA 9800.

During each scenario, a stationary target echo was simulated. Automatic calculation of drift, sea and ground speed parameters, as well as course over ground was calculated based on the tracked target. The initial position of the object was constant. It was located at a distance of 6 nautical miles in the azimuth 030° relative to the initial position of the OS.

In order to determine the calculation error of the actual course over ground (obtained by drift automatic calculation function), the target was acquired manually at the beginning of the simulation. In the first 4 minutes, OS proceeded with constant course and speed, then in the 4th minute of the scenario altered course to 090°. Each scenario lasted 15 minutes.

During the simulation, the actual course and speed over ground calculated by ARPA and real speed and course read from the instructor console were recorded. This allowed for evaluation of the errors that appeared in automatic radar plotting aid during drift calculation.

Results

As already stated, the calculation of course and speed over ground errors was determined. This analysis allowed for verification of the accuracy of the automatic drift and set calculation function in the equipment used during the experiment. The differences in courses and speeds over ground were determined, in short, as the course error and the speed error.

Simulated data in a particular series of experiment and coding of scenarios variants are presented in Table 2.

Table 2. Scenarios characteristics

| No.	Scenario code	Current [direction/value]	Radar type	Ship's type
1	v1s1	090°/3 kn	Furuno	bulk carrier
2	v1s2	090°/3 kn	Atlas	bulk carrier
3	v2s1	180°/3 kn	Furuno	bulk carrier
4	v2s2	180°/3 kn	Atlas	bulk carrier
5	v1s1c	090°/3 kn	Furuno	container
6	v1s2c	090°/3 kn	Atlas	container
7	v2s1c	180°/3 kn	Furuno	container
8	v2s2c	180°/3 kn	Atlas	container
9	v3s1	no current	Furuno	bulk carrier
10	v3s2	no current	Atlas	bulk carrier
11	v3s1c	no current	Furuno	container
12	v3s2c	no current	Atlas	container
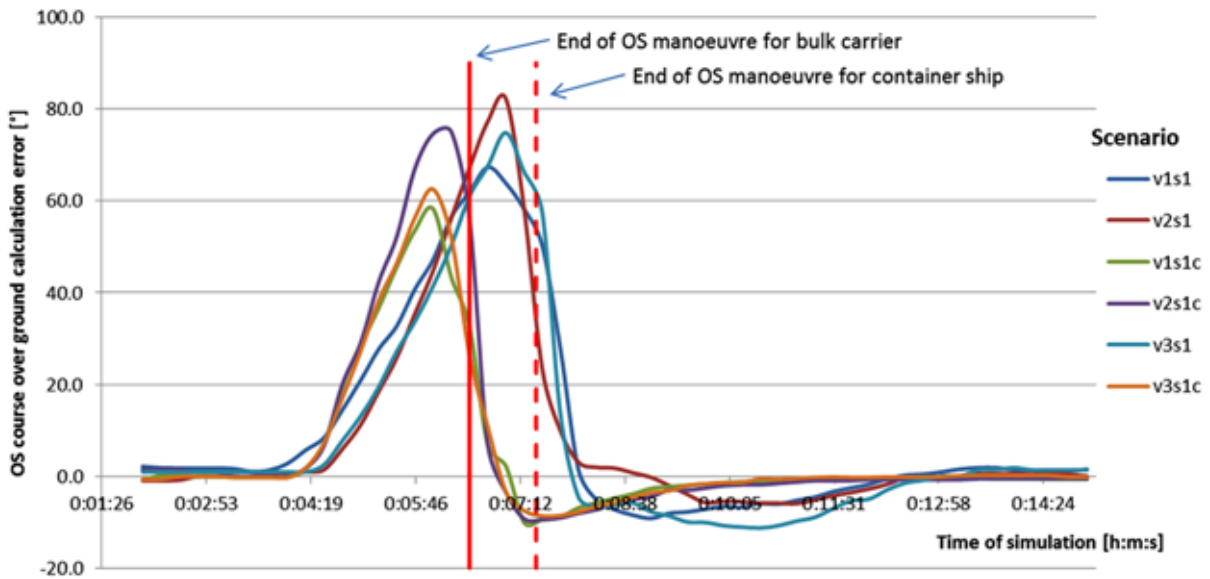
Figure 3. Ship course over ground calculation errors – station No. 1 – ARPA 2805 Furuno
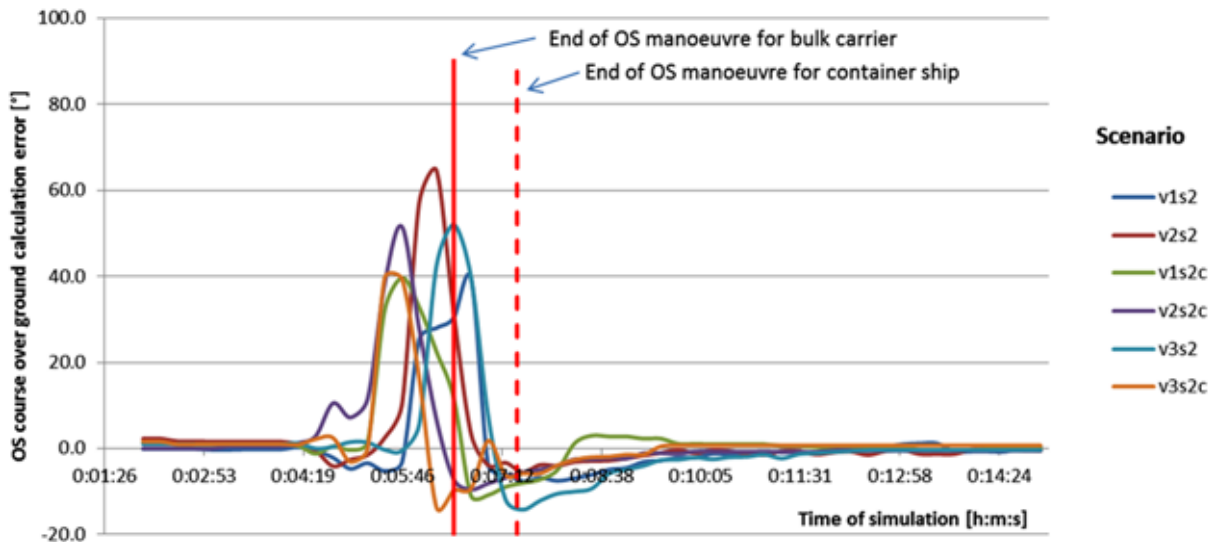

Figure 4. Ship course over ground calculation errors – station No. 2 – ARPA 9800 Atlas
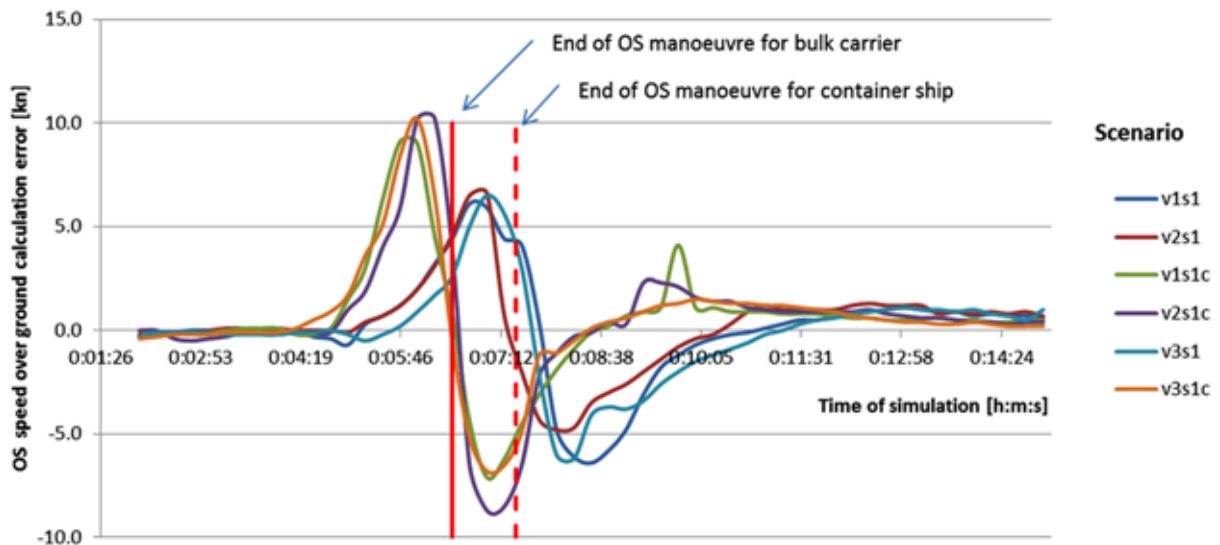

Figure 5. Ship speed over ground calculation errors – station No. 1 – ARPA 2805 Furuno
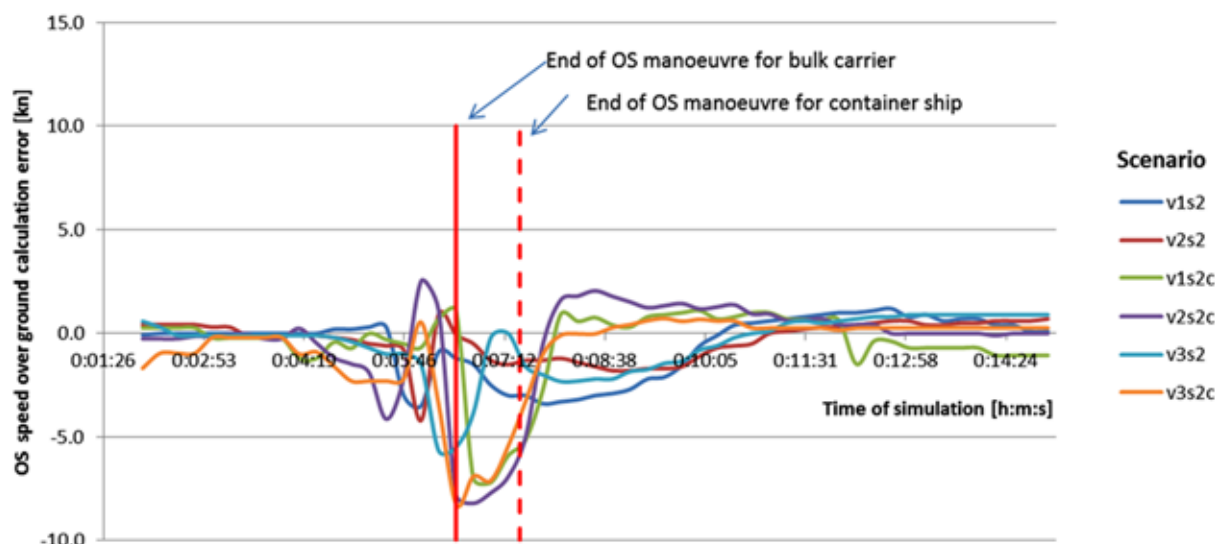
Figure 6. Ship speed over ground calculation errors – station No. 2 – ARPA 9800 Atlas

Calculated course and speed over ground errors of own ship (OS) are shown in Figures 3–6.

As can be observed after the initial stabilization of tracking, errors start to increase after the OS maneuver (in the 4th minute of simulation). The greatest error values of the actual course over ground are observed in the Furuno ARPA. The maximum value of this error comes to 82º in the 7th minute of simulation for the variant with an opposing current. For the same scenario for station number two, the maximum error is 64º in the 6th min. 15th sec. of the simulation. After termination of the maneuver, re-stabilization starts and the ship motion parameters over ground are recalculated with the appropriate accuracy.

It can be noticed that the maximum errors for various types of vessels achieve the maximum value in similar moments of the simulation, independent of the current value (i.e., the difference is the value of the error). At station number one for the container vessel, it is in the 7th minute and for the bulk carrier maximum, it is a minute later. For station number two for the container ship, the maximum error occurs in approximately the 6th minute and for the bulk carrier, it is half a minute later. In both cases, dependency of delay relative to the speed of the vessel is clearly shown.

The Furuno ARPA shows similar errors in both the course over ground calculation and the speed over ground errors. The maximum values of those errors are calculated as the difference between their values and the time of occurrence for different types of vessels. In station number one for the container ship, it occurs in the 6th minute and the maximum error reaches 10 knots. For the bulk carrier, the maximum occurs one minute earlier and the error reaches 6.6 knots. For station number two, for container ship it is the 7th minute and the value of the maximum error is 7.1 knots, whereas for bulk carrier in the 6th min. 15th sec. the error value is 5.7 knots.

By analyzing the simulations carried out, it can be concluded that the maximum errors in the transmission of the course over ground are on the Furuno radar with the bulk carrier model. To evaluate stabilization errors, Resolution A.823 (19) was taken into account. Due to the vessels' speed, in our case, ARPA should provide stabilization after three minutes, and after the maneuver for the bulk carrier (course accuracy values 7.4°, speed accuracy 1.2 knots) and container (course accuracy values 2.6°, speed accuracy 1.2 knots).

For the Furuno radar, course and speed over ground stabilization occurs in the 9th min. 45th sec. for the bulk carrier. In scenarios where the faster container ship is simulated, errors occur earlier and have the lowest values. However, taking into account the guidance, course stabilization takes place in the 9th minute and speed stabilization in the 8th min. 15th sec.

In case of the Atlas radar, the error fluctuations in each scenario are more varied but also some trends for different types of ships can be seen. Course stabilization of the bulk carrier was obtained in the 8th minute and for the container ship in the 8th min. 15th sec. In contrast, speed stabilization was achieved in the first case in the 10th minute and for the second vessel in the 8th minute.

There are also errors that received similar values for the scenarios simulated with no current.

The delay time calculation of tracked target parameters restabilization is also very important. For this reason, it is necessary to determine the end of simulated maneuvers. For the bulk carrier, it is in the 7th min. 25th sec. and for the container it is in the 6th min. 30th sec. of the simulation. In all scenarios, regardless of the simulated current, completion maneuvers are approximately identical and differ from each other by only 2 to 5 seconds. Therefore, it is assumed that the average maneuver completion time for the bulk carrier is 7 min 25 sec and for the container is 6 min 30 sec. The moments of maneuver completion are marked on Figures 3–6 as vertical lines (solid for the bulk carrier, dotted for the container ship).

Re-stabilization of true course indications (after OS completion maneuver) occurs on the radar screen:

- after 2 min. 20 sec. for the bulk carrier and 2 min. 30 sec. for the container ship (ARPA 2805 Furuno);
- after 35 sec. for the bulk carrier and 1 min. 45 sec. for a container (ARPA 9800 Atlas).

Stabilization of speed indications occurs on the radar:

- after 2 min. 20 sec. for bulk carrier and 2 min. 45 sec. for a container (ARPA 2805 Furuno);
- after 2 min.35 sec. for the bulk carrier and 1 min. 30 sec. for a container (ARPA 9800 Atlas).

In addition, in the Atlas radar, it is noted that approximately one minute after the start of the maneuver, the ship vectors change direction/tendency to the opposite and after about half a minute later showed the real trend of movement. This observation confirms that the navigator has to be aware of the limitations of the equipment in operation to avoid dangerous situations.

Conclusions

The target-tracking capability of the ARPA can provide the navigator with an important and potentially very useful piece of data to help with the navigation problem, namely, a continuously updated rate and set of the current being experienced (Bole, Dineley & Wall, 2005). The experiment conducted in the radar simulator was designed to assess the accuracy in determining the course over ground obtained during use of the automatic set and drift calculation. The accuracy of this function is affected by many factors. In the experiment, mainly the ship's speed

as well as direction and rate of current were taken into account. As was stated, the type of used radar equipment is very important and, consequently, implementations of automatic drift calculation function. Since (based on technical requirements) this function is mandatory, every user should be aware of whether he can rely on the data displayed on the radar screen.

Analyzing the simulated scenarios showed that during the stable movement of the ship (without maneuvers), both radars operate properly and the correct value of course and speed over ground can be read on the screen. Unfortunately, a strong deterioration in the quality of own ship over ground data was recorded during the maneuvers. This deterioration affected accuracy and created long delays in updating data (the own ship motion vector was frozen on-screen). The larger errors were calculated for a slower unit (a mathematical model of bulk carrier). The time of occurrence was later than for the container because of the speed. Vector stabilization was also achieved earlier in the case of a container. The maximum errors of speed over ground are larger for the faster vessel and the moment of its occurrence takes place later than for the bulk carrier.

The set and drift automatic calculation function using echoes from fixed targets can be used on difficult areas where the need for access to reliable and accurate information is especially important, which raises a question. Notably, the correct calculation of the current value during movement of the unit is important, but on the waters bounded with heavy traffic, it is difficult to imagine the avoidance of total maneuvers. In this case, uncertain information with significant errors can confuse the navigator.

Therefore, the verification of the accuracy of the automatic calculation of drift and disseminating this knowledge among users of collision avoidance equipment is very important from the point of view of navigation safety. During the ARPA equipment training, one should particularly pay attention to the limitations of these devices and the problem with having too much confidence in their indications. In this context, it is important to pay attention not only to the accuracy of tracked objects presented on the display, but also the accuracy of the automatic acquisition because its improper use and excessive confidence in it can lead to dangerous situations. In the context of the study, it should be stated that by using the discussed function one should always take into account the course over ground delay transmission, especially when working on a device with accuracy and reliability that has not been verified

in practice. An ARPA system in the hands of unqualified personnel is not only dangerous, but can indirectly be the main reason for an accident.

References

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