

# Investigation of Failures in the Operation of AIS Technology

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**Abstract** — Based on the analysis of messages received by AIS stations No. 4757 and No. 5064, three types of failures in AIS technology were identified: failures of onboard GPS equipment, jumps in vessel coordinates due to the transmission of incorrect pseudo range corrections by VTS, faulty AIS messages caused by a random match of the CRC code. Recommendations are given to eliminate the identified failures and improve the safety of navigation.

**Keywords** — Automatic Identification System (AIS), Vessel Traffic Service (VTS), onboard GPS failure, CRC code errors, navigation safety.

## I. INTRODUCTION

Initially developed for safety purposes, the focus of AIS has shifted towards a surveillance and security tool for maritime authorities AIS. In this context, anomaly detection can be an efficient tool for identifying conspicuous, dangerous, or even illegal behavior at sea across a wide range of applications [7]. In papers [8, 10] authors defined five general anomalous behaviors derived from AIS ship tracks, i.e. route deviation, unexpected activity, port arrival, close approach, zone entry. But there is lack of VTS anomaly detection approaches utilizing AIS data.

As noted in [1], the Department of Programmable Electronics, Electrical Engineering and Telecommunications of the Admiral Makarov National University of Shipbuilding (NUOS) conducts research on Automatic Identification System (AIS) signals for scientific and educational purposes. Currently, two AIS stations provided by MarineTraffic are functioning continuously at the department. Station No. 4757 is located on the building of the Institute of Automation and Electrical Engineering of the NUOS in Mykolaiv, and station No. 5064 is located at the recreation center of the NUOS in Ochakiv. Since 2020-08-20, all messages received by stations are recorded in the database in AIVDM format.

### A. Research Tasks and Objectives

The purpose of this paper is to study deviations and failures in the AIS technology operation based on data obtained using specially developed software.

## II. FAILURE OF ONBOARD GPS EQUIPMENT

Because of the failures in the AIS technology careful processing of the received messages is necessary, and, apparently, the final verdict on the reliability of some specific messages requires manual analysis, as will be seen from the data provided. The received messages from stations No. 4757 and No. 5064 are additionally processed

by the AIS Dispatcher 1.5 program available at [www.aishub.net](http://www.aishub.net)

According to the statistics obtained, the most common causes of failures are failures of onboard GPS equipment. These facts are recorded in messages in accordance with the AIS protocol with latitude and longitude values of 91 and 181 degrees, respectively, as shown below:

Station 4757, Date 2021-06-11, Time 01:20:45.614,  
Distance = 4689.84 km

Message\_Type: 3  
Repeat\_Indicator: 0  
MMSI: 671643000  
Navigation\_Status: 1  
Rate\_of\_Turn: 0  
Speed\_Over\_Ground: 102.3 % unavailable  
Position\_Accuracy: 0  
Longitude: 181 % unavailable  
Latitude: 91 % unavailable  
Course\_Over\_Ground: 360 % unavailable  
True\_Heading: 8  
Time\_Stamp: 46  
Maneuver\_Indicator: 1  
Spare: 0  
RAIM\_flag: 0  
Radio\_status: 131072  
Report\_Type: 'Position Report Class A'

Table 1 shows data on failures of onboard GPS equipment for June 11 and 12.

TABLE I. FAILURES OF ONBOARD GPS EQUIPMENT DURING JUNE 11-12, 2021

Date	MMSI	Total messages received	GPS failures
<i>Station No. 4757 Mykolaiv</i>			
2021-06-11	671643000	441	1
	272175600	701	241
	272592000	1873	1
2021-06-12	272175600	687	460
	272177400	5002	10
<i>Station No. 5064 Ochakiv</i>			
2021-06-11	No failures		
2021-06-12	248454000	1063	468
	2720175	23	23
	272750000	2727	1
	272972000	1339	12
	272978000	149	5

As can be seen from the table, an onboard GPS failure can affect a single message or a small number of messages;

be of a long-term nature, or even be fixed over the entire observed time interval. Of course, the absence of vessel coordinates for a long time increases the overall accident rate in the area where such a vessel is located. Of the measures aimed at eliminating such situations, it is necessary to note the timely reaction of the crew and the automatic redundancy of the GPS equipment. Upon further analysis of messages, such on-board GPS failures were excluded from the automatic search criteria.

### III. ERRORS IN DETERMINING COORDINATES

Along with the onboard GPS failure, which is detected on the vessel itself, errors in determining geographical coordinates quite often occur. They are easy to spot on the map when the vessel is on land. Several such examples are given in the paper [1], another case was recorded on May 26, 2021.

If the entire route of the vessel is mapped in accordance with the transmitted coordinates, the image even more clearly demonstrates the degree of distortion of the vessel's location (Fig. 1).

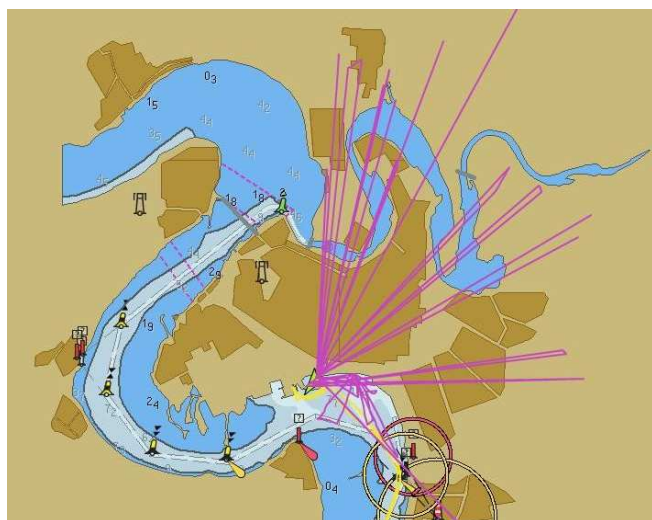


Fig. 1. The route of the vessel SPRYTNYJ (MMSI: 272085200) in accordance with the transmitted coordinates on May 26, 2021

As is known, a strong magnetic storm was predicted and recorded on May 25-26, and many sources reported failures in the operation of the AIS system and radar stations, although the US Coast Guard Navigation Center (NAVCEN) denies a noticeable impact of the storm on the operation of GPS navigation satellites [3]. Nevertheless, the influence was recorded by all three Vessel Traffic Service (VTS) base stations: MMSI 2723683 – on the Ruska Beak of the Pivdennyi Buh Firth, MMSI 2723682 – near Ochakiv and MMSI 2723681 – near Odessa, whose signals are constantly received by stations No. 4757 and No. 5064. Fig. 2 shows the dependences of the satellite data reliability (Health), which is decoded from AIS message No. 17, versus time for three VTSs mentioned above.

All three VTSs set the penultimate 6<sup>th</sup> level of decreasing the reliability of satellite information, i.e. “shall cause the user equipment to indicate that the transmission is unmonitored” [4]. The nature and time interval of the transition to the 6<sup>th</sup> level at the VTSs in Ochakiv and Odessa are very similar, and the data from the VTS on the Ruska Beak differ greatly in duration and nature. Table 2 shows the

interpretation of satellite data in message No. 17 of the VTS under consideration for two timestamps.

Note that similar behavior had the VTS in Ochakiv on August 15. The VTS in Odessa operated in normal mode: the coordinates in the AIS messages No. 4 and No. 17 were the same, parameter Station ID was always transmitted, the 6<sup>th</sup> level of reliability of pseudo range corrections was very rare in messages, for example, on August 15 out of 8137 messages it was set only in three ones.

Fig. 3 shows the range from station No. 4757 to three vessels with MMSI 272016100, 272019500 and 272085200 depending on time.

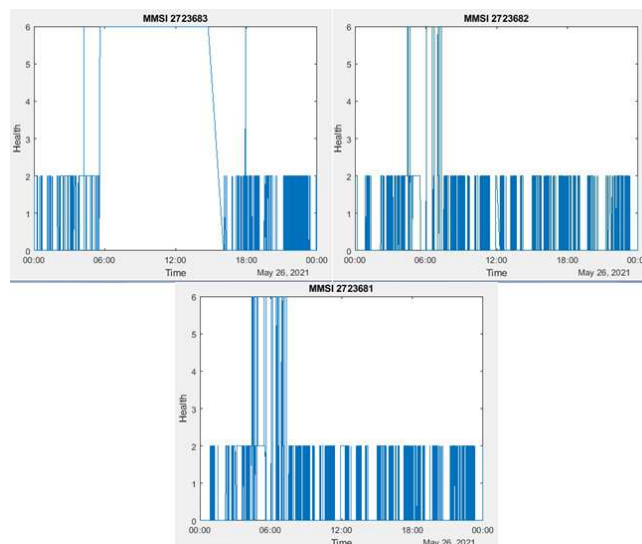


Fig. 2. Reliability of satellite data (Health) versus time for three VTSs on May 26, 2021

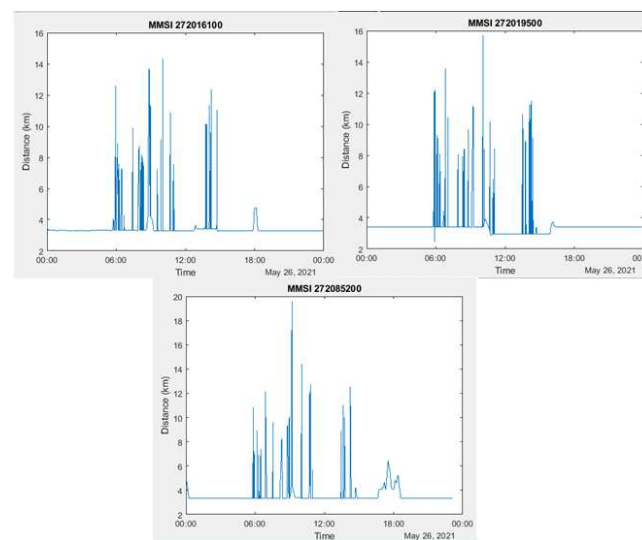


Fig. 3. Range versus time for three vessels on May 26, 2021

The data in Fig. 3 correlate well with each other and with the reliability of satellite data (Health) in Fig. 2 for VTS on the Ruska Beak.

The incorrect operation of VTS on the Ruska Beak belonging to the Mykolaiv Branch of the State Hydrographic Service of Ukraine [5, 6] has already been noticed in paper [1]. It was noted that the station generated a distorted synchropulse, examples of vessels with coordinate jumps were also given. The shutdown of this VTS led to the normalization of AIS messages in this area.

It is very possible that this time the jumps in the coordinates of the vessels were caused by VTS on the Ruska Beak with MMSI 2723683. For May 26, coordinate jumps were detected in 8 vessels, but there were vessels whose coordinates changed smoothly or they did not change at all. Perhaps these vessels did not use the AIS messages No. 17 with the 6<sup>th</sup> level of reliability or did not use the information of VTS on the Ruska Beak at all.

TABLE II. INTERPRETATION OF SATELLITE DATA IN MESSAGE No. 17 OF THE VTS No. 2723683, No. 2723682 AND No. 2723681 FOR TWO TIMESTAMPS

Date 2021-05-26 Time 00:00:07-00:00:09				
	MMSI	2723683	2723682	2723681
	Health	0	0	0
Satellite No.	StationID	91	89	89
1	Pseudo range correction, meters	9.64	9.72	9.72
3		4.06	3.78	3.76
4		4.28	3.68	3.68
6		7.04	7.32	7.30
9		6.26	5.38	5.38
19		19.38	17.90	17.90
22		7.06	6.56	6.56
26		11.12	11.92	11.94
31		8.72	10.10	10.10
7	14.52	-	-	
Date 2021-05-26, Time 12:17:57-12:17:59				
	MMSI	2723683	2723682	2723681
	Health	6	0	2
Satellite No.	Station ID	91	89	89
2	Pseudo range correction, meters	10486.00	7.22	7.22
5		655.36	16.74	16.74
6		10486.00	-	-
12		10486.00	7.46	7.50
18		-	22.70	22.66
20		-	18.88	18.78
25		10485.00	6.24	6.26
29		655.36	6.48	6.50
31		655.36	9.02	9.04

Reception of other VTS signals by vessels in the area under consideration was limited on May 26. The VTS with MMSI 2723666, which is next in distance from the area under consideration, is located on the Pivdennyi Buh Firth at a distance of 38 km from the station No. 4757. It transmitted only messages No. 4 (4742 messages on May 26). The stations No. 4757 and No. 5064 didn't receive messages from VTS in Ochakiv at all.

The class of failures considered above when determining the coordinates of vessels in AIS technology can certainly be minimized.

#### IV. CRC ERRORS

The following class of failures is caused by an error in the development of the main elements of the AIS technology, namely, the allocation of only 16 bits to the CRC checksum. This leads to a probability of  $1/2^{16} = 1.53 \cdot 10^{-5}$  of a random match of the CRC code, regardless of the amount of information encoded by the CRC code. For 10 days of every second checking of the CRC code on a uniform uncorrelated

bit stream, the probability of a random CRC match is almost equal to 1.

It is quite difficult to estimate the CRC code error detection rate in real conditions, since the AIS signal decoding algorithm has procedures for allocating a signal in time domain, sync pulse searching with a given correlation threshold and adjusting synchronization using StartByte. Only after these procedures the CRC is checked. It is clear that in case of a random match of the CRC code, the decoded information should be strongly distorted, the MMSI number should not match the number of the real vessel (the probability of a match for a completely random number does not exceed  $5 \cdot 10^{-5}$ , since the number of all ships in the world can be safely limited 500 thousand). It is also well known that for real systems the probabilities of rare events often differ significantly from the probabilities calculated from simple models. Table 3 shows the number of messages per day classified as randomly passing CRC.

Part of one of the messages that passed CRC looks like this:

Station 4757, Date 2021-06-11, Time 07:30:38.034  
 Distance = 12773.19 km  
 Message\_Type: 18  
 Repeat\_Indicator: 0  
 MMSI: 503848863 - No record found in MarineTraffic  
 Regional\_Reserved: 181  
 Speed\_Over\_Ground: 34.1  
 Position\_Accuracy: 0  
 Longitude: -148.5718  
 Latitude: 18.1579  
 Course\_Over\_Ground: 169.6  
 True\_Heading: 451  
 Time\_Stamp: 21  
 Report\_Type: 'Standard Class B CS Position Report'

TABLE III. NUMBER OF MESSAGES PER DAY CLASSIFIED AS RANDOMLY PASSING CRC

CRC error rate		
Date	Station No. 4757 (Mykolaiv)	Station No. 5064 (Ochakiv)
2021-05-26	1	7
2021-06-11	1	0
2021-06-12	1	1
2021-06-29	0	3
2021-06-30	0	6
2021-07-01	1	10
2021-07-02	1	1
2021-08-15	0	6
<b>Total</b>	<b>5</b>	<b>34</b>
<b>CRC error rate per day</b>	<b>0.63</b>	<b>4.25</b>

It would seem that among the 39 failed messages there should not be MMSI numbers that match the numbers of real vessels. However, there are 3 such cases, and with the same MMSI number. The main part of these three messages is shown in Table 4.

Attention is drawn to the very good similarity of parameters of the messages No. 1 and No. 2, which were received at intervals of more than a month at different stations. It is clear that the probability of receiving three such messages on a random signal stream approaches zero, therefore, there must be the same reason that causes the reception of such messages.

