4th INTERNATIONAL CONFERENCE
TRANSPORT SYSTEMS TELEMATICS TST'04

ZESZYTY NAUKOWE
POLITECHNIKI ŚLĄSKIEJ 2004
TRANSPORT z.55, nr kol. 1657

Vessel Traffic Service,
Automatic Identification System,
radar tracking system

Ryszard WAWRUCH[1]

QUALITY OF INFORMATION ABOUT RADAR TRACKED AND AIS REPORTED VESSEL IN VTS CENTRE

The paper describes selective results of tests performed in the area of the Gulf of Gdansk with the effect to compare information accuracy about position, heading and course over ground (COG) and speed over ground (SOG) of a tracked vessel equipped with gyrocompass, Automatic Identification System (AIS) and DGPS receiver, accessible on the ship and in the VTS centres with AIS shore base station and different shore based radar tracking systems. During the experiment one Real Time Kinematic (RTK) GPS and three DGPS receivers were installed on board the survey vessel and used as reference system. Presented results show advantages and disadvantages for the VTS purposes of the AIS application in comparison with the shore-based radar tracking system.

JAKOŚĆ INFORMACJI W CENTRUM KONTROLI RUCHU MORSKIEGO (VTS) O STATKU ŚLEDZONYM PRZEZ RADAR I ZGŁASZANYM PRZEZ AIS

Referat opisuje wyniki badań przeprowadzonych w Zatoce Gdańskiej celem porównania dokładności informacji o kursie, pozycji, kącie drogi nad dnem (COG) i prędkości nad dnem (SOG) śledzonego statku wyposażonego w żyrokompas, system automatycznej identyfikacji (AIS) i odbiornik GPS, dostępnej na statku i w centrum VTS z bazową stacją brzegową AIS i różnymi radarowymi brzegowymi systemami śledzącymi. W czasie eksperymentu jeden odbiornik RTK GPS i trzy DGPS były zainstalowane na badanym statku i stosowane jako system odniesienia. Przedstawione wyniki pokazują wady i zalety stosowania do celów VTS AIS w porównaniu z radarowymi brzegowymi systemami śledzącymi.

1. INTRODUCTION

According to the recommendation of the International Maritime Organisation, Vessel Traffic Service (VTS) "should have the capability to interact with the traffic and to respond to traffic situation developing in the VTS area". The VTS operator may fulfil his duties only when the information about controlled ships available in the VTS centre is received without time delay and has the same level of accuracy as the data available on board these vessels. A ship equipped with gyrocompass and DGPS receiver has continuous and accurate data

[1] Faculty of Navigation, Gdynia Maritime University, Morska 81-83, 81-225 Gdynia, Poland,
Gdynia Maritime Office, Chrzanowskiego 10, 81- 338 Gdynia, Poland, waw000@am.gdynia.pl

about her true position, heading, course over ground (COG) and speed over ground (SOG). The question is to what extent in a particular case the VTS operators can rely on information about controlled vessel obtained from the existing shore based radar tracking system and Automatic Identification System (AIS).

2. DESCRIPTION OF THE EXPERIMENTS

The following measurements were conducted to find answer to the above question:

1. In 1998 for:
   - VTS VOC 5000 delivered by Norcontrol (Norway) and equipped with one shore based X band radar with scanner installed on the tower of Gdynia Harbour Master's Office building at the height of 33,6 meters above sea level; and
   - VTS 8300 installed by Atlas Elektronik (Germany) and equipped with two shore based radars: X band with scanner on the tower of Harbour Master's Office building in Gdańsk Port Północny at the height of 68,9 meters and S band with scanner on the lighthouse in Hel at the height of 42,8 meters (not utilized during the experiment).
2. In 2003 for the new VTS system delivered by HITT (which replaced the two above mentioned old systems) at that time equipped with four X band radars with scanners situated in the positions of previously used radars (in Gdańsk Port Północny, Gdynia and Hel) and on the lighthouse Krynica Morska at the height of 56,4 meters above sea level.
3. In 2004 for the AIS base station with antenna installed on the lighthouse Hel.

During the experiments the shore based radar systems were automatically tracking two hydrographical vessels described in table I: "Zodiak" (in 1998) and "Tucana" (in 2003).

Table 1

Basic technical data of s/v "Tucana" and "Zodiak"

Vessel	Tucana	Zodiak
Function	Survey ship	
Gross tonnage	71	751
Length	23 m	61,3 m
Width	5,8 m	10,8 m
Mean draught	2,2 m	3,3 m
Effective power	2 x 280 KW	2 x 706 KW
Number of propellers	2	2
Maximum speed	12 knots	14 knots
Ship's owner	Maritime Office in Gdynia	

Both vessels were proceeding with the maximum and half ahead speeds keeping steady course and speed in leading line indicating axis of fairway to the port of Gdynia or Gdańsk and performed the following manoeuvres: ZIG-ZAG tests with rudder angles 10^{o} and 20^{o}, circulations to the starboard and port side, slowing down and acceleration from "stop engine" to "full ahead". The measurements were conducted at different distances from the scanners positions of the shore based VTS radars.

The experiments were conducted in good weather conditions (wind North-North-East to North-East 2-3 B^{o}, sea state 1-2 B^{o}). Total time of the dynamic measurements was 7,5 hours in 1998 and 7 hours in 2003.

The accuracy of the tested VTS systems, the navigational equipment of the vessels, including additional DGPS receivers installed for the measurement purposes and used methods of time synchronisation of the readings are described in [1,2,3,4,5].

The experiment with AIS was conducted in order to check the correctness of data transmitted by ship borne equipment and its presentation on the VTS graphical display with electronic navigational chart (ENC).

3. THE ACCURACY CHARACTERISTICS OF SATELLITE POSITIONING SYSTEMS USED IN THE EXPERIMENTS

During the experiments in 1998 and 2003 all differential receivers were tracking the same DGPS reference station Rozewie (ID No.482, 301kHz, 100 bits/s), which is established as a standard marine navigation beacon. Long-term statistics of logged signals from local integrity monitor at Rozewie is gathered by the computer at the reference station and transmitted, as routine, every 6 hours to the central control station in Maritime Office in Gdynia. The Real Time Kinematic (RTK) GPS positioning was based on reference station established in Gdynia. For the purpose of the described measurements the antenna of the RTK GPS reference station was settled in the precisely surveyed position on the building of the Faculty of Navigation of Gdynia Maritime University located near the south entrance to the port of Gdynia. The data from RTK GPS base station was transmitted to the remote receiver via UHF radio link in RTCM v.2.2 format [2].

The accuracy parameters of satellite positioning systems used in the experiments were verified during 12 hours of the static measurements conducted in the period preceding the marine tests while the survey vessels were berthed in Gdynia harbour. The accuracy of:

- the positions of DGPS and RTK GPS systems; and
- the heading estimation obtained as direction between two simultaneously observed DGPS positions (antennas located at ship's forward and aft) had been tested.

The results are summarized in Table 2.

The accuracy of RTK GPS degrades proportionally to the distance from the reference station with the rate of 1 ppm (part per million). Therefore, during the measurements in the areas located 10-15 km from the base station it has to be assumed that the RTK GPS positioning accuracy (horizontal RMS) is degraded by additional 0.01 to 0.015 m [2].

Table 2
The accuracy parameters obtained during static measurements at Gdynia harbour for heading estimation, RTK GPS receiver and selected DGPS receivers [2]

Source of information	The Accuracy Parameters
DGPS Leica MX 9212 (differential station – Rozewie)	Standard deviation (sigma): N-S axis: 0.81 m; W-E axis: 0.63 m; up: 1.59 m. horizontal RMS: 1.03 m
RTK GPS Trimble 4700 Total Station (position update 1Hz, baseline length 500 m)	Standard deviation (sigma): N-S axis: 0.027 m; W-E axis: 0.047 m; up: 0.012 m. horizontal RMS: 0.054 m
Heading estimation ("two DGPS antennas method") Leica MX 9212 + TOPCON Legacy-E	The differences between heading calculated from two DGPS positions and the true geographical direction of the quayside: max. value: + 2.1 deg; min. value: - 2.3 deg; average: + 0.3 deg; standard deviation: 0.95 deg

4. MARITIME MEASUREMENTS AND THEIR RESULTS

During the measurements in 1998 and 2003 the data received from gyrocompass and all on board satellite receivers of the tracked vessels and from the shore-based radar systems was automatically registered at the same time. It included: time, position, heading, course over ground (COG), speed over ground (SOG) and additional information available from the satellite receivers. In order to simulate the AIS transmission the data was recorded in 2003 with the sampling rate once per 2 seconds.

Taking into consideration the fact that GPS RTK system is a source of the most accurate information about position, the ships' positions received from this system were compared with the positions indicated by the ship borne DGPS receivers and the shore based VTS radar systems.

The next stage of data computing was calculation of COG and SOG accuracies accounted as the differences between:
- the ship's COG received from the VTS radar system and the vessel's heading and indication of its gyrocompass and DGPS receiver;
- the ship's SOG received from the VTS and the ship borne DGPS receiver.

The ship's heading was defined as a direction calculated from the simultaneous positions indicated by two ship borne DGPS receivers with aerials installed in the ship's lengthwise axis.

The results of these calculations are presented in tables 3-5. Due to the different methods of calculation and the consequent difficulties in comparison of result received in 1998 and 2003, the accuracies of COG are presented for measurements conducted in 2003 only.

Table 3

The accuracy of the ship's positions received from DGPS and VTS for RTK GPS used as references system

Position error [meters]							
VTS-RTK						DGPS-RTK	
Atlas Elektronik		HITT		Norcontrol			
Max	Mean	Max	Mean	Max	Mean	Max	Mean
Circulation							
118,5	54,4	43,7	16,9	105,4	49,5	1,8	0,5
Zig – zag test							
67,8	36,4	30,9	14,3	109,5	37,8	1,2	0,6
Stopping and acceleration							
57,1	39,5	38,4	17,6	109,2	44,9	0,8	0,3
Steady course (steering on compass or in leading line)							
86,4	39,8	31,8	17,1	79,8	25,5	1,3	0,4

Table 4

The accuracy of the speed over ground received from DGPS and VTS for RTK GPS used as references system

Speed over ground (SOG) error [m/s]					
Atlas Elektronik		HITT		Norcontrol	
Max	Mean	Max	Mean	Max	Mean
Circulation					
1,2	0,4	4,5	0,4	2,8	1,1
Zig – zag test					
0,8	0,4	5,0	0,5	1,2	0,5
Stopping and acceleration					
1,9	0,5	4,0	0,5	2,5	1,0
Steady course (steering on compass or in leading line)					
0,15	0,1	1,8	0,3	0,9	0,3

Table 5

The accuracy of the ship's course received from DGPS and VTS [2]

Course error (using two DGPS antennas method) [degrees]			
VTS (radar tracking)		Gyrocompass (AIS source)	
Max	Mean	Max	Mean
Circulation			
66,4	34,9	11,7	5,0
Zig – zag test			
105,5	47,6	10,5	4,4
Stopping and acceleration			
124,7	54,7	12,3	1,9
Steady course (steering on compass or in leading line)			
16,1	3,3	8,2	2,4

The accuracy of information sent by ship borne AIS was checked after installation of the AIS base station in 2004. Ship borne AIS transmits automatically readings from on board gyrocompass and GPS or DGPS receiver and may handle multiple reports at rapid update rates. It works in following modes:

- autonomous, sending reports at rates depending on ship's speed and the stability of movement (maximum frequency – 1 report/2 seconds);
- assigned, transmitting information at rates defined by the AIS base station; and
- polled, sending reports on the AIS base station request.

AIS should be a source of accurate data about ship's position and movement received without time delay and solve the problem of the above-mentioned errors of shore-based radar tracking systems.

Conducted test proved that there are problems with correctness of this data and its presentation, probably due to:

- compatibility deficiency of reference systems used in ship borne navigational equipment and Electronic Navigational Chart (ENC) installed in the VTS graphical display unit;
- different methods of smoothing, filtering and integrity checking in ship borne sensors connected to AIS;
- improper installation of AIS antennas on board ship; and
- negligence of ship's personnel in manual introduction of some information (navigational status, etc) into ship borne AIS.

The samples of incorrect data transmitted by ship borne AIS and presented on VTS graphical display with ENC are shown in Fig. 1 and 2

5. CONCLUSIONS

All trials were conducted in good weather conditions for small ships. They led to the following conclusions:

1. The accuracy of information about the tracked vessel available on its board and in the VTS centre equipped with the shore based radar system depends on the stability of ship's movement and the kind of performed manoeuvre.
2. The mean errors of the vessel's position received from the shore based radar systems and calculated in comparison with the values indicated by on board RTK GPS receiver are approximately between 14 and 110 meters.
   The mean errors of the vessel's position received from its DGPS receiver and calculated in comparison with the values indicated by the on board RTK GPS receiver are 0,3 - 0,6 m.
4. Heading indications given by the shore based radar systems and gyrocompass installed on the tracked vessel do not always present the same level of accuracy even when the ship is sailing on steady course and in the absence of current and wind.
5. The accuracy of indication given by the shore based radar systems about the heading of tracked vessel performing manoeuvres is ten times smaller than the accuracy of information available from on board gyrocompass.
6. The mean error of vessel's speed received from the shore based radar systems and calculated in comparison with the values indicated by onboard RTK GPS receiver depends on the type of used VTS system and is approximately between 0,3 and 0,5 m/s (HITT), 0,1 and 0,5 m/s (Atlas Elektronik) and 0,3 and 1,1 m/s (Norcontrol).

7. The experiments showed that the tested VTS radar systems characterize time delay of presented information. The smallest value of this delay appears in the system delivered by HITT (mean value 30 seconds).
8. The shore based radar equipment should not be the only source of information, which the VTS operators can rely on. The problems of accuracy and time delay should be given special consideration.
   There should be more than one system, covered one by the other, to ensure the accuracy and the reliability of information at VTS centre in order to give assistance for ships.
9. The use of Automatic Identification System (AIS) may be considered as one of the methods improving the quality of information about tracked vessels available in the VTS centres.
10. In relation to small point objects, the application of AIS system will mainly effect in more accurate and on time indication of ship's heading during manoeuvres.
11. AIS is a potential source of accurate information about vessels proceeding in the VTS area received without time delay. However, at present the integrity, reliability and accuracy of the ship borne source data cannot necessarily be relied on. For example, there are not requirements for GPS receivers installed before 1 July 2003 for:
    - receiver Autonomous Integrity Monitoring (RAIM);
    - generation of COG and SOG and output to the digital interface; and
    - accuracy and methods of smoothing, filtering and averaging of COG and SOG information before being output to the interface.

    Therefore, the accuracy of all received AIS information, including that of position, COG and SOG, transmitted via AIS should not be relied upon until the integrity of the information is proven, at least by association with radar display [6].
12. Compatibility deficiency may be a source of AIS data presentation errors on the graphical VTS operators' monitors.
13. Additionally, it should be noticed that AIS has significant potential to complement information provided by radar tracking systems, but it cannot replace them, as it is heavily dependant on signals and information from sources external to the VTS equipment. For the foreseeable future, radar will remain a primary tool for VTS purposes, as it performs its function totally independently from externally generated signals.
14. All above-mentioned conclusions are fragmentary and require further investigations for different vessels and different weather conditions.
15. A lot of aspects of the above-described experiments should be included in the education process conducted according to the STCW Convention.

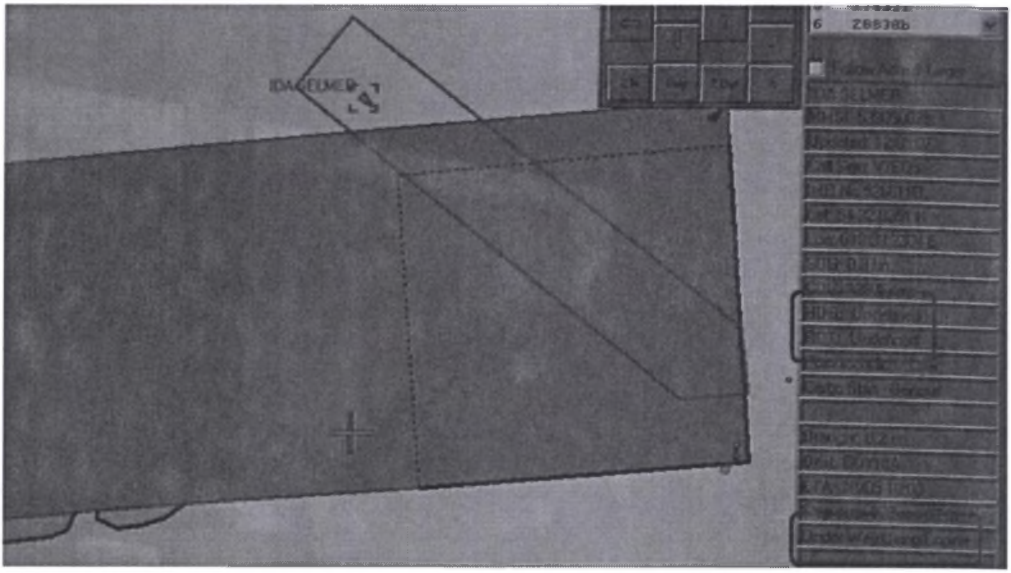

Fig.1. The sample of incorrect presentation of data transmitted by ship borne AIS on VTS graphical display with ENC

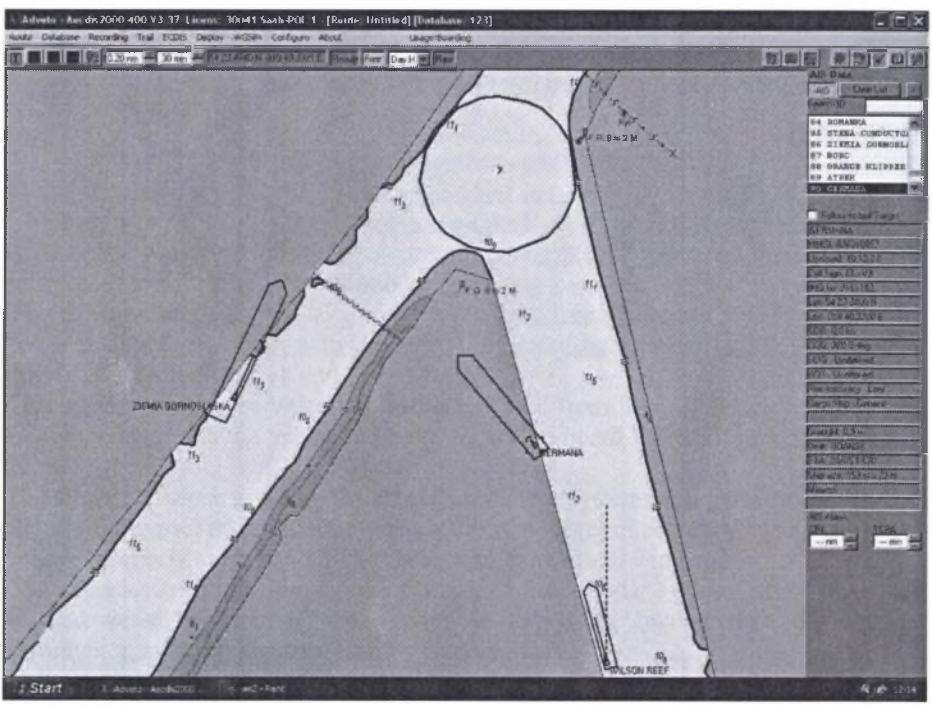

Fig.2. The sample of incorrect presentation of data transmitted by ship borne AIS on VTS graphical display with ENC

BIBLIOGRAPHY

[1] WAWRUCH R., Quality of information about tracked vessel in VTS Centre. 46th International Symposium Electronics in Marine "Elmar 2004", Zadar, 2004, Proceedings, pp. 95-101.

[2] WAWRUCH R., CYDEJKO J., Quality of Information about Tracked Vessel in VTS Centre with GNSS and AIS. 11th IAIN World Congress "Smart Navigation - Systems and Service", Berlin 2003, Proceedings, Session Radar and Radio I, Berlin, 2003, pp. 17.

[3] WAWRUCH R., CYDEJKO J., DZIEWICKI M., Testing quality of information about tracked vessel in VTS centre with GNSS. The Journal of Navigation. Vol. 52, No 2, Cambridge University Press, May 1999, pp. 252-258.

[4] WAWRUCH R., CYDEJKO J., DZIEWICKI M., Testing quality of information about tracked vessel in VTS centre with GNSS. 2nd European Symposium "Global Navigation Satellite Systems - GNSS 98", Tuluse 1998, Proceedings, Vol. 2, Session VII, pp. VII-0-04.

[5] WAWRUCH R., CYDEJKO J., DZIEWICKI M., LEDÓCHOWSKI M., Quality of information about tracked vessel in VTS Centre. XIV IALA Conference "Safe Navigation Through Systems Technology", Hamburg 1998, Proceedings, Vol. 2 "Vessel Traffic Services", pp. 67-90.

[6] Recommendation for the display and use of AIS information on ship borne navigational display. Recommendation to review resolution A.917(22), IMO Sub-Committee on Safety of Navigation, NAV 50/4/2, London, 2004.

Reviewer: Prof. Bernard Wiśniewski