Testing the Quality of Information on Tracked Vessels in a VTS Centre with GNSS

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This paper describes selective tests performed in the areas of Gdansk and Gdynia VTS Centres. The main goal of the tests was to determine the accuracy of position, speed and course estimations measured by shore-based radar VTS tracking systems by using measurements of the same parameters available on board a tracked vessel equipped with GPS and GLONASS receivers. Six DGPS/GPS/GLONASS receivers were installed on board a survey vessel, and all of them recorded the vessel's route simultaneously with two different VTS radars – one at Gdansk and one at Gdynia (20 km apart). All DGPS receivers tracked the same reference station. Presented results show that the radar information can be used by VTS operators to provide navigation assistance within certain limits, but these limits must be understood. A more detailed description of the experiment was presented during the IALA Conference in Hamburg in June 1998.

1. INTRODUCTION. According to terms presented in the Guidelines for Vessel Traffic Services, 'VTS should have the capability to interact with the traffic and to respond to a traffic situation developing in the VTS area'. The VTS operator is only able to fulfil his duties when the accuracy of data received from shore-based radar equipment is not significantly different from the accuracy of data available on board the controlled vessels. Ships equipped with DGPS receivers have continuous and accurate data about their true position, course made good and speed over ground. The question is, can VTS operators continue to rely on information about tracked targets from existing radar equipment? The experiment was carried out to answer this question.

2. DESCRIPTION OF THE EXPERIMENT. The experiment was conducted in November 1997 in the Bay of Gdansk. The tracked vessel proceeded with the maximum speed of 12 knots and performed the following manoeuvres: zig-zag test, circulation and slowing down. Total time of experiment was 7·5 hours. After the installation of additional equipment on board, a time synchronisation of computers was performed. From that moment, all data on shore and on board had a common UTC time stamp.

2.1. *Navigation Receivers on the Ship*. For the purpose of the experiment, the hydrographic survey vessel was additionally equipped with extra positioning equipment comprising six satellite navigation receivers with computers for data

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registration and logging. The antennas for the three DGPS receivers were mounted on the main axis of the ship; one on the bow, one on midship and one on the stern, about 20 metres apart. The function of this group was to provide data on the ship's trajectory, course and speed, and a means of checking data integrity (in case one of the receivers was unserviceable or jammed). Additionally three other receivers were used during the experiment: a GPS/GLONASS integrated receiver (24 ch.) with work mode set for *GPS+GLONASS*; a GPS (six ch.) set for work mode *GPS only*; and a GPS/GLONASS integrated receiver (24 ch.) set for work mode *GLONASS only*. These non-differential receivers were to deliver data for inter-system comparison especially for measured speed (SOG) and course (COG) in the dynamic application.

2.2. *Monitoring of the Reference System.* All three differential receivers tracked the same DGPS reference station established as a standard marine navigation beacon, permanently monitored for integrity. To check its proper operation during experiment, the parameters of the correction signal were additionally monitored ashore by a static DGPS receiver installed in the vicinity of Gdynia Port. Data from that remote monitor were analysed to determine any possible position deviations in the area of the experiment. DGPS performances monitored ashore at the time of the experiment were as follows:

(i) Horizontal drms – 1·25 metres
(ii) Average HDOP – 1·1
(iii) Maximal observed errors: latitude – 3·5 metres, longitude – 4·3 metres
(iv) Differential corrections availability – 100 %
(v) Signal: SS: 42–45 dB, SNR: 14–16 dB.

2.3. *Onboard Data Recording.* All navigation equipment and computers were working simultaneously with a redundant sampling rate of 1 per second. Output raw data available in a form of NMEA 0183 code sentences were logged on hard discs. The files assigned for each type of equipment were grouped for certain types of manoeuvres.

2.4. *Technical Structure of VTS System.* Two shore-based X-band radars automatically tracked the ship. The 22-foot long scanner of one radar is installed on the tower of the Harbour Master's building in Gdansk Port Pólnocny at a height of 66 metres. The 18-foot long scanner of the second radar is situated on the tower of the Gdynia Harbour Master's building at 31 metres height. Base computers were used for data collection and timing. All data were registered in digital form and computer clocks were synchronised before the experiment. The radar systems at Gdansk and Gdynia produce output data in different specific formats and at different periods. Data delay was also created by the integration time of the radar scanner and its associated software; for Gdynia radar, it was a period of 3 seconds, and for Gdansk radar it was 20 seconds.

3. MARINE TRIALS.

3.1. *Static Measurements.* Antenna positions of the satellite receivers installed on board were surveyed by two methods: traditional (by tape) and electronically (by DGPS). Their relative static positions by DGPS were verified with over 13 hours observation, when the ship was berthed in the port at Gdynia. Computed standard deviations of the 2D positions were less than 1·8 metres. The triangle created by antenna positions was useful for checking the reliable operation of navigation receivers during the experiment.

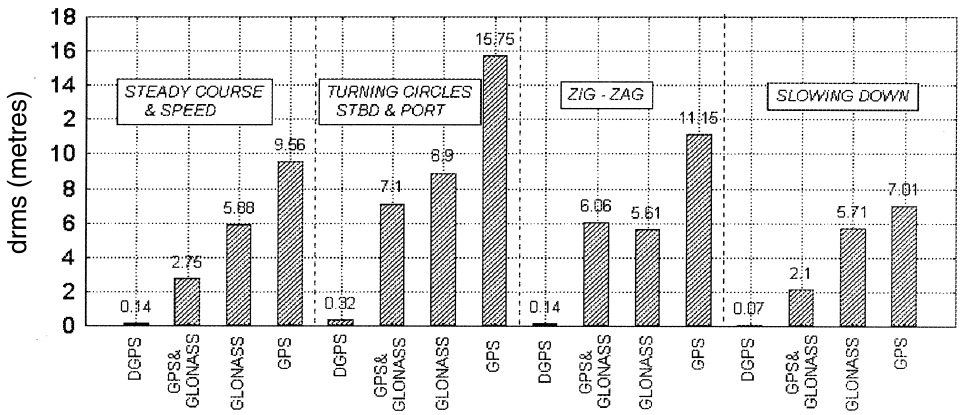

Figure 1. The accuracy of On Board Positioning Systems with DGPS as reference. (All values corrected for fixed distances between antennae; value for DGPS error calculated as a comparison of positions observed at two DGPS receivers.)

Table 1. VTC Gdansk – Position differences between VTS Radar and Reference Systems for different manoeuvres.

Ship's manoeuvre	Reference system	Difference between VTS radar and reference systems (metres)			
		Average	Min.	Max.	drms
Steady course and speed	DGPS	39·8	2·6	86·4	46·11
	GPS	55·0	5·0	111·6	61·91
	GLONASS	23·4	0·5	67·2	29·90
	GPS+GLONASS	24·9	1·7	67·3	31·48
Turning circle STBD	DGPS	52·0	11·0	100·5	59·14
	GPS	63·5	10·7	98·8	67·39
	GLONASS	38·8	3·7	79·8	45·04
	GPS+GLONASS	33·7	2·2	82·4	45·39
Turning circle PORT	DGPS	56·7	3·0	118·5	63·90
	GPS	26·2	6·2	78·1	32·87
	GLONASS	43·2	0·4	107·5	52·27
	GPS+GLONASS	42·2	0·7	106·4	51·15
Zig-zag	DGPS	36·4	5·9	67·8	39·08
	GPS	33·1	0·4	69·9	39·05
	GLONASS	26·8	1·6	51·9	29·28
	GPS+GLONASS	26·7	3·1	52·7	29·04
Slowing down	DGPS	39·5	3·3	57·1	41·85
	GPS	40·9	4·1	75·3	45·33
	GLONASS	28·0	6·8	43·4	29·71
	GPS+GLONASS	28·2	7·0	42·6	29·73

3.2. *Dynamic Measurements of the Tracked Ship's Position, COG and SOG.* During the experiment, positions, course over ground (COG) and speed over ground (SOG) of the tracked vessel obtained from all on-board satellite receivers and both of the shore-based VTS radars were automatically logged simultaneously. Taking into consideration that the DGPS systems are the source of the most accurate data available, the differences between the values of the above-mentioned parameters calculated by GPS, GPS+GLONASS and GLONASS receivers were compared with DGPS. To verify DGPS accuracy, data from two different DGPS receivers were also compared. The values describing the accuracy of above-mentioned systems are presented in Figure 1.

The next stage of data computation was an analysis of the accuracy of positions, COG and SOG of the tracked vessel obtained by the radars at the VTS centres. The differences between these radar parameters and those recorded by the DGPS receiver installed on midship of the tracked ship were calculated for each of the manoeuvres. The results are presented in Tables 1, 2 and 3. Tables 1 and 2 show the minimum and

Table 2. VTC Gdynia – Position differences between VTS Radar and the Reference Systems for different manoeuvres.

		Difference between VTS radar and reference systems (metres)			
Ship's manoeuvre	Reference system	Average	Min.	Max.	drms
Steady course and speed	DGPS	25·5	0·5	79·8	32·13
	GPS+GLONASS	43·6	3·8	104·9	40·19
	GLONASS	46·5	2·5	114·0	53·01
	GPS	32·9	0·4	80·0	49·63
Turning circle STBD	DGPS	37·0	0·5	105·4	46·75
	GPS+GLONASS	52·4	0·4	126·9	43·90
	GLONASS	52·9	0·7	126·3	63·86
	GPS	34·7	0·3	101·4	63·26
Turning circle PORT	DGPS	62·0	8·7	103·5	67·18
	GPS+GLONASS	85·0	33·9	133·3	111·79
	GLONASS	83·7	33·0	132·9	87·57
	GPS	107·9	34·1	148·8	89·07
Zig-zag	DGPS	37·8	0·24	109·5	47·25
	GPS+GLONASS	51·9	4·1	129·3	53·78
	GLONASS	51·9	2·1	127·5	62·20
	GPS	45·8	0·8	123·4	62·19
Slowing down	DGPS	44·9	2·6	109·2	55·96
	GPS+GLONASS	38·6	0·8	94·1	49·25
	GLONASS	38·6	0·4	93·7	50·67
	GPS	39·5	4·9	96·8	50·75

Table 3. Differences of Speed and Course estimation observed between VTS Gdansk radar and DGPS during different manoeuvres of the tracked vessel.

	Course difference (degrees)			Speed difference (knots)		
Ship's manoeuvres	Min.	Max.	Standard deviation	Min.	Max.	Standard deviation
Steady course and speed	−2·4	2·8	1·2	−0·31	0·21	0·11
Turning circle – Stbd	−2·7	55·0	18·7	−1·58	2·42	0·94
Turning circle – Port	−45·9	31·4	20·1	−0·94	1·74	0·78
Zig-zag	−30·1	30·1	19·6	−1·02	1·57	0·71
Slowing down	−22·1	0	7·5	−3·53	0·51	1·04

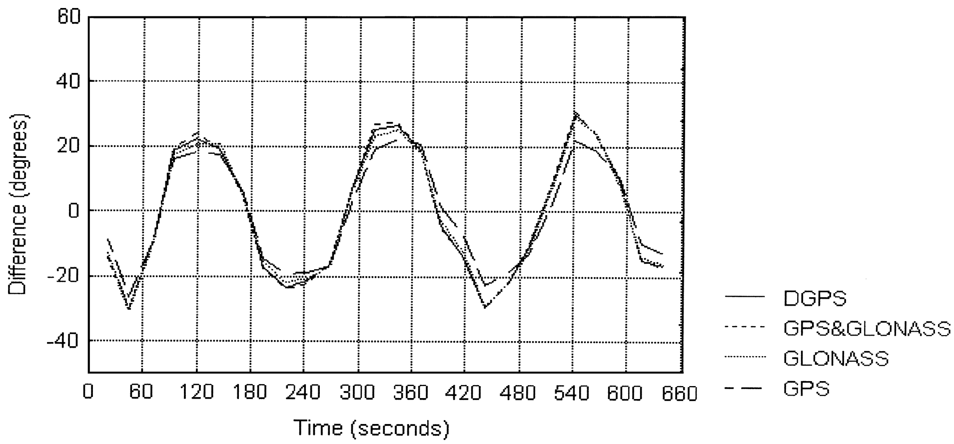

Figure 2. Difference in Course Over the Ground (COG) measurements between the Gdansk VTS Radar and the Reference DGPS Receiver during the Zig-Zag manoeuvre.

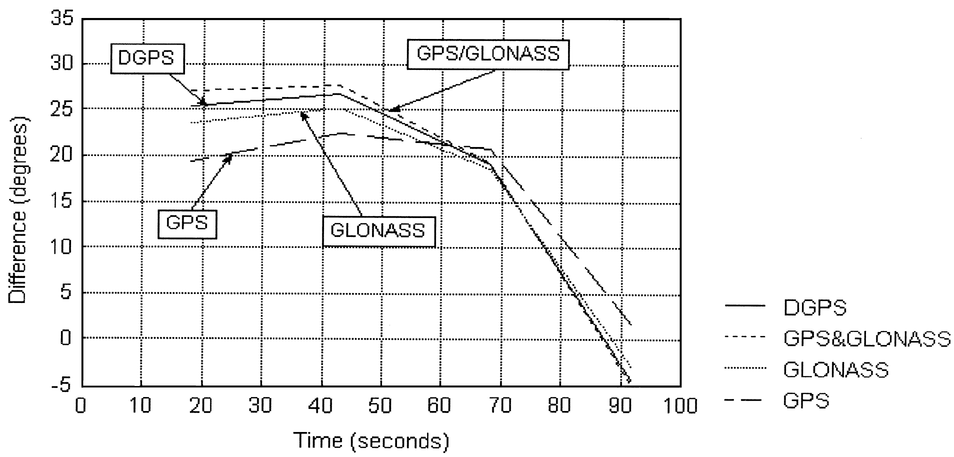

Figure 3. Difference in Course Over the Ground (COG) measurements between the Gdansk VTS Radar and the Reference DGPS Receiver at a Turning Point during the Zig-Zag manoeuvre.

maximum values of the position differences, together with the drms values. Table 3 shows the minimum and maximum values and standard deviations for COG and SOG. For the ship's positions in Tables 1 and 2, mean values of differences are also shown. These values might be considered as the systematic component of the total error, and depend on the kind of manoeuvres, distance to the radar scanner at the shore station and the type of equipment.

As a sample of the data recorded, Figures 2 and 3 show COG estimated differences between reference system receivers and the VTC Gdansk tracking radar as a function of time for the zig-zag manoeuvre and during a turn in the manoeuvre.

5. CONCLUSIONS AND RECOMMENDATIONS. During the performed tests, the accuracy of the ship's parameters—position, course over ground (COG) and speed over ground (SOG) from shore-based radar equipment—was determined by comparing the measurements achieved with the same parameters recorded on satellite receivers installed on board a tracked, manoeuvring vessel.

Trials were conducted for only one ship in good weather conditions—wind 2–3° B—sea state 2° B and led to the following conclusions and recommendations:

(*a*) The accuracy of DGPS observed at the shore monitor station during the experiment was 1·3 metres (horizontal drms), and the accuracy of DGPS positions observed on board the moving vessel degraded due to uncompensated ship's roll, pitch and heave might be estimated, for weather conditions at the time of the experiment, as less than 3 metres (horizontal drms). By comparing other reference systems to DGPS (Figure 1) their relative accuracies (horizontal drms) could be estimated as:

(i) GPS+GLONASS 4–7 metres (horizontal drms relative to DGPS).
(ii) GLONASS 6–9 metres (horizontal drms relative to DGPS).
(iii) GPS 10–15 metres (horizontal drms relative to DGPS).

(*b*) The information about the ship's position measured by shore-based radar equipment comprised a certain component of systematic error, mainly due to the different geodetic datums used for GPS and VTS electronic charts installed in Gdansk and Gdynia VTS Centres. In situations when communication between a VTS centre and the service user is based on exchange of information about a ship's fix position reported in geographical coordinates, special caution must be exercised. It is recommended, whenever possible, that positions are defined by ranges and bearings to identify navigational objects.

(*c*) The standard deviation of true ship's position, COG and SOG received from shore-based radar equipment and calculated in comparison to values indicated by on-board DGPS receivers, depends on the kind of manoeuvres performed, type of radar equipment used and distance to its scanner. Even when the same geodetic datums are used, the difference between ship's position derived from a shore-based tracking radar and a ship's satellite receivers may reach values of 100–150 metres (see Tables 1 and 2).

(*d*) The values of drms presented in Tables 1 and 2 should be taken into account in calculations of a ship's domain for certain fairways. These values should be taken into consideration by VTS operators during traffic organisation and navigational assistance in calculation of maximum dimensions and speed of vessels, which can sail along a defined fairway.

(*e*) The test of quality of information available from radars and full compatibility of geodetic datum used in shore-based radar equipment, VTS electronic charts and satellite systems should be periodically undertaken.

(*f*) Shore-based radar equipment should not be the only source of information on which VTS operators rely. Especially, the problem of accuracy should be considered. There should be more than one system to ensure that data at VTS centres are accurate and reliable enough to provide navigational assistance to ships. The future use of Automatic Identification Systems (AIS) to transmit data from on board satellite receivers may be considered as one method of improving the quality of information about tracked vesssels available in VTS centres.

(*g*) All the above-mentioned conclusions are fragmentary and require further investigations for different vessels under different weather conditions. If further trials confirm these results on the accuracy of data from shore-based radars, it may be necessary to introduce some corrections into the software of existing Data Management Systems.

(*h*) Many aspects of above experiment should be included in the education programme of VTS operators.

REFERENCE

Wawruch, R., Cydejko, J., Dziewicki, M. and Ledóchowski, M. (1998). Quality of information about tracked vessel in VTS centre. *Proceedings of the IALA Conference*. June 1998, Hamburg, Germany.

KEY WORDS

1. Marine. 2. VTS. 3. Accuracy. 4. Trials.