Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2014, 40(112) pp. 67–72
ISSN 1733-8670

Shipborne satellite navigation systems receivers, exploitation remarks

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Key words: GPS system, GPS receiver, shipborne GPS receiver, type of GPS receivers

Abstract
Currently (July 2014) an uninterrupted information about the ship's position can be obtained from specialized electronic position-fixing systems, in particular, Satellite Navigation Systems (SNSs) as GSP and GLONASS and Satellite Based Augmentation Systems (SBASs) as EGNOS or WAAS. On each ship's bridge one GPS stationary receiver is installed at least but on many ships there are two or even more GPS receivers. Nowadays, several hundred different end-user products and broad/chipset/modules are available on the world market, however for ship's bridge several dozen models provided by a dozen or so manufacturers are designed only. In this paper 309 GPS receivers, 47 different models of 12 manufacturers installed on 188 ships of different types and with different lengths were taken into account. The relations between the type and the length of the ship, the number of the GPS receivers installed on one ship, the manufacturers and the models the most frequently used are presented.

Introduction

An uninterrupted information about the ship's position is one of the most important elements of the safety of navigation in the sea transport in restricted and coastal areas, recommended by International Maritime Organization – IMO. Currently (July 2014) the information about user's position is obtained generally from specialized electronic position–fixing systems, in particular, satellite navigation systems (SNS) as the American GPS system, Russian GLONASS system and Satellite Based Augmentation Systems (SBAS) as EGNOS, WAAS, MSAS and since February 14, 2014 Indian GAGAN also [1, 2, 3, 4]. The generic name given to all these systems is Global Navigation Satellite Systems (GNSS).

On each ship's bridge one GNSS stationary receiver with LCD display screen is installed at least but on many ships there are two or even more GNSS receivers. Typical maritime applications consist in coupling GNSS receivers with dedicated sensors such as radar, ARPA, autopilot, echo-sounder, fish-finder, and so on [5, 6, 7]. At present, the receivers used and installed on the ship's bridge are in the straight majority the units of GPS system only. However, in marine transport on the ships there are many Differential GPS receivers or GPS + SBAS augmentation or DGPS + SBAS models [8].

Performance standards for GPS receiver equipment are described in IMO Resolution MSC.112(73), adopted on 1 December 2000 [9] and in IEC (International Electrotechnical Commission) 61108–1 ed. 2 standards [10]. Receiver equipment for the GPS is intended for navigational purposes on ships with maximum speed not exceeding 70 knots. Additionally, these standards cover the basis requirements of position-fixing for navigation purposes only and do not cover other computational facilities which may be in the equipment [11, 12].

Nowadays, several hundred different GNSS receivers provided by more than one hundred manufacturers are available on the world market. The number and the type of the receiver installed

on the ship's board depend on the type of the ship, its capacity and the length in particular.

Types of the ship, number of GNSS receivers on the board

The students of Gdynia Maritime University during the study must attest individual practical onboard training on Polish or foreign ships, merchant ships in the straight majority. In the paper were made the most of information placed in the final student's reports, period 2012–2014 about the ships parameters and GNSS receivers [13]. Totally 188 ships navigating entire world of several dozen companies**,** of different types and with different lengths were taken into account (Tab. 1).

Table 1. Distribution of 188 ships depending on their type and length L

The type of the ship	The number of the ships			Total number of the ships	
	$L <$ 120 m	120 m ≤ $L \leq$ 300 m	$L >$ 300 m	Number	%
Container	3	57	10	70	37.2
Bulk cargo	4	21	–	25	13.3
Oil tanker	–	21	2	23	12.2
General cargo	4	9	–	13	6.9
Ro-ro	–	12	–	12	6.4
Chemical tanker	9	2	–	11	4.8
LNG carrier	–	8	1	9	4.8
Ferry boat	–	5	–	5	2.7
Ro–Pax	–	3	–	3	1.6
Cement carrier	3	–	–	3	1.6
Others	10	4	–	14	7.4
Total number / percentage	33 / 17.6	142 / 75.5	13 / 6.9	188	100

The length of the ships L [m] was divided into 3 groups: the first, if $L < 120$, the second, if $120 \leq L \leq 300$ and the third, if $L > 300$. Ten types of the ships were distinguished, the term "other" includes all the others types as refrigerated and sailing vessel, passenger ship or tug boat. The biggest numbers of the ships are in the case of container (37.2%), bulk cargo (13.3%) and oil tanker (12.2 %). More than 75% of all ships have the length from second interval. The straight majority of the longest ships are containers (77%), in the case of the smallest ships the majority are chemical tankers and all ships named the term "other".

Table 2. Requirements according to IMO and IEC standards concerning selected parameters of GNSS receivers designed for ship's board [9, 10]

Parameter	MSC.112(73), IEC 61108-1ed.2
Accuracy	13 m (95%)
SOG (speed over ground)	Required to accuracy of SDME (Software Development and Maintenance Environment)
COG (course over ground)	Required to accuracy of ± 1° (> 17 kt), ± 3° (≤ 17 kt)
UTC	Required to output
RAIM (Receiver Autonomous Integrity Monitoring)	Required to indicate integrity indication of Safe, Caution, Unsafe at confidence level of 10 m and 100 m
Display update rate	1 second at latest

The 309 GNSS receivers were installed together on 188 ships mentioned in the table 1. All these receivers are GPS receivers designed for the SOLAS ships according to the GPS performance standards IMO [14] and IEC [10] effective on and after July 1, 2003. The straight majority of them are a highly reliable standalone EPFS (Electronic Position Fixing System) receiver that fleets positioning information to AIS, Radar, VDR, VideoPlotter, Autopilot, Echo Sounder and Sonar. The current requirements according to IMO and IEC standards concerning selected parameters are shown in the table 2.

The distribution of the number of the receivers depending the ship's length is presented in the table 3. The number of the receivers installed on one ship can be equal 1, 2 or 3 but the last value is in one case only (1 ship of 188); it was the container equipped with three the same receivers, Leica MX420. One or two receivers can be met on each ship, independently of its length, however majority of them (more than 62%) is equipped with two receivers.

Table 3. Distribution of 309 GNSS receivers on 188 ships with different length L [m]

Number		$L <$ 120 m		120 ≤ $L \leq$ 300		$L >$ 300		Total number of the ships		Total number of the receivers
		Number of the ships	%	Number of the ships	%	Number of the ships	%	Number	%	
Number of the receivers on the ship	1	26	78.8	39	27.5	3	23.1	68	36.2	68
	2	7	21.2	102	71.8	10	76.9	119	63.3	238
	3	–	–	1	0.7	–	–	1	0.5	3
Total number of the ships		33	100	142	100	13	100	188	100	
Total number of the receivers		40		246		23				309

We can say that if L increases, the percentage of the ships with two receivers increases also from 21.2% (the shortest ships) to 76.9% (the longest). Meanwhile there are 3 the longest ships ($L >$ 300 m) with one receiver on board only. On the ship equipped with two receivers in the majority cases there are two the same models, if theses receivers are different, theirs manufacturers are different too.

Type of the GNSS receivers, theirs performance parameters

Despite the fact that since December 2011 GLONASS system has again Full Operational Capability [4], on the ships, merchant ships, in particular are installed GPS receivers only. Some of them determine ship's position in option stand alone, others use differential (DGPS) [15] or satellite based augmentation (SBAS). The distribution of 309 GPS receivers on 188 ships of different manufacturers and with different length is shown in the table 4. The manufacturers were presented in alphabetical order. We can recapitulate that:

- on the ships there are receivers of 12 different manufacturers; 11 manufacturers (without Kelvin Hughes only) in the case of the ships with $L < 120$ m, 10 (without Garmin and JAVAD) in the case of the ship with $120 \le L \le 300$, 4 of the longest ships;
- the number of different models installed on the ships is equal 47, the biggest numbers of models provided by one manufacture are in the case of Furuno (10) and Koden (9), the lowest, only one, in the case of four manufacturers;
- the most frequently selected by the companies are the models of three manufacturers: Furuno (37.5 %), Leica (24.6 %) and Simrad (9.7 %), a couple of the least likely: Garmin, JAVAD and Kelvin Hughes (1% or less);
- the models the most frequently installed on the ships are: Leica MX 420 (59 receivers), Furuno 150 (46 receivers) and Furuno 90 (33). These three models constitute as many as 45 % of all receivers (138 of 309) and the straight majority of the receivers installed on the longest ships (19 of 23) and are the best receivers which can be installed on the ships irrespective of their length. Two manufacturers, Furuno and Leica, provide about 63 % of all receivers (192 of 309);
- the R4 is the only model of SAAB manufacturer but this receiver is very frequently used, fourth place on the list;
- the mean number of the receivers installed on the ship is greater than 1.6 and depends on the length L of the ships; the smallest (1.21) is for the ship with $L < 120$ m, the biggest (1.77) for the ship with $L > 300$ m.

Table 4. The detailed distribution of 309 GPS receivers on 188 ships with different lengths L

Manufacturer	Model	Number of the models			Total number of the models	Total number of all receivers of given manufacturer / percentage
		$L < 120$	$120 \le L \le 300$	$L > 300$		
Furuno	30	1	1	–	2	116 / 37.5
	31	3	3	–	6	
	32	3	5	–	8	
	33	–	1	–	1	
	50	–	1	–	1	
	70	2	–	–	2	
	80	1	14	–	15	
	90	3	23	7	33	
	150	2	43	1	46	
	LC-90	–	1	1	2	
Garmin	128	3	–	–	3	3 / 1.0
JAVAD	Nav500	1	–	–	1	1 / 0.3
JRC JLR	4321	1	–	–	1	16 / 5.2
	4570	1	2	–	3	
	6800	–	1	–	1	
	7500	–	1	–	1	
	7700	1	9	–	10	
Kelvin Hughes	420	–	2	1	3	3 / 1.0
Koden	90	–	1	–	1	16 / 5.2
	95	1	–	–	1	
	97	–	1	–	1	
	98	–	2	–	2	
	911	–	1	–	1	
	912	1	2	–	3	
	913	–	2	–	2	
	920	–	2	–	2	
	931	–	3	–	3	
Leica	Mk 10	–	4	–	4	76 / 24.6
	Mk 12	–	1	–	1	
	Mx 200	–	1	–	1	
	MX 400	–	9	–	9	
	MX 412	–	2	–	2	
	MX 420	3	45	11	59	
SAAB	R4	6	16	–	22	22 / 7.1
Sam Electronics	4100	1	–	–	1	12 / 3.9
	4400	–	3	–	3	
	4412	–	1	2	3	
	4422	–	5	–	5	
Shipmate/ Philips	Mk 8	–	1	–	1	5 / 1.6
	Mk 10	2	–	–	2	
	RS 5310	–	2	–	2	
Simrad	GN 30	–	8	–	8	30 / 9.7
	GN 33	1	18	–	19	
	MX 500	–	3	–	3	
Trimble	NT XL	–	2	–	2	9 / 2.9
	NT 100	2	3	–	5	
	NT 200	1	1	–	2	
Total number of the receivers / percentage		40 / 12.9	246 / 79.6	23 / 7.5	309	309 / 100
Mean number of the receivers on the ship		1.21	1.72	1.77	1.63	

Performance parameters of seven GPS receivers, five the most frequently used on the ships (Tab. 3) and two other models (Koden 912 and Garmin 128) are presented in the table 5. We can say that:

- at the time of this writing (July 2014) any of these seven models are not mentioned in the most known and certainly most comprehensive receiver survey of database of GPS equipment published each year in the magazine GPS World January number [1]. In the January 2014 number four manufacturers, Furuno, JAVAD, Leica and Trimble, from twelve mentioned in the table 4 were taken into account only. This situation can be explained that this survey comprises the receivers – end-user product and broad / chipset / module for Original Equipment Manufacturer (OEM) designed for different groups of the users. Only a little of them can be installed on the ship's bridges, additionally annual survey in the straight majority, includes the newest models;
- all seven models operate on the L1 frequency signal (1575.42 MHz) and C/A code, in many cases with carrier phase smoothing;
- all seven models can operate in differential mode (DGPS), but at sea the straight majority of deck officers passes over differential mode and position fix is obtained from GPS system stand alone only;
- three models can use SBAS augmentation, the SAAB R4 and Simrad GN33 models have 2 channels dedicated for this purpose only, in Furuno model two channels are the type SBAS or GPS. As in some models corrections to pseudorange measurements can be taken from either differential ground reference stations or satellite differential SBAS GEO satellites, in some publications SBAS augmentation is called SDGPS (Satellite DGPS). As in the case of differential augmentation, also in this case at sea almost all deck officers omit the possibility of the use of SBAS;
- some models, as Furuno or SAAB, perform RAIM (Receiver Autonomous Integrity Monitoring) calculations in accordance with IEC 61108-1 ed. 2. When at least five satellites are available the RAIM system will evaluate the accuracy of the receiver data from position determination. The status (Safe, Caution and Unsafe) is given with respect to user selected accuracy level, 10 m or 100 m. RAIM also works on DGPS signals;
- the number of local chart datums is from several dozen (e.g. 46 in JRC model) to more than one hundred (e.g. 118 in Simrad model);
- the majority of the models has 6 inch LCD display screen with 320 × 240 pixels;
- the user must remember always that 2D (two dimensional) GPS position accuracy depends on ionospheric activity and multipath, and DGPS accuracy, in particular 1m value in the case of SAAB R4, is reliable on condition that the number of satellites used for position fix is at least 6, HDOP (Horizontal Dilution of Precision) coefficient value is less than 2, PRC (Pseudo Range Correction) data were calculated by a dual frequency reference station, this station is near (a dozen or so kilometres only) and multipath environment is low;

Table 5. Performance parameters of the seven selected GPS receivers [16, 17, 18, 19, 20, 21, 22]

Manufacturer model	Channel number	Accuracy 95% [m]	Start [s]		Dimensions [mm]	Weight [g]	Display [inch]
			Cold	Warm			
Leica MX 420	12	2D – 3 DGPS – 1	120	48	271 × 145 × 53	1238	5
Furuno GP 150	10 2 GPS/SBAS	2D – 10 DGPS – 5 SBAS – 3	90	12	290 × 180 × 80	2200	6
SAAB R4	10 GPS 2 SBAS	2D – 5 DGPS – 1 SBAS – 1	60	< 30	270 × 207 × 102	1600	6
Simrad GN33	12 GPS 2 SBAS	2D – 8 DGPS – 2÷5 SBAS – 3÷7	< 60	< 20	252 ×144 × 70	1 500	6
JRC JLR 7700	12	2D – 15 DGPS – 5	90	50	252 × 150 × 94	1 800	5
Koden KG P912	12	2D – 10 DGPS – 1÷5	< 180	< 60	220 × 120 × 90	920	5.7
Garmin GPS 128	12	2D – 15 DGPS – 1÷5	45	15	125 × 134 × 61	454	4.25

Table 6. Survey of three manufacturers with the biggest number of GPS receivers installed on 5 selected types of the ships

Type of the ship	Total number of the ships	Total number of the receivers	Percentage of the ships with at least 2 receivers	Manufacturer, number of the receivers, (percentage)
Container	70	112	60	Furuno 27 (24%), Leica 27 (24%), SAAB 13 (12%)
Bulk cargo	25	39	56	Furuno 16 (41%), Leica 8 (21%), Simrad 7 (18%),
Oil tanker	23	38	65	Leica 18 (47%), Furuno 8 (21%), Koden 4 (11%)
General cargo	13	20	50	Furuno 8 (40%), Simrad 6 (30%), SAAB 4 (20%)
Ro-ro	12	22	83	Furuno 13 (59%), Leica 6 (27%), Trimble 1 (5%)
Total number / mean percentage	143	231	61	Furuno 72 (31%)

- navigation calculations; even 2,000 points for ship's track and marks (e.g. model GP 150), even 100 routes with several hundred waypoints per route (e.g. model Leica MX 420);
- compliance of all receivers with mentioned in introduction IMO and IEC performance standards for GPS system;
- cold and warm start values depend on the model, the shortest and the longest are in the case of Garmin 128 and Koden 912 models, respectively;
- some models, as Furuno GP–150, are capable of operating as a pair on the ship's bridge, in order to provide enhanced functionality and redundancy. These receivers communicate with each other via serial connection, and share waypoint, route and other information.

The survey of three manufacturers with the biggest number of GPS receivers installed on five types of the ships with the biggest number is shown in the table 6. We can say that 143 ships of five mentioned in the table types constitutes 76% of total number of the ships and 231 receivers 75% of total number of the receivers. Percentage of the ships with at least two receivers is equal 61%, the biggest is in the case of Ro-ro (83%) and oil tanker (65%), the smallest in the case of general cargo (50% only).

We must remember that currently new and usually at that time the best receiver (receivers) is (are) installed on the ship's bridge in the shipyard during the construction and is (are) exploited many years, event a dozen or so. Later, the change of one or two receivers is first of all in the case of the out of service for any reason. The choice of the manufacturer and the model depends on the ship's bridge equipment and the possibility of the purchase. If damaged receiver was the component of integrated bridge or all equipment of ship's bridge was the product of one manufacturer only, the choice is evident – the same manufacturer, but new model. However, if the damaged receiver was the only on the ship and the purchase must be realized immediately, the choice is limited to the receivers available in the nearest port.

On each of the five types of the ships the biggest number of the receivers constitutes the Furuno models; in the case of general cargo about 40%, container 24%. Finally, we can say that one on three receivers installed on these ships is Furuno manufacturer. The next most frequently used manufacturers are Leica, Simrad, SAAB and Koden.

The detailed distribution of GPS receivers installed on the longest ships is presented in the table 7. On therteen ships there are 23 receivers, ten ships are equipped with two receivers, in eight cases with the same models; four ships with two

Table 7. The Distribution of 23 GPS receivers on the 13 longest ships (length > 300 m)

Type of the ship	Number of the ships	Number of the ships, manufacturer and model, number of the receivers
Container	10	3 × Furuno GP 90 × 2, 3 × Leica MX 420 × 2, 1 × Furuno GP 150 × 1, 1 × Sam Electronic 4412 × 2 1 × Furuno GP 90 × 1, 1 × Leica 420 × 1
Oil tanker	2	1 × Leica MX 420 × 1 & Furuno LC-90 × 1, 1 × Leica MX 420 × 1 & Kelvin Hughes 420 × 1
LNG carrier	1	1 × Leica MX 420 × 2

Leica MX420, three with two Furuno GP 90 and one with two SAM Electronics 4412.

Conclusions

1) Currently two global satellite navigation systems, GPS and GLONASS, are available and fully operational but on the ship's bridge the GPS receivers with or without differential or based augmentation are installed only;
2) on each ship's bridge one GPS stationary receiver is installed at least but majority of the ship's (more than 62%) is equipped with two receivers;
3) the number and the type of the receiver on the ship's board depend on areas of navigation, the type of the ship, its capacity and the length in particular. This number increases with the length;
4) additionally the choice of the type of the receivers depends on the ship's company and the year of the installation of the receivers on the bridge;
5) on the ship's bridge are installed the different receivers of a dozen or so manufacturers but the most frequently used are the different models of Furuno and Leica, more than 62% of all.

References

1. www.gpsworld.com (date of access: July 21, 2014)
2. www.insidegnss.com (date of access: July 21, 2014)
3. www.gps.gov (date of access: July 21, 2014)
4. www.glonass-ianc.rsa.ru (date of access: July 21, 2014)
5. HOFMANN-WELLENHOF B. et al.: GNSS Global Navigation Satellite Systems GPS, GLONASS, Galileo & more. Springer, Wien – NewYork 2008.
6. KAPLAN E.D., HEGARTY C.J.: Understanding GPS Principles and Applications. Artech House, Boston – London 2006.
7. SAMAMA N.: Global Technologies Technologies and Performance. John Viley & Sons, New Jersey 2008.
8. JANUSZEWSKI J.: Systemy satelitarne GPS, Galileo i inne. Wydawnictwo Naukowe PWN, Warszawa 2010 (in Polish).
9. IMO Resolution MSC.112(73), 2000.
10. www.IEC.ch (date of access: July 11, 2014).
11. www.iala-aism.org (date of access: July 14, 2014).
12. www.navcen.uscg.gov (date of access: July 14, 2014).
13. Students reports of individual practical onboard training, subject navigational equipment, Faculty of Navigation, Gdynia Maritime University, 2012–2014.
14. www.IMO.org (date of access: July 11, 2014).
15. Admiralty List of Radio Signals, The United Kingdom Hydrographic Office, vol. 2, NP 282, 2013/2014.
16. www.ja-gps.com.au (date of access: July 14, 2014).
17. www.furuno.com (date of access: July 14, 2014).
18. www.saabgroup.com (date of access: July 14, 2014).
19. www.simrad-yachting.com (date of access: July 14, 2014).
20. www.jrc.co.jp (date of access: July 14, 2014).
21. www.koden-electronics.co.jp (date of access: July 14, 2014).
22. www.garmin.com (date of access: July 14, 2014).