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GNSS RECEIVERS, THEIRS FEATURES, USER ENVIRONMENT AND APPLICATIONS

ABSTRACT

Since many years the coordinates of the position can be obtained with the use of satellite navigation and augmentation systems, SNS and SBAS, respectively. All these systems are called GNSS (Global Navigation Satellite Systems). The main task of the user segment is to transform the products delivered by the GNSS infrastructure into services that users are mainly interested in. That's why GNSS receiver selection depends on user application. Nowadays several hundred different receivers provided by more than one hundred manufacturers are available on the world market. The review of the performance parameters of GNSS receivers accessible in 2014 and last three years is presented in this paper. Additionally the paper gives the reply to some important questions as: for how many applications the given model is destined, which is the percentage of the receivers designed for marine and navigation users, which equipment features of the receiver are the most important for given application, which satellite signals apart from GPS signals can be tracked in the receiver?

Keywords:

GNSS receivers, GNSS applications, GNSS comparison.

INTRODUCTION

At the time of this writing two satellite navigation systems (SNS), GPS and GLONASS, four satellite based augmentation systems (SBAS), EGNOS, WAAS, MSAS and GAGAN (the last since February 14, 2014 formally offered to civil aviation users) were operational, two next SNS, Galileo and BeiDou (earlier known as Compass), one SBAS — SDCM, and one regional system QZSS were under construction. All these systems are called GNSS (Global Navigation Satellite Systems).

Each SNS and each SBAS is comprised of three segments: satellite constellation, ground-control/monitoring network, and user receiving equipment. The last segment, i.e. user segment, performs the navigation, timing, or other related functions, e.g. surveying. Actually there were well over one hundred GNSS set manufacturers in the world. Some offer a few different chips set receivers for integration with other electronic functions, other companies have many different end products ranging from handhelds to automobile and aircraft navigators to complex survey receivers [Kaplan E. D., Hegarty C. J., 2006]. In each case the user has at his disposal a single terminal allowing localization, time reference, altitude determination, speed indicator, and so on.

GNSS receiver selection depends on user application. The intended application strongly influences receiver design, construction, and capability. For each application numerous environmental, operational, and performance parameters must be examined.

GNSS RECEIVER SURVEY, TYPES OF THE USERS

The most known and certainly most comprehensive receiver survey of database of GPS and GNSS equipment is published in the magazine *GPS World* the number January each year. In this survey we can find detailed information, i.e. 19 performance parameters, about several hundred receivers provided by several dozen manufacturers. Till 2011 when the majority of GPS receivers had the option ‘stand alone’ the name of this survey was *GPS Receiver Survey*. As recently GLONASS system became fully operational again, next two EGNOS services, SoL and EDAS, became available (since March 2011 and July 2014, respectively), the first determination of a position relying on signals emitted only from four Galileo satellites was achieved on 12 March 2013, the announcement of the launch of three next QZSS satellites, and BeiDou system became operational in China and Asia-Pacific region since December 2012, the majority of GPS receivers is actually integrated with the SBAS receiver and/or other SNS receivers [Januszewski J., 2014], [insidegnss...]. That’s why since 2012 this survey has name ‘Receiver Survey’ simply [gpsworld...].

One of the mentioned above performance parameters of each receiver is information about system and signal tracked (frequency and code). In the table 1 between the years 2011–2014 are presented the numbers of GNSS receivers in which the signals from GPS, GLONASS, SBAS, QZSS, Galileo and BeiDou satellites can be tracked [GPS World, 2011–2014].

We can recapitulate that:

1. As the number of GPS satellites transmitting second civil signal L2C (block IIR-M and IIF) and third civil signal L5 (block IIF) increases continuously, the percentage of GPS receivers that track the signals on more than one frequency increases also; in the case of two and three frequencies receivers this rise was from 20.7% in 2011 to 30.5% in 2014 and from 13.9% to 16.2% respectively. However the L1 C/A receivers constitute still the majority of all GPS receivers available on the market. Additionally we must distinguish the GNSS ‘stand alone’ receivers that track the GPS L1, C/A signals only from the receivers that track not only GPS L1 C/A signal but also SBAS, QZSS and other SNS signals. In 2014 there were e.g. five models of Survey Satellite Technology Ltd. and twelve models of CSR manufacturer respectively.
2. The total number of two frequencies GLONASS receivers is greater than one frequency receivers because since 2012 all 24 satellites block M transmit the signals on two civil frequencies (L1 and L2).
3. The number of GLONASS receivers increases continuously from 25.9% in 2011 to 44.9% in 2014 because since December 2012 this system is fully operational again.
4. As the number of SBAS systems and their services increases the percentage of GPS receivers that use augmentation systems has been increased at the same time, currently (2014) it is more than 65%.
5. The number and the percentage of QZSS receivers increases continuously and considerably from 0.2% in 2011 to 30.5% in 2014 because Michibiki — the first satellite of this system is in orbit since September 11, 2010 and the next three satellites will be launched in the following years. In QZSS receiver the signal tracked is at least L1, C/A and optionally one, two or even five next signals.
6. As two next global SNS are under construction currently more than 25% of GPS receivers is already integrated with Galileo receiver or/and BeiDou receiver. In Galileo receiver signal tracked is at least E1 and depending on the model E5a, E5b and E6 also. In BeiDou receiver signal tracked is at least B1 and optionally B2 & B3.
7. The option ‘other’ in the table 1 means that the signal tracked concerns one or more systems other than mentioned in this table; e.g. in 2014 it was 15 Omnistar receivers and 6 DGPS receivers.

The receiver survey via performance parameter user environment and applications distinguishes 15 different types of the users. The numbers of GNSS receivers designed for each type between the years 2011–2014 are showed in the table 2.

We can say that:

1. Since 2011 year the biggest number and percentage of the receivers is designed for three groups of the users, land, navigation and marine, in 2014 the first two near 80%, the last near 70%.
2. In the case of next four groups (aviation, survey/GIS, other position reporting and real time DGPS) more than 50% of the receivers was in 2014 year designed for the users of each group.
3. In the case of all others 8 groups the percentage of GNSS receivers is in this period practically the same.
4. The smallest group of the users is since many years space, always less than 5% of the receivers.
5. At present 50% of GNSS receivers can use the differential mode option. That's why since many years the number of radiobeacons transmitting DGPS corrections slowly increases. In 2014 there were 288 operational radiobeacons [Admiralty..., 2014].

Table 1. The number (N) and the distribution (%) of the GNSS receivers in which the signals from SNS satellites can be tracked between the years 2011–2014 [GPS World, 2011–2014]

System signal tracked	Number of the GNSS receivers							
	2011		2012		2013		2014	
	N	%	N	%	N	%	N	%
GPS L1	301	65.4	299	63.3	296	60.0	204	53.3
GPS L1, L2	95	20.7	105	22.2	124	25.2	117	30.5
GPS L1, L2, L5	64	13.9	68	14.5	73	14.8	62	16.2
GLONASS L1	46	10.0	65	13.8	42	8.5	71	18.5
GLONASS L1, L2	73	15.9	93	19.8	97	19.7	101	26.4
SBAS	213	46.3	260	55.3	284	57.6	250	65.3
QZSS	1	0.2	38	8.1	59	12.0	117	30.5
Galileo	67	14.6	86	18.3	114	23.1	109	28.5
BeiDou	6	1.3	55	11.7	65	13.2	94	25.6
Other	18	3.9	23	4.9	19	3.9	21	5.5
Total number of the receivers	460	X	472	X	493	X	383	X

Table 2. The number (N) and the distribution (%) of the GNSS receivers designed for different groups of the users between the years 2011–2014 [GPS World, 2011–2014]

User environment and applications	Number of the GNSS receivers							
	2011		2012		2013		2014	
	N	%	N	%	N	%	N	%
Aviation	240	52.2	254	53.8	263	53.3	214	55.9
Recreational	100	21.7	111	23.5	111	22.5	75	19.6
Defence	185	40.2	211	44.7	224	45.4	172	44.9
Survey/GIS	238	51.7	246	52.1	258	52.3	235	61.4
Handheld	122	26.5	155	32.8	146	29.6	116	30.3
Land	360	78.3	377	79.8	327	66.3	306	79.9
Marine	278	60.4	325	68.8	326	66.1	265	69.2
Meteorology	138	30.0	183	38.7	178	36.1	133	34.7
Navigation	318	69.1	376	79.7	369	74.8	300	78.3
Other	160	34.8	179	37.9	193	39.1	144	37.6
Other position reporting	201	43.7	242	51.2	238	48.3	213	55.6
Real time DGPS	180	39.1	205	43.4	192	38.9	197	51.4
Space	17	3.7	23	4.8	24	4.9	18	4.7
Timing	197	42.8	213	45.1	235	47.7	172	44.9
Vehicle/vessel tracking	188	40.9	235	49.8	226	45.8	164	42.8
Total number of the receivers	460	X	472	X	493	X	383	X

The number and the percentage of the GNSS receivers designed for the same number of groups of the users between the years 2011–2014 is presented in the table 3.

We can recapitulate that:

1. In each year there are the receivers designed for each number of groups from interval 1–15.
2. The mean number of group is in each year between 7 and 8, it means that about 50% of the receivers is always designed for seven groups at least.
3. Since few years there are receivers designed for all 15 groups described in the table 2. In 2013 and 2014 years there were two models of Nottingham Scientific Ltd., Sabre and Jingo, fully configurable.
4. In each year there are at least twenty receivers designed for one group of the users only, in 2014 there were e.g. five models of Trimble for time users and seven models of Interstate Electronics Corporation for defence users.

5. Each year 3% or less of the receivers don't indicate information about the group of the users. In 2014 year there were three models (MicroGRAM, SAASM, DIGAR) of Rockwell Collins, one model (Normand 900G) of Trimble and one (OEM625S) of NovAtel.

Table 3. The number (N) and the distribution (%) of the GNSS receivers designed for the same numbers of the groups of the users between the years 2011–2014 [GPS World, 2011–2014]

Number of groups	Number of the GNSS receivers							
	2011		2012		2013		2014	
	N	%	N	%	N	%	N	%
1	30	6.5	29	6.2	28	5.7	24	6.2
2	42	9.1	18	3.8	17	3.4	24	6.2
3	38	8.3	34	7.2	41	8.3	20	5.2
4	29	6.3	34	7.2	39	7.9	23	6.0
5	10	2.2	15	3.2	21	4.3	18	4.7
6	40	8.7	23	4.9	22	4.5	16	4.2
7	46	10.0	43	9.1	54	11.0	32	8.4
8	41	8.9	54	11.4	48	9.7	48	12.6
9	100	21.7	87	18.4	91	18.5	50	13.0
10	23	5.0	71	15.0	64	13.0	64	16.8
11	14	3.0	6	1.3	13	2.6	11	2.9
12	22	4.8	29	6.2	25	5.1	19	5.0
13	6	1.3	9	1.9	8	1.6	21	5.5
14	4	0.9	4	0.8	5	1.0	6	1.5
15	5	1.1	5	1.1	2	0.4	2	0.5
No data	10	2.2	11	2.3	15	3.0	5	1.3
Total	460	100	472	100	493	100	383	100

Additional distributions of the marine and/or navigation receivers designed for other groups of users also are showed in the table 4.

We can observe than:

1. In the case of the receivers designed for marine users but no for navigation users, in 2014 year there are only 10 units which additionally they can be used by 2, 4, 7 or 8 of the above mentioned groups also.
2. In the case of the receivers designed for navigation users but no for marine users, in 2014 year there are 43 units which additionally can be used by 1, 2, 3, 4 or 5 of

- the above mentioned groups also. Two Furuno models GN86F and GN87F are designed for navigation user only.
- The majority (255) of all (383) receivers (67%) are designed for marine as well as navigation users, these receivers are designed for other groups of the users, from 3 to all 13 others also.

Table 4. The number of receivers (NR) designed for marine (M) group of the users but no for navigation (N) group, for navigation group but no for marine, for marine and navigation which are simultaneously designed for given number (NG) of groups of the users in 2014 [GPS World, 2014]

NG	M without N		N without M		M and N	
	NR	%	NR	%	NR	%
0	–	–	2	4.4	–	–
1	–	–	11	24.5	–	–
2	1	10	5	11.1	–	–
3	–	–	14	31.1	4	1.6
4	3	30	12	26.7	12	4.7
5	–	–	1	2.2	30	11.8
6	–	–	–	–	43	16.8
7	2	20	–	–	41	16.1
8	4	40	–	–	63	24.7
9	–	–	–	–	14	5.5
10	–	–	–	–	21	8.2
11	–	–	–	–	19	7.5
12	–	–	–	–	6	2.3
13	–	–	–	–	2	0.8
Σ	10	100	45	100	255	100

We can distinguish two types of the GNSS receivers — end-user product and broad/chipset/module for Original Equipment Manufacturer (OEM). Information about the type of the receiver is published together with the information about user environment and applications. In the table 5 was showed the distribution of these two types of the receivers between the years 2011–2014.

Additionally we can say that:

- Since 2011 the percentage of the receivers of both types is almost the same, some units (5% or less) are the receivers of two types; in 2014 year e.g. nine models of NovAtel and three models of Baseband Technologies, Inc.

2. Less than 10% of the receivers is without information about their type. In 2014 year there were two models (MNS Receiver, EGR 2500) of Exells for defence users and three models (GS-101, GS-102 and ORCA637VME) of ORCA Technologies, LLC for time, frequency, position users.

Table 5. The number and the distribution of the GNSS receivers of different types between the years 2011–2014 [GPS World, 2011–2014]

Types of the receiver	Number of the receivers (N)							
	2011		2012		2013		2014	
	N	%	N	%	N	%	N	%
End-user product (1)	196	42.6	188	39.8	209	42.4	154	40.2
Board/chipset/module for OEM apps (2)	199	43.3	211	44.7	207	42.0	181	47.3
(1) and (2)	21	4.6	35	5.3	24	4.9	15	3.9
Without information about (1) and (2)	36	7.8	45	9.6	42	8.5	28	7.3
Without information about (1) and (2) and the group of the user	8	1.7	3	0.6	11	2.2	5	1.3
Total number of the receivers	460	100	472	100	493	100	383	100

EQUIPMENT FEATURES

In GNSS receiver selection process the first step is the choice of the right group, the second the choice of the specific model for individual needs and requirements [Kaplan, E. D., Hegarty C. J., 2006; Hofmann-Wellenhof B. et al., 2008]. In each case the selected performance parameters must be taken into account. Besides of parameters described earlier for the marine user the most important are:

- the number of channels to track satellites;
- maximum number of satellites tracked;
- economics, physical size, weight, vibration requirements, humidity extremes and operating temperature of the receiver and its antenna;
- size of the display and its parameters;
- dynamic conditions, i.e. acceleration and velocity of the ship;

- position accuracy in the case of stand-alone GPS and all available in the receiver other SNS and SBAS systems;
- time accuracy;
- position fix update;
- the number of local datums;
- cold, warm and hot start;
- reacquisition;
- operation in a high-multipath environment, e.g. in harbour area;
- number of ports, port type and baud rate;
- power source and power consumption;
- access to such function as navigate, plotter, position, sailplan and the number of routes, waypoint storage capability, alarms;
- possibility of the association with maritime maps and integration with other sensors, like radar, ARPA, autopilot, echo-sounder, fisher-finder, and so on.

Final decision depends also on the type of the ship, region of its navigation, etc.

CONCLUSIONS

1. The user segment of GNSS is composed of great variety of terminals, from military to mass market ones, and also scientific ones. The main task of this segment is to transform the products delivered by the GNSS infrastructure, i.e. different kind of the signals from satellites and terrestrial stations, into services that users are mainly interested in.
2. In 2014 most GPS receivers were integrated with at least one SBAS receiver, near half with GLONASS receiver.
3. As next systems as Galileo, BeiDou and QZSS are under construction and the dates of their FOC are already known the number of the GPS receivers integrated with one or more of these systems is more and more numerous, in 2014 year the percentage in each case was greater than 26%.
4. In the straight majority of cases (more than 90%) the GNSS receivers are designed for more than one group of the users, in the case of some receivers for all distinguished 15 groups.
5. The majority of the receivers are designed for marine users, in 2014 it was almost 70%. Sometimes the receivers for other group can be used also.
6. About 10% of GNSS receivers don't display information about their type.

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STRESZCZENIE

Współrzędne pozycji można otrzymać z użyciem nawigacji satelitarnej i systemów wspomagających, odpowiednio GNSS i SBAS. Wszystkie są nazywane mianem GNSS (globalne, nawigacyjne systemy satelitarne). Zadaniem głównym segmentu użytkownika tych systemów jest przekształcenie sygnałów dostarczanych przez infrastrukturę GNSS w usługi, którymi jest on najbardziej zainteresowany, dlatego wybór rodzaju odbiornika GNSS zależy od indywidualnych potrzeb. Obecnie na światowym rynku dostępnych jest kilkaset różnych odbiorników oferowanych przez ponad stu producentów. W artykule przedstawiono przegląd parametrów odbiorników GNSS dostępnych w 2014 roku i w trzech poprzednich latach. Dodatkowo artykuł daje odpowiedź na pytania, dla ilu zastosowań dany model jest przeznaczony, jaki procent odbiorników jest przydatny dla zastosowań morskich, które z cech odbiornika są najważniejsze dla użytkownika, które systemy, oprócz GPS, mogą być śledzone w odbiorniku.