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COMPARISON OF GEOMETRY OF GALILEO AND GPS IN MARITIME AND URBAN RESTRICTED AREA

ABSRACT In open area the accuracy of the observer's position obtained from the satellite navigation systems depends on a number of satellites (ls) visible above masking elevation angle (H_{min}) and the geometry of systems – GDOP coefficient. In restricted area (coastal navigation, urban area) system accuracy depends on the parameters mentioned for open area and the dimensions and situated area of the obstacles additionally. The calculations were made for the observer situated on the ship sailing along the coast and in the middle of the street for different obstacles heights for Galileo system and for GPS system. Street parameters were: the street axis azimuth and latitude φ.

INTRODUCTION

An observer's position can be obtained by many different methods. At present (July 2003) the most common methods are based on the global satellite navigation systems. Nowadays, there are two worldwide systems – American GPS and Russian GLONASS, but only GPS system is fully operational. The number of GLONASS satellites is less than nominal number 24 considerably. a new system – Galileo, sponsored by the European Union, is under construction as the European contribution to the next generation of satellite navigation. The calculations were made for GPS system and Galileo (GAL) system. It was considered 27 satellites fully operational for both systems.

The receiver of satellite navigation system (SNS) needs to see at least four satellites to calculate latitude, longitude, altitude and time. The geometry of the visible satellites changes with time due to the relative motion of the satellites constellation. Position fix can be calculated only from these satellites SO (SO – satellite fully operational), which elevation angle at the moment of measurement in the observer's receiver is higher than the masking elevation angle H_{min}. If the number of satellites visible by the observer is less than 4, its 3D (three–dimensional) position cannot be obtained (the position is not available – No fix > 0).

The accuracy of the position solution determined by SNS is ultimately expressed as the product of a geometry factor and a pseudorange error factor [Kaplan, 1996]:

$$\text{error in SNS solution} = (\text{geometry factor}) \cdot (\text{pseudorange error factor}) \quad (1)$$

As the error in mentioned solution can be expressed by σ_ρ – the standard deviation of the positioning accuracy, geometry factor by the dilution of precision (DOP) coefficient and pseudorange error factor by the term UERE (User Equivalent Range Error) σ_{UERE}, the relation (1) can be defined as:

$$\sigma_\rho = DOP \cdot \sigma_{UERE} \quad (2)$$

If we can obtain four coordinates of the observer's position (latitude, longitude, altitude, time – φ, λ, h, t), geometry factor DOP is expressed by GDOP (Geometric Dilution of Precision) and the position accuracy with 95% confidence level $M^{95\%}_{\varphi,\lambda,h,t}$ can be approximated by:

$$M^{95\%}_{\varphi,\lambda,h,t} \approx 2\ GDOP \cdot \sigma_{UERE} \quad (3)$$

In open area GDOP coefficient value depends on the number of satellites (ls) visible above H_{min} by the observer and the configuration of these satellites. As in restricted area (coastal and harbour navigation, urban area) system accuracy depends on the parameters mentioned for open area and the dimensions and position of the obstacles the calculations were made for the area where some satellites above horizon cannot be visible by the observer. These satellites can be named as Satellites Not Visible (SNV). This situation concerns maritime navigation along the coast and land navigation in urban area. As in urban area the width of the streets (L) and the height of the buildings (B) have the tens of meters, the number of SNO can be greater than during the coastal and harbour navigation.

TEST METHOD

The calculations were performed for two systems:

- Galileo (GAL); 27 satellites SO distributed in three planes with nine satellites on the altitude 23616 km and with the inclination 56 degrees,
- GPS–Navstar (GPS); 27 satellites SO distributed in three planes with five satellites and three planes with four satellites on the altitude 20 183 km and with the inclination 55 degrees.

The interval of the latitude of the observer between 0^O and 90^O was divided into 9 zones, each 10^O wide. Orbit parameters – right ascension of ascending nodes and arguments of latitude for all 27 GAL satellites and all 27 GPS satellites at the referred time were known.

For every system, for each zone of latitude and for each masking elevation angle (H_{min}), one thousand (1000) geographic–time coordinates of the observer were generated by random–number generator with uniform distribution:

- latitude interval 0 – 600 minutes (10^O),
- longitude interval 0 – 21600 minutes (360^O),
- time interval 0 – 1440 minutes (24 hours).

Elevation H_{min} was assumed to be 5^O, 20^O, 25^O, 30^O etc. Satellite selection criteria (combination of 4 satellites) were founded on the minimization of GDOP. All calculations, based upon a reference ellipsoid WGS–84, were made with the use of author's simulating program.

For each geographic–time coordinates the number of visible satellites (ls) and GDOP coefficient value were calculated. GDOP value (v) was divided into 6 intervals: 1st for $v \le 2$, 2nd for $2 < v \le 3$, 3rd for $3 < v \le 4$, 4th for $4 < v \le 6$, 5th for $6 < v \le 20$ and 6th for $v > 20$ or into 7 intervals (interval no 4th was divided into two, $4 < v \le 5$ and $5 < v \le 6$).

GEOMETRY IN OPEN AREA

The minimal, maximal and weighted mean numbers of satellites visible by the observer and the distributions (in per cent) of GDOP coefficient values at different latitudes and different elevations H_{min}, for GPS and Galileo systems and for different numbers of operational satellites were described by [Januszewski, 2002a].

The percentage of satellites visible above given angle and the distribution (in per cent) of satellite azimuths for different masking elevation angles (H_{min}) for both systems at different observer's latitudes are presented by [Januszewski, 2002b]. We recapitulate that:

- The percentage of satellites visible decreases with angle H in each zone. The diminution is practically the same for both systems (except zone 80–90^O). Galileo plane is higher than GPS plane although the weighted mean number of satellites visible above horizon ($H = 0^O$) is for Galileo greater than for GPS, independently of observer's latitude.
- If the masking angle H_{min} is equal 0^O we can say that 100% of visible satellites can be used by the observer, if this angle is equal 20^O the percentage of these satellites decreases to 60%, if $H_{min} = 40^O$ this percentage is about 30% only.

- The distributions of satellite azimuths for both systems are practically the same at given angle H_{min}, but these distributions depend on observer's latitude.
- The number of satellites visible in the different intervals of the horizon is different.

GEOMETRY IN MARITIME RESTRICTED AREA

GDOP coefficient values are greater in maritime restricted area (the observer on the ship) than in open area for both systems. This increasing depends on the height of the coast, the distance between the observer and the coast, the ship course and the ship antenna height. The coast can decrease the number SO if the masking angle (α) causing by this coast (fig.1) is greater than masking elevation angle H_{min} used in the observer's receiver. The α values for different distances (D) from the coast for the different coast heights (B) are presented in the table 1. It was considered the observer's antenna height above sea level H_{ant} = 20 m.

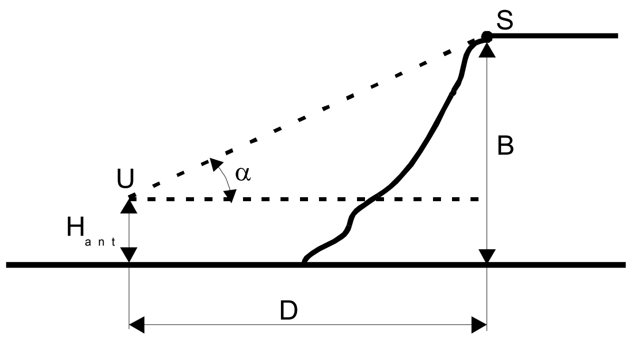

Fig.1. Masking angle α for the observer (U),
S – the top of the coast,
H_{ant} – antenna height above sea level

The angle α increases with the height B and decreases with distance D. As the angle H_{min} is in the most ship's receivers equal 5^{O}, the distances D for which the masking angle α is equal 5^{O} are demonstrated in the table 2. The calculations were made for different heights B and for different ship antenna heights H_{ant}. We can say that:

- If for given values of H_{ant} and B the distance between the observer and the coast is less than D, SNV can be greater than 0 and the position accuracy less.
- The distance D increases with the height B and decreases with the height H_{ant}, but the decreasing of D is for B = 100 m greater than for B = 1000 m considerably.

No Fix (in per cent) and the comparison of the distribution (in per cent) of GDOP coefficient values for the observer situated on the ship sailing along the coast (height B) in the distance D and for open area for GPS system and Galileo system are presented in the table 3. It was considered $H_{min} = 5^O$, the course of the ship 090^O, the coast on the south side, $H_{ant} = 0$ m, observer's latitude $50–60^O$. We recapitulate that:

- The increasing of GDOP coefficient and the number No Fix are for GPS system greater than for Galileo system.
- The increasing of GDOP coefficient and the number No Fix depend on the relation D/B for both systems, if D/B is less, than the increasing of these parameters greater.
- As the number of satellites visible by the observer situated on the ship in different intervals of the horizon is different, the increasing of GDOP and the number No Fix depend on the ship course and the side of the coast.

Table 1. Masking angle α [^{O}] for different distances (D) from the coast for different coast heights (B), antenna height 20 m

D [m]	Height B [m]				
	100	250	500	750	1000
10 000	0,46	1,3	2,7	4,2	5,6
7 500	0,61	1,8	3,7	5,6	7,4
5 000	0,92	2,6	5,5	8,3	11,1
2 500	1,8	5,3	10,9	16,3	21,4
1 000	4,6	12,9	25,6	36,1	44,2
750	6,1	17,0	32,6	44,2	52,6
500	9,1	24,7	43,8	55,6	63,0
400	11,3	29,9	50,2	61,3	67,8
300	14,9	37,5	58,0	67,7	73,0
200	21,8	49,0	67,4	74,7	78,5
100	38,7	66,5	78,2	82,2	84,2
75	46,8	71,9	81,1	84,1	85,6
50	58,0	77,7	84,1	86,0	87,1
25	72,6	83,8	87,0	88,0	88,5
10	82,9	87,5	88,8	89,2	89,4

Table 2. Distance [m] from the coast for which masking angle is equal 5^O for different coast heights (B) and for different antenna heights (H_{ant})

H_{ant} [m]	Height B [m]				
	100	**250**	**500**	**750**	**1000**
0	1 149	2 873	5 747	8 621	11 495
5	1 091	2 816	5 690	8 563	11 437
10	1 034	2 759	5 632	8 506	11 379
15	977	2 701	5 575	8 448	11 322
20	919	2 644	5 517	8 390	11 264
25	862	2 586	5 460	8 333	11 207
30	805	2 529	5 402	8 276	11 149

Table 3. No Fix (in per cent) and comparison of the distribution (in per cent) of GDOP values for restricted maritime area (RMA) for the observer situated on the ship sailing (course 090^O) along the coast (height B = 70 m) in the distance D and for open area (OPA), for masking elevation angle $H_{min} = 5^O$ at observer's latitude $50–60^O$ for Galileo system (GAL) and GPS system (GPS); ''+'' stands for increasing values, ''–'' for decreasing values, and ''0'' for no change

D [m]	Sys–tem	No Fix [%]	GDOP(RMA) – GDOP(OPA) = v [%]					
			v≤3	3<v≤4	4<v≤6	6<v≤8	8<v≤20	v>20
500	GAL	–	– 0.5	+ 0.5	0	–	–	–
	GPS	–	– 0.9	+ 0.9	0	–	–	–
300	GAL	–	– 2.8	+ 2.8	0	–	–	–
	GPS	–	– 3.1	+ 3.0	0	+ 0.1	–	–
100	GAL	–	– 12.9	+ 12.6	+ 0.3	+ 1.4	+ 0.4	–
	GPS	–	– 21.8	+ 16.0	+ 5.4	+ 0.1	+ 0.3	–
50	GAL	–	– 22.0	+ 17.7	+ 4.1	+ 0.2	–	–
	GPS	–	– 29.3	+ 22.5	+ 14.2	+ 1.0	+ 1.3	+ 0.3
25	GAL	–	– 33.9	+ 17.9	+ 14.7	+ 1.3	–	–
	GPS	0.6	– 49.1	+ 20.9	+ 19.7	+ 3.3	+ 3.4	+ 1.2
10	GAL	1.5	– 43.7	+ 9.4	+ 25.0	+ 3.6	+ 3.5	+ 0.7
	GPS	4.8	– 59.2	+ 13.9	+ 25.9	+ 5.4	+ 5.9	+ 2.3

The influence of the coasts for the satellite position accuracy in maritime navigation is very small, for instance for the ship sailing in Gibraltar Strait (Sidi Musa on the African side – 839 m and Gitano on the European side – 830 m) the increasing of GDOP is in 0.1% of the cases only.

GEOMETRY IN URBAN RESTRICTED AREA

GDOP coefficient values are greater in urban restricted area than in open area for both systems considerably. This increasing depends on the width L of the street, the height of its building, the observer's latitude and the street axis azimuth β (the angle between the North and the street axis) [Januszewski, 2003].

Table 4. Comparison of the distribution (in per cent) of GDOP values for restricted urban area (RUA) for the observer situated 35 m from the obstacle (height B = 15 m) on the one hand (E, W, N or S) and for open area (OPA), for masking elevation angle $H_{min} = 5^{O}$ for different street axis azimuths β at observer's latitude 50–60^{O} for Galileo system (GAL) and GPS system (GPS); ''+'' stands for increasing values, ''–'' for decreasing values, and ''0'' for no change

Angle β [^{O}]	Side	System	GDOP(RUA) – GDOP(OPA) = v [%]					
			v≤3	3<v≤4	4<v≤5	5<v≤6	6<v≤8	8<v≤20
0	E	GAL	– 11.8	+ 10.1	+ 1.2	+ 0.5	–	–
		GPS	– 10.7	+ 7.1	+ 3.0	+ 0.5	+ 0.1	–
	W	GAL	– 13.1	+ 10.4	+ 2.4	+ 0.2	+ 0.1	–
		GPS	– 17.7	+ 13.0	+ 3.8	+ 0.8	+ 0.1	–
45	E	GAL	– 7.5	+ 7.2	+ 0.1	+ 0.2	–	–
		GPS	– 8.8	+ 6.5	+ 2.1	+ 0.2	–	–
	W	GAL	– 24.0	+ 16.9	+ 6.4	+ 0.7	–	–
		GPS	– 16.5	+ 12.2	+ 3.2	+ 0.7	+ 0.4	–
90	N	GAL	– 21.0	+ 11.9	+ 8.1	+ 1.0	–	–
		GPS	– 15.8	+ 12.5	+ 2.4	+ 0.8	+ 0.1	–
	S	GAL	– 9.0	+ 8.9	+ 0.1	–	–	–
		GPS	– 10.8	+ 9.3	+ 1.4	–	–	+ 0.1
135	N	GAL	– 17.5	+ 11.6	+ 5.6	+ 0.3	–	–
		GPS	– 13.4	+ 8.8	+ 3.5	+ 1.1	–	–
	S	GAL	– 7.0	+ 6.8	+ 0.2	–	–	–
		GPS	– 16.0	+ 14.3	+ 1.3	+ 0.1	–	+ 0.3

Comparison of the distribution (in per cent) of GDOP values for the observer situated 35 m from the buildings (height B = 15 m) on the one hand (East, West, North or South) and for open area (OPA), for different street axis azimuth β for Galileo system and GPS system are presented in the table 4. It was considered $H_{min} = 5^O$, observer's latitude 50–60^O.

We can say that:

- The increasing of GDOP coefficient is for both systems practically the same;
- The increasing of GDOP depends on the angle β and the side of the obstacles; for instance if $\beta = 45^O$ this increasing is for the side West greater than for the side East considerably.

The calculations for urban area were made for the observer situated in the middle of the street with the buildings on both sides; for the building height B= 15 m the width L of the street was between 60 and 35 with the step 5 m, for B = 25 m the width L between 100 and 60 with the same step. No Fix (in per cent) and the comparison of the distribution (in per cent) of GDOP coefficient values for this urban area and open area are presented in the table 5. It was considered angle $H_{min} = 5^O$, street axis azimuth $\beta = 0^O$, observer's latitude 50–60^O. As in land navigation in urban area observer's receiver is located in the car, it was considered that receiver's antenna height $H_{ant} = 0$ m.

We recapitulate that:

- No Fix and the increasing of GDOP depend on the relation L/B for both systems.
- No Fix is for GPS system greater than for Galileo system considerably, the relation L/B for which "3D" Galileo and GPS positions can be obtained must be greater than 3 and 4 adequately.
- The increasing of GDOP is for Galileo less than for GPS independently of the relation L/B.

Table 5. No Fix (in per cent) and the comparison of the distribution (in per cent) of GDOP values for restricted urban area (RUA) for the observer situated in the middle of the street with different width L and different height B and for open area (OPA), for masking elevation angle H_{min} = 5^O for street axis azimuth β = 0^O at observer's latitude 50–60^O for Galileo system (GAL) and GPS system (GPS); ''+'' stands for increasing values, ''–'' for decreasing values, and ''0'' for no change

B [m]	L [m]	Sys–tem	No Fix [%]	GDOP(RUA) – GDOP(OPA) = v [%]					
				v≤3	3<v≤4	4<v≤6	6<v≤8	8<v≤20	v>20
15	60	GAL GPS	– –	– 35.1 – 43.1	+ 24.8 + 20.9	+9.8 + 18.1	+0.3 + 2.1	0 + 1.6	+ 0.2 + 0.4
	55	GAL GPS	– 0.2	– 41.2 – 48.3	+ 27.9 + 19.6	+12.5 + 22.5	+ 0.5 + 2.9	0 + 2.6	+ 0.3 + 0.5
	50	GAL GPS	– 1.1	– 46.9 – 53.2	+ 27.5 + 14.4	+ 17.1 + 28.2	+ 1.4 + 4.6	+ 0.4 + 3.8	+ 0.5 + 1.1
	45	GAL GPS	– 4.7	– 54.1 – 57.9	+ 25.5 + 8.2	+ 21.6 + 31.3	+ 3.9 + 6.2	+ 2.0 + 4.9	+ 1.1 + 2.6
	40	GAL GPS	5.7 13.1	– 58.1 – 61.9	+ 13.8 + 0.3	+ 22.9 + 31.7	+ 7.2 + 7.8	+ 5.0 + 6.0	+ 3.5 + 3.0
	35	GAL GPS	14.1 24.5	– 61.2 – 65.0	+ 4.0 – 6.8	+ 22.9 + 27.7	+ 9.4 + 9.3	+ 6.5 + 7.1	+ 4.3 + 3.2
25	100	GAL GPS	– –	– 35.1 – 43.1	+ 24.8 + 20.9	+ 9.8 + 18.1	+ 0.3 + 2.1	– + 1.6	+ 0.2 + 0.4
	95	GAL GPS	– –	– 38.8 – 46.4	+ 26.8 + 20.8	+ 11.4 + 20.6	+ 0.4 + 2.4	– + 2.2	+ 0.2 + 0.4
	90	GAL GPS	– 0.2	– 42.2 – 49.1	+ 27.9 + 18.5	+ 13.3 + 23.8	+ 0.6 + 3.0	+ 0.1 + 3.0	+ 0.3 + 0.6
	85	GAL GPS	– 0.9	– 45.8 – 52.0	+ 27.7 + 15.2	+ 16.2 + 27.2	+ 1.3 + 4.3	+ 0.2 + 3.4	+ 0.4 + 1.0
	80	GAL GPS	– 1.6	– 49.4 – 55.6	+ 26.7 + 12.0	+ 19.1 + 30.6	+ 2.2 + 5.3	+ 0.9 + 4.7	+ 0.5 + 1.4
	75	GAL GPS	– 4.7	– 54.1 – 57.9	+ 25.5 + 8.2	+ 21.6 + 31.3	+ 3.9 + 6.2	+ 2.0 + 4.9	+ 1.1 + 2.6
	70	GAL GPS	1.6 9.1	– 56.9 – 60.6	+ 19.4 + 3.8	+ 22.9 + 32.5	+ 5.9 + 7.1	+ 4.3 + 5.4	+ 2.3 + 2.7
	65	GAL GPS	7.5 15.8	– 59.0 – 62.4	+ 11.4 – 1.0	+ 23.6 + 30.9	+ 8.2 + 8.1	+ 4.7 + 5.6	+ 3.6 + 3.0
	60	GAL GPS	12.7 22.8	– 60.9 – 64.7	+ 6.0 – 4.5	+ 22.9 + 28.1	+ 9.1 + 8.9	+ 5.9 + 6.6	+ 4.3 + 2.8

Table 6. Comparison of the distribution (in per cent) of GDOP values for restricted urban area (RUA) for the observer situated in the middle of the street (width L = 70 m, height B = 15 m) and for open area (OPA), for masking elevation angle $H_{min} = 5^O$ for different street axis azimuths β at observer's latitude 50–60^O for Galileo system (GAL) and GPS system (GPS); ''+'' stands for increasing values, ''–'' for decreasing values, and ''0'' for no change

Angle β [^{O}]	System	GDOP(RUA) – GDOP(OPA) = v [%]						
		v≤3	3<v≤4	4<v≤5	5<v≤6	6<v≤8	8<v≤20	v>20
0	GAL GPS	– 26.0 – 34.7	+ 19.4 + 21.3	+ 5.5 + 9.2	+ 1.0 + 2.9	+ 0.1 + 0.6	– + 0.5	– + 0.2
45	GAL GPS	– 36.9 – 29.3	+ 27.7 + 18.7	+ 8.0 + 6.6	+ 0.9 + 2.3	+ 0.3 + 0.8	– + 0.7	– + 0.2
90	GAL GPS	– 34.2 – 30.7	+ 21.2 + 22.6	+ 10.5 + 5.3	+ 1.5 + 1.6	+ 0.2 + 0.9	+ 0.5 + 0.3	+ 0.3 –
135	GAL GPS^x	– 29.1 – 35.0	+ 19.6 + 22.1	+ 7.5 + 9.2	+ 0.9 + 2.0	+ 0.8 + 0.5	+ 0.3 + 0.8	– + 0.2

^{x} – No Fix = 0.2%

The additional calculations were made for the observer situated in middle of the street (with given parameters L = 70 m, B = 15 m) for $H_{min} = 5^O$ for different street axis azimuths β between the North and street axis at different observer's latitudes. The dimensions L = 70 m and B = 15 m are the parameters of Champs Elysees in Paris. The distributions (in per cent) of GDOP coefficient values for the zone 50–60^O (latitude of Poland) for four angles β (0^O, 45^O, 90^O and 135^O) are demonstrated in the table 6, for all other zones for two angles (0^O and 90^O) in the table 7. We can say that:

- The increasing of GDOP coefficient values depends on the angle β and the observer's latitude zone for both systems.
- The increasing of GDOP is for GPS system greater than for Galileo system in majority of cases.
- As the distribution of satellite azimuths depends on observer's latitudes, the increasing of GDOP at latitudes 0 – 20^O is for β = 90^O greater than for β = 0^O for both systems, at latitudes 20 – 50^O for β = 90^O less than for β = 0^O for both systems also, at latitudes greater than 50^O it depends on the system.

Table 7. Comparison of the distribution (in per cent) of GDOP values for restricted urban area (RUA) for the observer situated in the middle of the street (width L = 70 m, height B = 15 m) and for open area (OPA), for masking elevation angle $H_{min} = 5^{O}$ for street axis azimuth $\beta = 0^{O}$ and $\beta = 90^{O}$ at different observer latitudes for Galileo system (GAL) and GPS system (GPS); ''+'' stands for increasing values, ''–'' for decreasing values, and ''0'' for no change

φ [^{O}]	Angle β [^{O}]	System	GDOP(RUA) – GDOP(OPA) = v [%]					
			v≤3	3<v≤4	4<v≤6	6<v≤8	8<v≤20	v>20
0 – 10	0	GAL	– 13.6	+ 13.0	+ 0.6	–	–	–
		GPS	– 19.4	+15.9	+ 2.6	+ 0.7	+ 0.2	–
	90	GAL	– 21.3	+ 16.5	+ 3.9	+ 0.5	+ 0.3	+ 0.1
		GPS	– 36.8	+ 25.5	+ 8.9	+ 1.7	+ 0.6	+ 0.1
10 – 20	0	GAL	– 21.1	+ 17.7	+ 3.3	–	+ 0.1	–
		GPS	– 24.5	+ 18.4	+ 5.4	+ 0.2	+ 0.5	–
	90	GAL	– 25.3	+ 21.4	+ 3.7	+ 0.2	–	–
		GPS	– 31.3	+ 24.0	+ 6.2	+ 0.6	+ 0.3	+ 0.2
20 – 30	0	GAL	– 28.7	+ 21.9	+ 6.5	+ 0.1	+ 0.2	–
		GPS	– 36.0	+ 23.9	+ 10.6	+ 0.6	+ 0.9	–
	90	GAL	– 25.6	+ 20.2	+ 5.2	+ 0.2	–	–
		GPS	– 29.1	+ 20.7	+ 7.4	+ 0.9	+ 0.1	–
30 – 40	0	GAL	– 33.6	+ 21.2	+ 11.6	+ 0.5	+ 0.3	–
		GPS	– 34.8	+ 21.3	+ 11.3	+ 1.5	+ 0.5	+ 0.2
	90	GAL	– 26.6	+ 18.0	+ 8.3	+ 0.3	–	–
		GPS	– 24.7	+ 20.4	+ 3.6	+ 0.7	–	–
40 – 50	0	GAL	– 33.3	+ 23.1	+ 9.2	+ 0.5	+ 0.3	+ 0.2
		GPS	– 34.5	+ 20.1	+ 13.2	+ 0.7	+ 0.4	+ 0.1
	90	GAL	– 24.9	+ 18.6	+ 6.1	+ 0.2	–	–
		GPS	– 22.1	+ 17.4	+ 4.0	+ 0.5	+ 0.2	–
60 – 70	0	GAL	– 13.6	+ 8.9	+ 4.3	+ 0.4	–	–
		GPS	– 17.2	– 1.5	+ 14.9	+ 2.2	+ 1.5	+ 0.1
	90	GAL	– 15.7	– 3.5	+ 17.9	+ 0.6	+ 0.2	+ 0.5
		GPS	– 21.0	– 0.7	+ 18.9	+ 1.9	+ 0.8	+ 0.1
70 – 80	0	GAL	0	– 11.6	+ 10.6	+ 1.0	–	–
		GPS	–	– 16.9	+ 6.2	+ 8.7	+ 1.8	+ 0.2
	90	GAL	0	– 8.5	+ 7.7	+ 0.8	–	–
		GPS	–	– 17.5	+ 8.1	+ 8.0	+ 1.4	–
80 – 90	0	GAL	–	–	– 6.2	+ 1.2	+ 3.7	+ 1.3
		GPS	–	–	– 6.1	– 0.6	+ 4.3	+ 2.4
	90	GAL	–	–	– 3.5	+ 0.4	+ 2.5	+ 0.6
		GPS	–	–	– 6.1	– 1.2	+ 4.4	+ 2.9

CONCLUSIONS

- The position accuracy can be decreased in restricted area when the masking elevation angle causing by the obstacles is greater than masking angle of observer's receiver.
- In maritime restricted area the accuracy diminution is very small, it depends on the ship course, observer's latitude and the coast side.
- In urban restricted area the position accuracy is less than in open area considerably for both systems. This accuracy depends on the height of the buildings, the width of the street and the street axis azimuth.
- As the distribution of satellite azimuths depends on observer's latitude, the position accuracy in the town depends on its geographic location. It means that the accuracy in the street with the same widths and the height of the buildings is in Oslo, Warsaw, Lisbon and Dakar different.
- In urban area for the observer situated in the middle of the street (with given width and height of the buildings) the dependence of position accuracy on angle between the North and street axis is for Galileo system less than for GPS system.
- Nowadays only GPS is fully operational, the exploitation of the second system, as GLONASS or Galileo (in 2008), will assure in urban area the possibility of fix position in almost all cases and will increase its accuracy. That's why the question GPS or Galileo doesn't exist already, now the goal is GPS and Galileo!

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