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COMBINED CONSTELLATIONS GPS AND GALILEO SYSTEMS

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ABSTRACT. As for the users of satellite navigation systems the actual slogan is GPS and Galileo the advantages and disadvantages of different combined constellations of these systems must be taken into account. The distributions (in per cent) of the numbers of satellites visible by the observer at different latitudes situated in open and restricted (urban canyon) area for different masking elevation angles (H_{min}) for two combined constellations GPS + Galileo systems (I − 29 GPS satellites + 27 Galileo satellites, II − 29 GPS + 30 Galileo) are presented in this paper. In addition to it the detailed distributions for the observer at latitudes 50−60^O for other constellations & elevation angles are demonstrated.

For the first constellation the difference between the number of GPS satellites visible by the observer above horizon (H_{min} = 0^O) at latitudes 50−60^O and the number of Galileo satellites visible by the same observer at the same time can be equal each number between plus 7 and minus 7. This fact must be taken into account in the production and the determination of the number of channel of GPS–Galileo integrated receivers.

1. INTRODUCTION

The error M of the observer's position obtained from satellite navigation systems depends on geometry factor DOP (Dilution of Precision) among other things. That's why the knowledge of the number of satellites visible by this observer above given masking elevation angle H_{min} is very important. The detailed distributions of the number of satellites visible by the observer at different latitudes for different H_{min} were presented by the author for the different Galileo constellations in (Januszewski, 2001) and for GPS & Galileo constellations for the observer situated in open and restricted area in (Januszewski 2003, 2005). In these simulations the calculations were made for GPS constellations and different Galileo constellations separately in order to compare both the systems. It was considered so−called baseline GPS constellation: 4 or 5 satellites in one plane, all separations $\Delta\Omega$ in right ascension between two orbital adjacent planes are 60^O, all orbit inclinations are equal to the nominal value 55^O.

Today, the number of GPS satellites is most often equal 29, sometimes 28, rarely 27. The number of satellites in one plane is between 4 & 6, the differences of arguments of latitude between two adjacent satellites in one orbit change between 11^O & 150^O, and the separations $\Delta\Omega$ are not equal 60^O. Additionally for the majority of satellites orbit inclination i is not equal to the nominal value 55^O. That's why the difference between maximum and minimum number of GPS satellites visible by the observer is greater for actual constellation than for previous constellation considerably.

As the question GPS or Galileo doesn't exist already and the actual slogan is GPS and Galileo, the new simulations must be made for the combined constellations: GPS + Galileo. It was considered 27, 28, 29 and 30 satellites fully operational for both the systems. The mentioned above distributions for the observer situated in open area and restricted area (urban canyon) were made for all 16 possible combined constellations (27 GPS satellites + 27 Galileo satellites, 28 GPS + 27 Galileo etc.). The results are presented for the two most probable constellations: I − 29 GPS satellites + 27 Galileo satellites, II − 29 GPS + 30 Galileo.

2. TEST METHOD

The GPS satellite positions were calculated by the author from the almanac data (week 329) obtained from the website: www.navcen.uscg.gov. The longitudes of the ascending node and the arguments of latitude of all 29 GPS satellites operational in 20 February 2006 are presented in the Table 1. The nominal position of 27 Galileo operational satellites and 3 spare satellites are demonstrated in the Table 2.

Table 1. GPS System – position of 29 satellites in 20 February 2006, β – longitude of the ascending node, u – argument of latitude, PRN – pseudorandom noise number

Orbit	Parameter	Satellite/slot					
		1	2	3	4	5	6
A	PRN	9	25	8	27	–	–
	β	295,9	292,8	300,4	294,6	–	–
	u	135,9	61,0	270,3	298,3	–	–
B	PRN	16	30	28	5	–	–
	β	358,5	356,1	359,1	353,6	–	–
	u	344,6	70,3	213,0	103,3	–	–
C	PRN	6	3	19	17	7	–
	β	56,3	52,9	61,4	58,0	54,8	–
	u	11,6	275,3	238,4	30,0	66,1	–
D	PRN	2	11	21	4	15	24
	β	118,0	110,0	120,3	119,2	122,4	121,0
	u	40,6	169,9	296,1	67,4	271,4	103,3
E	PRN	20	22	10	18	–	–
	β	177,6	181,1	179,3	180,5	–	–
	u	101,1	203,7	326,0	238,1	–	–
F	PRN	14	26	13	23	29	1
	β	238,6	239,4	239,4	238,0	237,5	240,2
	u	352,4	250,4	6,2	37,5	261,6	105,8

In constellations combined of two or more systems the reciprocal positions of all orbits of these systems, i.e. the longitudes of ascending nodes (lan) of all plane must be defined (Leonard et al. 2003). In constellation GPS and Galileo two plane positions are possible:

Table 2. Galileo System – nominal position of 27 operational satellites and 3 spare satellites*, β – longitude of the ascending node, u – argument of latitude

Orbit I			**Orbit II**			**Orbit III**		
Satellite	**β [^{O}]**	**u [^{O}]**	**Satellite**	**β [^{O}]**	**u [^{O}]**	**Satellite**	**β [^{O}]**	**u [^{O}]**
1	296	0	10	176	14	19	56	28
2		40	11		54	20		68
3		80	12		94	21		108
4		120	13		134	22		148
5		160	14		174	23		188
6		200	15		214	24		228
7		240	16		254	25		268
8		280	17		294	26		308
9		320	18		334	27		348
28*		20	29*		154	30*		288

- PP1; three Galileo planes (G) are complanar with three of six GPS planes (S), which will be referred “inphase” (fig.1a),
- PP2; three Galileo planes are directly in between two GPS planes, which will be referred “out − of − phase” (fig.1b).

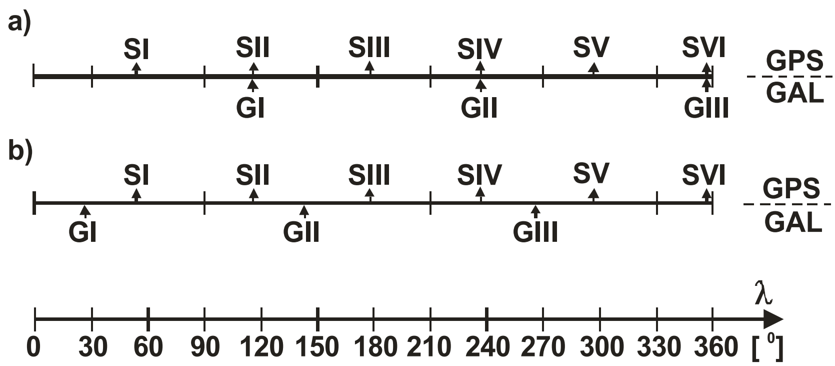

Fig. 1. Combined constellation GPS and Galileo, plane positions “inphase” (**a**), plane positions “out of plane” (**b**)

In mentioned constellations GPS and Galileo it was assumed longitudes lan are SI − 56^O, SII − 116^O, SIII − 176^O, SIV − 236^O, SV − 296^O, SVI − 356^O, and GI − 56^O, GII − 176^O, GIII − 296^O, respectively. The number of satellites (ls) visible by the observer and GDOP coefficient value for different geographic−time coordinates were calculated for PP1 and PP2. As the number ls and GDOP value depend on observer position, for one set of coordinates the results are different for both plane positions, evidently, but if the number of these coordinates increases (e.g. one thousand in this paper) the ls and GDOP values are practically the same.

That's why the different distributions of the number ls were made for one plane positions called "inphase" only (fig.1a).

Table 3. Combined constellations, number of satellites visible above H_{min} by the observer at latitudes 50–60^{O} for different numbers of GPS & Galileo satellites, for different H_{min}, ls_{min} – minimal number, ls_{max} – maximal number, ls_m – weighted mean number

Number of satellites		H_{min} [^{O}]	Number of satellites visible above H_{min}		
GPS	GAL		ls_{min}	ls_{max}	ls_m
27	27	0	15	29	21.4
		5	13	26	19.0
		10	10	24	16.4
		15	8	22	14.1
28	27	0	16	29	21.8
		5	14	26	19.3
		10	11	24	16.7
		15	9	22	14.4
29	27	0	16	29	22.1
		5	14	27	19.6
		10	11	24	16.9
		15	10	22	14.6
27	30	0	16	31	22.6
		5	14	27	20.1
		10	11	25	17.3
		15	10	22	15.0
28	30	0	17	31	23.0
		5	14	27	20.4
		10	11	25	17.6
		15	10	22	15.2
29	30	0	17	31	23.4
		5	14	28	20.7
		10	11	25	17.9
		15	10	22	15.4

All calculations based on reference ellipsoid WGS–84 were performed with author's simulating program. The interval of the latitude of the observer between 0^{O} and 90^{O} was divided into 9 zones, each 10^{O} wide. Elevation H_{min} was assumed to be 0^{O}, 5^{O}, 10^{O}, 15^{O}, 20^{O} and 25^{O}. For each combination, 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).

For each mentioned geographic–time coordinates the number of satellites visible by the observer above given H_{min} was calculated.

3. RESULTS

The minimal (ls_{min}), maximal (ls_{max}) and the weighted mean numbers (ls_m) of satellites visible above H_{min} by the observer at latitudes 50–60^O (latitude zone of Poland) for six combined constellations GPS and Galileo are presented in the Table 3. The calculations were made for four values of H_{min} (0^O, 5^O, 10^O and 15^O) for the constellations of GPS satellites and 27 & 30 Galileo satellites, where n was equal 27, 28 or 29. We can say that:

- for all constellations the ls_{min}, ls_{max} and ls_m decrease with H_{min} considerably, the differences between ls_{max} for H = 0^O and H = 15^O for all combinations with 27 or 30 Galileo satellites equal to 7 and 9, respectively,
- the ls_{max} & ls_m are the greatest (31 & 23.4 respectively) for H_{min} = 0^O for the constellation of 29 GPS + 30 GAL,
- for all three constellations with 30 Galileo satellites the number ls_{max} is the same (22) for H_{min} = 15^O,
- if the number of GPS satellites decreases from 29 to 28, the ls_{min} and ls_{max} are the same for H_{min} = 5^O and H_{min} = 10^O, independently of the number of Galileo satellites in constellation. It's very important information for all GPS users, when they fix position.

The ls_{min}, ls_{max} and ls_m number of satellites visible by the observer above H_{min} = 0^O and H_{min} = 15^O in all 8 other latitude zones for two constellations: I – 29 GPS satellites and 27 Galileo satellites, II – 29 GPS and 30 Galileo are demonstrated in the Table 4. We can recapitulate that:

- the ls_{min}, ls_{max} and ls_m depend on latitude for both H_{min} and both constellations. This dependence is practically the same as for GPS or Galileo system separately (Januszewski 2003, 2005).
- ls_{min} and ls_{max} are the lowest and the greatest at latitudes 20–30^O and 60–70^O respectively, for both angles H_{min} and both constellations,
- at latitudes 60–90^O for H_{min} = 0^O the number ls_{max} is for constellation I & II equal to 30 & 32 respectively. It means that for both constellations the number of satellites visible above horizon by the observer is greater that half of total number of satellites in given constellation, 56 and 59 respectively.

In combined constellations GPS and Galileo the number of Galileo satellites l_{GAL} visible by the observer above given H_{min} can be equal, greater or less than the number of GPS satellites l_{GPS} visible by this observer at the same time. The distributions (in per cent) of the differences $l_{GPS} - l_{GAL}$ for the observer at latitudes 50−60^O for different angle H_{min} (0^O, 5^O, 10^O and 15^O) for two mentioned constellations are demonstrated in the Table 5. The distributions of these differences in all other latitude zones for the same constellations, but for $H_{min} = 0^O$ and $H_{min} = 15^O$ only are showed in the Table 6. We can say that:

Table 4. Number of satellites visible by the observer above H_{min} in open area for different latitudes φ for two combined constellations I − 29 GPS satellites and 27 Galileo satellites, *II −29 GPS and 30 Galileo satellites (in italic)*, ls_{min} – minimal number, ls_{max} – maximal number, ls_m – weighted mean number

φ [^{O}]	H_{min} [^{O}]	Number of satellites visible above H_{min}					
		ls_{min}		ls_{max}		ls_m	
		Const I	Const II	Const I	Const II	Const I	Const II
0 – 10	0	16	*17*	28	*29*	22.6	*23.8*
	15	10	*11*	23	*24*	15.9	*16.8*
10 – 20	0	15	*16*	28	*29*	22.3	*23.4*
	15	10	*10*	22	*23*	15.0	*15.8*
20 – 30	0	14	*15*	28	*29*	20.9	*22.0*
	15	8	*10*	21	*22*	14.6	*15.4*
30 – 40	0	15	*15*	28	*31*	20.4	*21.4*
	15	9	*9*	21	*22*	14.3	*15.1*
40 – 50	0	14	*15*	28	*31*	20.8	*22.0*
	15	9	*10*	22	*23*	14.3	*15.1*
60 – 70	0	17	*17*	30	*32*	22.8	*24.1*
	15	10	*10*	24	*25*	16.1	*17.0*
70 – 80	0	16	*17*	30	*32*	23.1	*22.4*
	15	10	*11*	25	*26*	17.2	*18.2*
80 – 90	0	16	*17*	30	*32*	23.3	*24.6*
	15	11	*11*	25	*27*	17.5	*18.6*

- for constellation I and constellation II the difference $l_{GPS} - l_{GAL}$ is in most of the cases greater or less than zero, respectively,
- in all latitude zones the distribution of the difference $l_{GPS} - l_{GAL}$ is for given constellation practically the same, independently of angle H_{min},
- for the constellation II the number l_{GAL} is greater than l_{GPS} in 50% or more of the cases, independently of latitude zone and H_{min}.

The detailed distributions (in per cent) of the differences $l_{GPS} - l_{GAL}$ for different H_{min} (0^O, 5^O, 10^O and 15^O) for the two constellations mentioned are presented in the Table 7. We can recapitulate that:

Table 5. Distribution (in per cent) of the differences $l_{GPS} - l_{GAL}$ for different latitudes for different H_{min} for two combined constellations I − 29 GPS satellites and 27 Galileo satellites, *II −29 GPS and 30 Galileo satellites (in italic)*

φ [^{O}]	H_{min} [^{O}]	Constellation	$l_{GAL} = l_{GPS}$	$l_{GAL} > l_{GPS}$	$l_{GAL} < l_{GPS}$
0 − 10^O	0	I	21.7	31.8	46.5
		II	*21.2*	*59.2*	*19.6*
	15	I	18.7	36.2	45.1
		II	*22.2*	*53.0*	*24.8*
10 − 20^O	0	I	20.1	31.9	48.0
		II	*22.8*	*56.2*	*21.0*
	15	I	17.9	37.2	44.9
		II	*21.7*	*53.1*	*25.2*
20 − 30^O	0	I	18.8	37.3	43.9
		II	*20.3*	*58.6*	*21.1*
	15	I	20.3	36.3	43.4
		II	*25.7*	*50.1*	*24.2*
30 − 40^O	0	I	20.5	34.4	45.1
		II	*22.4*	*57.0*	*20.6*
	15	I	20.2	39.8	40.0
		II	*24.3*	*54.1*	*21.6*
40 − 50^O	0	I	18.4	38.9	42.7
		II	*18.2*	*62.7*	*19.1*
	15	I	23.3	39.8	36.9
		II	*23.3*	*57.0*	*19.7*
60 − 70^O	0	I	14.4	35.4	50.2
		II	*18.5*	*58.3*	*23.2*
	15	I	15.5	44.6	39.9
		II	*14.8*	*61.6*	*23.6*
70 − 80^O	0	I	15.9	33.6	50.5
		II	*16.5*	*61.7*	*21.8*
	15	I	13.8	40.0	46.2
		II	*17.3*	*57.0*	*25.7*
80 − 90^O	0	I	15.0	34.6	50.4
		II	*17.4*	*60.2*	*22.4*
	15	I	12.4	37.2	50.4
		II	*16.9*	*53.3*	*29.8*

Table 6. Distribution (in per cent) of the differences $l_{GPS} - l_{GAL}$ at latitudes 50–60^O for different H_{min} for two combined constellations: I – 29 GPS satellites and 27 Galileo satellites, *II –29 GPS and 30 Galileo satellites (in italic)*

φ [^{O}]	H_{min} [^{O}]	Constellation	$l_{GAL} = l_{GPS}$	$l_{GAL} > l_{GPS}$	$l_{GAL} < l_{GPS}$
50 – 60^O	0	I	16.2	37.4	46.4
		II	*17.4*	*60.8*	*21.8*
	5	I	20.1	40.4	39.5
		II	*15.8*	*63.0*	*21.2*
	10	I	20.7	43.5	35.8
		II	*17.0*	*62.1*	*20.9*
	15	I	21.4	41.9	36.7
		II	*20.3*	*57.3*	*22.4*

- for $H_{min} = 0^O$ la difference $l_{GPS} - l_{GAL}$ for constellation I and II changes between – 7 & + 6 and between – 6 & + 7, respectively,
- the probability of $|l_{GPS} - l_{GAL}|$ equal 0, 1 or 2 is less than probability of $|l_{GPS} - l_{GAL}|$ equal 6 or 7 considerably,
- for both constellations la probability of the extreme values of the mentioned difference is for $H_{min} = 25^O$ less than for $H_{min} = 0^O$ considerably.

In urban area the mean number of satellites (ls_m) visible above H_{min} and the obstacles blocking the observer situated on the street depends on the angle (α) between the North and street axis, the observer's latitude and the combined constellations. The calculations were made for the observer situated in the middle of the street (width L = 20 m, height B = 20 m) for angle α between 0 and 170^O with the step 10^O for angle $H_{min} = 5^O$ for two representative latitude zones 0–10^O and 50–60^O for two combined constellations: I – 29 GPS satellites & 27 Galileo satellites and II – 29 GPS & 30 Galileo. The results are presented in the Table 8. We can say that:

- the number ls_m depends on angle α and observer's latitude considerably for both constellations,
- for zone 0–10^O the number ls_m changes between 4.35 & 6.07 and between 4.57 & 6.39 for constellation I and II respectively, for zone 50–60^O for the same constellations les changes are equal 4.25 & 7.28 and 4.51 & 7.69 respectively,
- at latitudes 0–10^O the maximal and minimal value of ls_m are for α = 20^O & 90^O respectively for both constellations. At latitudes 50–60^O the maximum and minimum are for 90^O and 0^O respectively for both constellations also. These distributions are due to GPS and Galileo plane inclination equal 55^O and 56^O respectively.

Additional calculations were made for the same observer at latitudes 50–60^O, $H_{min} = 5^O$, α = 0^O, the same constellations, but for L between 14 & 23 m with the step 1 m and for the height B between 20 & 23 m with the step 1 m also. The results are showed in the Table 9:

Table 7. Detailed distributions (in per cent) of the differences $l_{GPS} - l_{GAL}$ at latitudes 50–60^O for different H_{min} for two combined constellations: I − 29 GPS satellites and 27 Galileo satellites, *II −29 GPS and 30 Galileo satellites (in italic)*

Differences $l_{GAL} - l_{GPS}$ and $l_{GPS} - l_{GAL}$		**$H_{min} = 0^O$**		**$H_{min} = 5^O$**		**$H_{min} = 15^O$**		**$H_{min} = 25^O$**	
		Const I	**Const II**	**Const I**	**Const II**	**Const I**	**Const II**	**Const I**	**Const II**
$l_{GAL} - l_{GPS}$	7	–	*0.2*	–	*0.1*	–	–	–	–
	6	0.2	*0.9*	0.1	*1.1*	–	*0.1*	0.1	–
	5	1.0	*3.3*	1.1	*4.6*	0.5	*1.1*	0.3	*0.4*
	4	2.1	*9.1*	4.6	*8.4*	1.8	*5.5*	3.4	*0.6*
	3	7.6	*12.5*	8.9	*13.9*	6.8	*13.9*	6.0	*3.4*
	2	11.9	*15.8*	11.5	*16.9*	13.5	*17.6*	12.3	*6.8*
	1	14.6	*19.0*	14.2	*18.0*	19.3	*19.1*	20.2	*10.0*
$l_{GAL} - l_{GPS} = 0$		16.2	*17.4*	20.1	*15.8*	21.4	*20.3*	23.2	*22.9*
$l_{GPS} - l_{GAL}$	1	18.9	*10.6*	15.8	*23.1*	16.2	*10.6*	17.2	*12.6*
	2	14.4	*6.1*	12.8	*16.7*	11.1	*7.5*	10.9	*4.8*
	3	7.9	*2.7*	6.8	*10.7*	5.8	*3.4*	4.5	*2.4*
	4	3.6	*1.9*	2.4	*4.1*	2.9	*1.4*	1.7	*0.9*
	5	1.3	*0.4*	1.7	*1.4*	0.6	*0.2*	0.1	*0.2*
	6	0.2	*0.1*	–	*0.2*	0.1	–	0.1	–
	7	0.1	–	–	–	–	–	–	–

- if for given height B the width L decreases, the number ls_m decreases for both constellations; e.g. for B = 21 m and Const I if L decreases from 21 to 16 m, ls_m changes from 4,25 to 3,25;
- if for given width L the height B decreases, the number ls_m increases for both constellations,
- for given width L and height B the observer's position "3D" ($ls_m \geq 4$) for Const II can be obtained, while for Const I cannot be, e.g. for L = 20 m and B = 22 m.

Table 8. Mean number of satellites ls_m visible above H_{min} = 5^O and the obstacles by the observer situated in the middle of the street (width L = 20 m, height B = 20 m) for different angle between the North and street axis (α) for two latitude zones, 0 − 10^O and *50 − 60^O (in italic)* for for two combined constellations: I − 29 GPS satellites and 27 Galileo satellites, II −29 GPS and 30 Galileo satellites

α [^{O}]	φ [^{O}]	ls_m		α [^{O}]	φ [^{O}]	ls_m	
		Const I	Const II			Const I	Const II
0	0 − 10	5.93	6.26	90	0 − 10	4.35	4.57
	50 − 60	*4.25*	*4.51*		50 − 60	*7.28*	*7.69*
10	0 − 10	5.94	6.26	100	0 − 10	4.37	4.59
	50 − 60	*4.35*	*4.62*		50 − 60	*7.16*	*7.56*
20	0 − 10	6.07	6.39	110	0 − 10	4.48	4.72
	50 − 60	*4.66*	*4.95*		50 − 60	*7.11*	*7.51*
30	0 − 10	6.03	6.34	120	0 − 10	4.67	4.92
	50 − 60	*5.25*	*5.56*		50 − 60	*7.00*	*7.41*
40	0 − 10	5.32	5.62	130	0 − 10	4.90	5.16
	50 − 60	*6.26*	*6.62*		50 − 60	*6.70*	*7.10*
50	0 − 10	4.86	5.12	140	0 − 10	5.30	5.59
	50 − 60	*6.73*	*7.11*		50 − 60	*6.18*	*6.56*
60	0 − 10	4.63	4.86	150	0 − 10	5.98	6.51
	50 − 60	*6.95*	*7.34*		50 − 60	*5.16*	*5.47*
70	0 − 10	4.49	4.71	160	0 − 10	6.03	6.37
	50 − 60	*7.09*	*7.48*		50 − 60	*4.52*	*4.81*
80	0 − 10	4.48	4.63	170	0 − 10	5.91	6.27
	50 − 60	*7.19*	*7.60*		50 − 60	*4.37*	*4.64*

Table 9. The weighted mean number of satellites visible above the obstacles and H_{min} = 5^O by the observer at latitudes 50−60^O in the middle of the street, angle between the North and street axis = 0^O, for different widths L and different heights B for two combined constellations: I − 29 GPS satellites and 27 Galileo satellites, *II −29 GPS and 30 Galileo satellites (in italic)*

B [m]	Const	Width L [m]									
		14	15	16	17	18	19	20	21	22	23
20	I	3.00	3.20	3.38	3.62	3.83	4.03	4.25	4.47	4.69	4.86
	II	3.18	3.39	3.59	3.84	4.06	4.28	4.51	4.74	4.97	5.15
21	I	−	3.05	3.25	3.42	3.64	3.85	4.04	4.25	4.47	4.69
	II	3.02	3.23	3.44	3.64	3.87	4.08	4.29	4.51	4.74	4.95
22	I	−	−	3.11	3.29	3.46	3.68	3.86	4.10	4.25	4.46
	II	−	3.09	3.29	3.49	3.68	3.90	4.10	4.30	4.51	4.73
23	I	−	−	−	3.15	3.33	3.51	3.70	3.88	4.06	4.25
	II	−	−	3.16	3.34	3.53	3.73	3.93	4.12	4.31	4.51

CONCLUSIONS

- for the most probably combined constellation of 29 GPS satellites and 27 Galileo satellites the number of satellites visible by the observer above $H_{min} = 25^{O}$ is greater than 4 independently of observer latitude. It means that "3D" observer's position can be obtained in each cases. If in this constellation the number of GPS satellites decreases to 28 or 27 the position "3D" can be obtained as before;
- in combined constellations (29 GPS satellites + n Galileo satellites) the increasing of the number of Galileo satellites (from 27 to 30) means, that the weighted mean number (ls_m) and the maximal number (ls_{max}) will be greater, meanwhile the minimal number (ls_{min}) will be greater or the same;
- for all combined constellations (GPS system + Galileo system) the number of Galileo satellites l_{GAL} visible by the observer can be greater or less than the number of GPS satellites l_{GPS} visible at the same time by this observer. This fact must be taken into account in the production and the determination of the number of channel of GPS–Galileo integrated receivers; $|l_{GAL} - l_{GPS}|$ can be equal 8;
- as the distribution of satellite azimuths is non–uniform and depends on latitude, in urban area for the observer situated in the middle of the street (with given width and height of the buildings) the position accuracy depends on the angle between the North & street's axis and observer's latitude also;

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