Multi-Constellation System as Augmentation To GPS Performance in Difficult Environment or Critical Application

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BIOGRAPHY

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ABSTRACT

The GPS Standard Positioning Service (SPS) does not provide suitable performance in all environment conditions or in every possible applications. In severely signal degraded environments, e.g. mountainous or urban areas, where a lot of GPS signals are blocked by buildings or natural obstacles, the positioning is inaccurate because of bad satellite configuration or impossible owing to lack of minimum number of visible satellites. Otherwise GPS SPS is inadequate for critical safety applications like aircraft take-off or landing, because does not satisfy the Required Navigation Parameters (RNP) relative to these flight phases.

To solve the GPS gap on regional scale, space-based augmentations could be employed. In this study a simulation is carried out, considering GLONASS and EGNOS GEO constellations and a set of 3 geosynchronous satellites (similar to QZSS space segment). A software for constellation analysis is developed in MATLAB® environment to evaluate the considered augmentations performances in critical conditions (urban canyon or critical phase of flight). The used indicators to evaluate coverage performance are the VSN (Visible Satellites Number), DOP (Dilution of Precision) and the probability that integrity is available to be computed in autonomous.

INTRODUCTION

Radio-Navigation systems, particularly satellite ones, are characterized by a set of parameters which define the system performance: coverage, availability, continuity, accuracy and integrity.

Coverage is defined as the surface area or spatial volume where the system provides a service in a manner to meet the specified level of accuracy.

Availability is defined as the percentage of time that the system service is available to a receiver.

Continuity is defined to be the probability that the service will be provided continuously and healthy without unscheduled interruption over a specified time interval.

Accuracy is defined to be the statistical difference between the estimate and the true value of the fix (at the 95% probability level).

Integrity is a measure of the trust which can be placed in the correctness of the information supplied by the system and includes the ability of the system to provide timely alerts to users when the system should not be used.

GPS civil service is not able to provide suitable performances in every condition, environment or application.

Typical difficult environments are urban or mountainous areas, characterized by bad electro-magnetic visibility; in fact a lot of GPS satellites are masked by buildings or natural obstacles and there are not enough GPS signals available at receivers to compute fix or to get a good observation geometry.

Otherwise for air navigation purpose, positioning systems have to meet severe requirements, owing to safety implication and so GPS SPS is inadequate for some critical phases of flight.

In these scenarios GPS SPS performances become insufficient and to solve GPS gap the integration with other systems is necessary (inertial sensors, DGPS, pseudolites, ground and space augmentation systems).

This study is focused on the use of space augmentations to improve GPS SPS performances on regional basis (particularly on Europe). The integration with different constellation is simulated in various scenarios. GLONASS and EGNOS GEO constellations and a set of 3 geosynchronous satellites (similar to QZSS space segment) are considered; to evaluate coverage performance VSN (Visible Satellites Number), DOP (Dilution of Precision) and geometric RAIM availability are the metrics employed.

GPS AND SPACE AUGMENTATIONS

GPS constellation

GPS space segment is nominally a 24-slot constellation with 6 orbital planes and 4 slots per plane; the ascending nodes are equally spaced of 60° on equator. The orbits inclination and eccentricity are 55° and 0 (with operational range ±3° and 0-0.02). The semi-major axis nominal value is 26559.7 Km, producing a semi-synchronous orbit, i.e. an orbit with period of 11^h58^m (=0.5 sidereal days) and a stationary ground trace. The baseline 24 constellation is intentionally non-symmetric to optimize the coverage for a satellite outage: on each plane the 4 satellites are not uniformly spaced. Three among the 24 slots are “expandable”, i.e. they can house a close pair of satellites instead of one. Further surplus satellites have no a priori specified slots. All the healthy GPS satellites, from baseline/expandable slots and from surplus group are available to be used. At January 2009 GPS operational space vehicles (SV) are 32.

GLONASS constellation

GLONASS constellation consists nominally of 24 satellites placed in three orbital planes, with ascending nodes spaced 120° each other. Nominal spacing between adjacent satellites within a single orbital plane is equal to 45°, while shift between orbits is 15°. Orbits are circular with altitude 19100 km and period $11^h15^m44^s$, generating ground tracks repeating every $7^D23^h27^m28^s$ (=17 orbital periods). Inclination is 64.8°, providing a better coverage than GPS at high latitudes. At January 2009 GLONASS operational SV are 17.

EGNOS GEO constellation

EGNOS is the European SBAS (Satellite Based Augmentation Systems) and it has been developed by the ESA in co-operation with the European Commission and Eurocontrol. The EGNOS space segment is composed by the already existing GPS constellation and by 3 geostationary satellites, broadcasting Wide Area Differential corrections and integrity information. In this paper we focus on the Geostationary satellites that, broadcasting GPS-like signal, improve the availability and the satellites geometry on Europe.

EGNOS GEO satellites are: AOR-E at 15.5°W, ARTEMIS at 21.5°E and IOR-W at 25°E.

A snapshot of sub-satellites points of GPS, GLONASS and EGNOS-GEO for a fixed epoch is showed in fig.1.

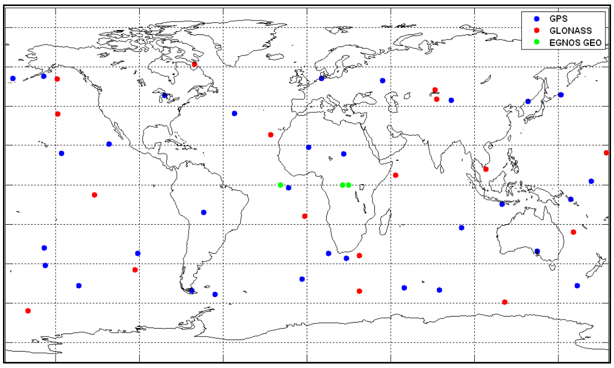

Fig.1 – Sub-satellites points snapshot

Geosynchronous constellation

To improve the visibility and the quality of the satellite coverage, a constellation of 3 geosynchronous satellites (called "GeoSync") is considered as possible augmentation of the existing constellations.

Geosynchronous satellites have the same period of the geostationary ones (equal to a sidereal day) with non-zero orbital inclination and eccentricity.

GeoSync has characteristic similar to the QZSS (Quasi Zenith Satellite System) space segment. The 3 orbits are elliptical and identical and have a large inclination on the equatorial plane (they are known as High-inclined Elliptical Orbits or HEO). The considered space vehicles produce coincident 8-shaped ground tracks centered on 15°E meridian (QZS tracks are centered on 135° meridian). The geosynchronous constellation is planned to have always at least one satellite near zenith over the served area (area under orbital apogee), so that users can receive signals without obstructions in "urban canyons" and mountainous areas. GeoSync ground tracks and orbital parameters are showed in fig. 2 and tab. 1.

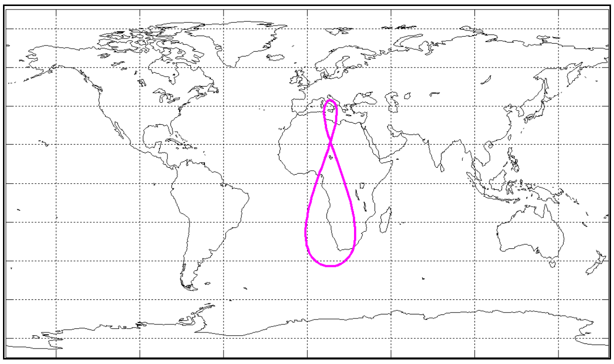

Fig.2 – GeoSync Ground Tracks

Number of Satellites	3
Number of Orbits	3
Inclination	43°
Eccentricity	0.075
Major Semiaxis	42164 Km
Orbital Period	1 Sideral Day
Perigee Distance	39002 Km
Apogee Distance	45326 Km
RAAN	To Be Defined
Argument of Perigee	270°
Central Long. Ground Trace	15°

Table 1: GeoSync Orbital Parameters

In simulation, constellations with slightly different orbital parameters are been tested and not too different performances are been noticed.

VISIBILITY and GDOP

Satellite navigation is based on simultaneous range measurements to all visible satellites; range measurements to a single SV are expressed as:

$$\rho = d + c \cdot \left(\delta t_{sat} - \delta t_{rec}\right) + d_{ion} + d_{trop} + \varepsilon_n \qquad (1)$$

with:

ρ measured pseudo-range,
d geometric range Satellite-Receiver,
c light speed,
δt_{sat} satellite clock error,
δt_{rec} receiver clock error,
d_{ion} ionospheric error,
d_{trop} tropospheric error,
ε_n measurement noise.

The geometric range d is a function of the known satellite position and of the unknown receiver position. All the remaining terms can be modeled and so considered known, except the receiver clock error, that with the three receiver spatial coordinates makes up the four unknowns to estimate.

To estimate the receiver position and clock error at least four visible satellites are necessary, but a fourfold visibility is critical because:

- an only one SV lost makes the positioning impossible
- the satellite geometry, that affects the fix accuracy, can likely be poor
- self-consistency measurements check can not be carried out

For these reasons a five visible satellites threshold is considered.

Pseudo-range equations are linearized around a set of a priori values of the receiver position and clock bias, forming the new measurement model:

$$\Delta\rho = H \cdot \Delta x + \varepsilon \qquad (2)$$

with

Δρ (nx1) vector of measures compensated by a priori information,
H (nx4) geometry matrix,
Δx (4x1) unknown vector of corrections from a priori to updated state,
ε (nx1) vector of measurement errors (considered Gaussian),
n number of visible satellites.

The set of equation is solved for Δx by means of least square method and the solution is given by:

$$\Delta\hat{x} = \left(H^T R^{-1} H\right)^{-1} H^T R^{-1} \Delta\rho \qquad (3)$$

where $R=E[\Delta\rho\Delta\rho^T]$ is the pseudo-range measurements covariance matrix (nxn). In these general conditions the solution error covariance matrix (4x4) is:

$$C = \left(H^T H\right)^{-1} H^T R H \left(H^T H\right)^{-1} \qquad (4)$$

If the measurements errors are considered independent, with zero mean and equal variance σ^2, the R matrix is simplified as $R= \sigma^2 I$ and the solution error covariance matrix becomes:

$$C = \left(H^T H\right)^{-1} \sigma^2 \qquad (5)$$

The DOP (Dilution Of Precision) parameters represent the satellite geometry influence on positioning accuracy and are defined as:

$$\begin{aligned}
GDOP &= \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 + \sigma_b^2} \,\big/ \sigma && \text{Geometric DOP}\\
PDOP &= \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \,\big/ \sigma && \text{Position DOP}\\
HDOP &= \sqrt{\sigma_x^2 + \sigma_y^2} \,\big/ \sigma && \text{Horizontal DOP}\\
VDOP &= \sigma_z^2 \big/ \sigma && \text{Vertical DOP}\\
TDOP &= \sigma_b^2 \big/ \sigma && \text{Time DOP}
\end{aligned} \qquad (6)$$

where σ_x, σ_y, σ_z, σ_b are the rms errors in the estimated user coordinates and clock bias and σ is the measurements rms error.

In the assumption that all satellite pseudo-range measurement errors are independent with the same statistics, the DOP parameters represent an approximation of geometry contribution on fixing accuracy and are function of matrix H only:

$$\begin{aligned}
G &= \left(H^T H\right)^{-1} && \text{GDOP matrix}\\
GDOP &= \sqrt{trace(G)} && \text{Geometric DOP}\\
PDOP &= \sqrt{G_{11} + G_{22} + G_{33}} && \text{Position DOP}\\
HDOP &= \sqrt{G_{11} + G_{22}} && \text{Horizontal DOP}\\
VDOP &= \sqrt{G_{33}} && \text{Vertical DOP}\\
TDOP &= \sqrt{G_{44}} && \text{Time DOP}
\end{aligned} \qquad (7)$$

GDOP concept is a powerful, simple and widely used metric for evaluating the effectiveness of the satellite geometry. Generally low GDOP values coincide with good geometries and vice versa; satellite geometry with GDOP values up to 3 are considered excellent, GDOP up to 6 are good. GDOP value 8 is considered the limit of a moderate geometry.

It can be mathematically shown that increasing the number of visible satellites will always reduce the GDOP value, but the reduction amount depends on the positions of the “added” satellites with respect to the existing constellation. A goal of the study is to analyze the levels of improvement in GDOP, integrating GPS space segment with other constellations.

GDOP metric has only geometric value, because of its inherent concept of independent measurements errors with equal variance. Obviously these hypotheses are not realistic: certain measurements are noisier than others (e.g. from lower elevation satellites) and atmospheric measurements errors are highly correlated for satellites at the same elevation angles. So a more realistic measure error model should be used to consider these phenomena, affecting the measurements covariance matrix R and DOP expressions (that becomes a Weighted DOP).

Mask angle is a threshold elevation angle below which the receiver no longer use a satellite in its computations. Satellites low on the horizon are characterized by very large atmospheric errors and are cut out. In this study a mask angle equal to 15° is accepted in areas with good visibility and a mask angle of 40° is used to simulate an urban canyon.

To use a multi-constellation for navigation, the problems of the compatibility and the interoperability between the systems have to be faced. In this work the integration between GPS and GLONASS is considered. The two systems are similar but not identical. In fact GPS and GLONASS systems operate with different time references and with different coordinates frames. GPS time is related with UTC(USNO), Coordinated Universal Time as maintained at the United States Naval Observatory, and GLONASS time is related to UTC(SU), UTC as maintained by Russia. The offset between the two time references can be calibrated, but this information is not included in the navigation messages broadcasted by the satellites. This causes an increase in the unknowns number from 4 to 5: three coordinates of user position and the biases of the receiver clock relative to the two time scales (the measurements model (2) should be modified). The problem will be overcome with the new generation of satellites GLONASS-M, that are planned to broadcast the offset between the time scales (for this reason the model (2) with 4 unknowns is used in this simulation). The different datum of GPS and GLONASS does not require an additional state to account, because WGS84 and PZ90 are known and fixed, and they are linked by a well-defined mathematical transformation. Other differences are related to the signals nature (different Signal Bandwidths and Multiple Access

Schemes) and so they are not considered in the geometrical analysis carried out in this study.

GEOMETRIC RAIM AVAILABILITY

The integrity concept is fundamental for a navigation system above all for safety-critical applications (e.g. aircraft take-off and landing). It includes the ability of the system to provide timely warnings when the system should not be used to navigation.

GPS system already provides integrity information by means of the "SV health" parameter, broadcasted in the navigation message by each satellite, but this information is not provided in real time and so it is not suitable to meet civil aviation application requirements. Also the GLONASS system broadcasts in the navigation message an "health flag" to indicate a malfunction of a satellite, but not in a timely mode. So additional means of providing integrity information are required. Integrity can be provided to the users externally by systems monitoring the signal in space (like SBAS and GBAS); otherwise the integrity can be achieved by an autonomous technique based on a consistency check within the user equipment. The two methods can be used at the same time as different layers of the same integrity monitoring system.

The method to obtain integrity information on which this paper focuses is RAIM (Receiver Autonomous Integrity Monitoring). It is based on a consistency check on redundant measurements within the user receiver to detect the faulty ones before they corrupt the navigation outputs. Such local integrity check allows the detection of certain error modes as excessive multipath, local interference, localized ionospheric and tropospheric effects.

A variety of RAIM algorithms have been proposed in literature, all based on a self-consistency check among redundant pseudo-range measures using statistical decision theory. A decision variable, closely linked to measurements self-consistency, is tested against a threshold, strictly connected with the required integrity performance. An alarm occurs when the chosen decision variable exceeds the threshold.

At least 5 satellites have to be visible and also a minimum satellite geometry is necessary to apply a RAIM algorithm. The minimum satellite geometry is constrained to the RNP (Required Navigation Performance):

- Probability of False Alarm P_{FA} (detection in absence of failure)
- Probability of Missed Detection P_{MD} (no detection in presence of failure)
- Horizontal Alarm Limit HAL (maximum allowed error in horizontal position, for which no alert needs to be raised)
- Time to Alarm TTA (maximum elapsed time from failure to alarm)

RNP are defined by RTCA (Radio Technical Commission for Civil Aviation) for each phase of flight. In this study we focus on the phases of flight resumed in table 2 (En Route, Terminal, Not Precision Approach).

	P_{FA}	P_{MD}	***HAL***	***TTA***
En Route/ Terminal	10^{-5}	10^{-3}	1850 m	15 s
NPA (Not Precision Approach)	10^{-5}	10^{-3}	555 m	10 s

Table 2: Required Navigation Performance

A group of RAIM algorithms (including Parity and Least Square Residuals Methods) define the decision variable as the sum of the squared Gaussian-distributed residuals; thus the test statistics have a chi-square distribution. So the Probability of False Alarm P_{FA} is expressed as a centered chi-square distribution with n-4 DOF (Degree Of Freedom)

$$P_{FA} = Q\left(T/\sigma^2 \mid n-4\right) \tag{8}$$

where

n is the number of visible SV,

T is the threshold,

Q is the complementary of chi-square probability function P.

The Missed Detection event is modeled as a non-centered chi-square distribution with a non-centrality parameter λ and n-4 DOF:

$$P_{MD} = P\left(T/\sigma^2 \mid n-4, \lambda\right) \tag{9}$$

$$\lambda = \frac{HAL^2}{\sigma^2}\frac{1}{dH_i^2} \tag{10}$$

$$dH_i^2 = HDOP_i^2 - HDOP^2 \tag{11}$$

with

σ Standard Deviation of pseudo-range measurement errors,

$HDOP_i$ Horizontal DOP computed by the exclusion of a SV in the worst case.

When P_{FA} (from Tab. 2), σ and n are given, the threshold T can be calculated solving equation (8); so the equation (9) can be solved for dH^2_{max}, introducing the calculated T, P_{MD} and HAL from Tab. 2, and σ and n.

A medium value of 33.3 meters is assigned to σ, calculated from the equation (12), assuming an average Horizontal Position Error accuracy (95%) of 100 m and an average HDOP of 1.5.

$$HPE_{2drms} = 2 \cdot HDOP \cdot \sigma \qquad (12)$$

The chosen σ value is very prudent, considering the current pseudo-range errors.

dH^2_{max} is the constellation geometric limit for RAIM availability, i.e. if the dH^2_i calculated from constellation exceeds the dH^2_{max} (required by the phase of flight) the RAIM algorithm can not be applied. dH^2_{max} depends on the RNP of the considered flight phase. In table 3 dH_{max} values are shown in function of the phase of flight and the number of visible satellites.

SV Number	dH max	
	Enroute/ Terminal	**NPA**
5	7,40	2,22
6	7,12	2,13
7	6,92	2,08
8	6,78	2,03
9	6,65	2,00
10	6,55	1,96
11	6,45	1,94
12	6,37	1,91
13	6,30	1,89
14	6,23	1,87
15	6,16	1,85
16	6,10	1,83
17	6,05	1,82
18	6,00	1,80
19	5,95	1,79
20	5,90	1,77
21	5,86	1,76
22	5,82	1,75
23	5,78	1,73
24	5,74	1,72
25	5,71	1,71

Table 3: dH_{max} thresholds

The dH^2_i parameter is a measure of the error detectability that a certain satellite geometry offers. Assuming the measurement i contains a bias, if the remaining measurements show a weak geometry, they provide only inaccurate position, hiding the error on satellite i and making hard the check on it.

In some literature the dH^2_i parameter is called iDOP (integrity DOP) because it plays the same role in failure detection that DOP does in navigation accuracy.

dH^2_i metric, like DOP, has purely geometric value, because of its inherent concept of independent measurements errors with equal variance. Moreover it is only meaningful for the assumption of a single failure, because of the way it is defined (this can be a great limit when a multi-constellation is considered).

TOOL: CONSTELLATION ANALYZER

To assess the performances of a constellation for navigation purpose, a software is developed in MATLAB environment. A flow diagram of its fundamental steps is shown in fig. 3.

The main inputs of the software are the ephemerides of the considered constellation. The ephemerides of GPS, GLONASS and EGNOS GEO constellations are extracted from Navigation Rinex files; simulated constellations (like the Geosync) ephemeredes are loaded in tabular form by theoretical orbital parameters.

GPS Broadcast Ephemerides are in perturbed keplerian form and are transformed in ECEF (WGS84) coordinates using the algorithm proposed in the IS-GPS-200. GLONASS satellites ephemerides are expressed as position, velocity and perturbations in ECEF (PZ90) coordinates; the satellite position in every epoch is obtained using the 4th order Runge-Kutta method to integrate the motion equation. The transformation from PZ90 to WGS84 is performed by a well-defined seven parameters relationship.

The transformation from ECEF to local ENU (East North Up) frame is obtained by a roto-translation, depending on the coordinates of the local system origin. ENU coordinates are strictly connected to Elevation and Azimuth coordinates.

The VSN is computed considering visible only the satellites with elevation angle greater than the mask angle. The mask angle is used to simulate the different visibility of the various environments: 15° for airport areas and 40° for urban canyons.

Known the SV elevations h and azimuths az, the geometry matrix H is computed as:

$$H = \begin{pmatrix} \cos(h_1)\sin(az_1) & \cos(h_1)\cos(az_1) & \sin(h_1) & 1 \\ \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet \\ \cos(h_n)\sin(az_n) & \cos(h_n)\cos(az_n) & \sin(h_n) & 1 \end{pmatrix} \qquad (13)$$

The GDOP matrix is obtained by the first of the (7) and finally the GDOP from the second of (7) and dH_i from the (11).

The outputs of the Constellation Analyzer are:

- VSN
- GDOP
- dH_i (iDOP)

To study the global performance of a constellation, a grid of observers is adopted with a step of 5° in latitude and longitude. To obtain information on the time evolution of the metrics, a whole day is considered with a step between the epochs equal to 10 minutes. Trials with smaller step in time and space did not provide significantly different results.

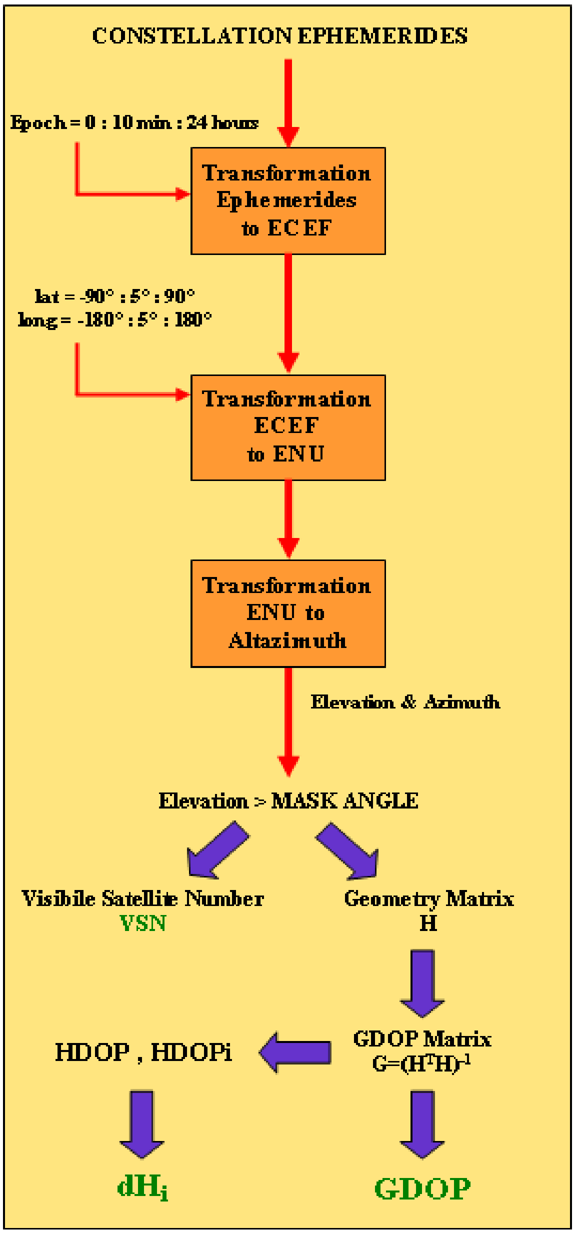

Fig.3 – Constellation Analyzer flow diagram

RESULTS

The fundamental parameters to define the performances of a navigation satellite system in urban environments are above all the availability and the continuity; these concepts are now intended in a local meaning, i.e. inside an urban canyon it is necessary that a constellation always allows the positioning, so it has to provide at least 5 visible satellites at every time. The fixing accuracy in land navigation is less critical, because detailed maps are usually available and they are used to force the fix to belong to the covered road (obviously a good initial fix and the service continuity have to be guaranteed). The integrity is also a not stringent constraint in urban navigation.

So the parameters used to assess the performances of GPS and the considered augmentations in urban environment are the probability that VSN≥5 and the probability that GDOP<8 (limit value for a moderate geometry); to summarize in a more effective way the constellations performance, the joint probability of these events is showed.

To simulate the visibility inside an urban canyon the mask angle is set equal to 40°.

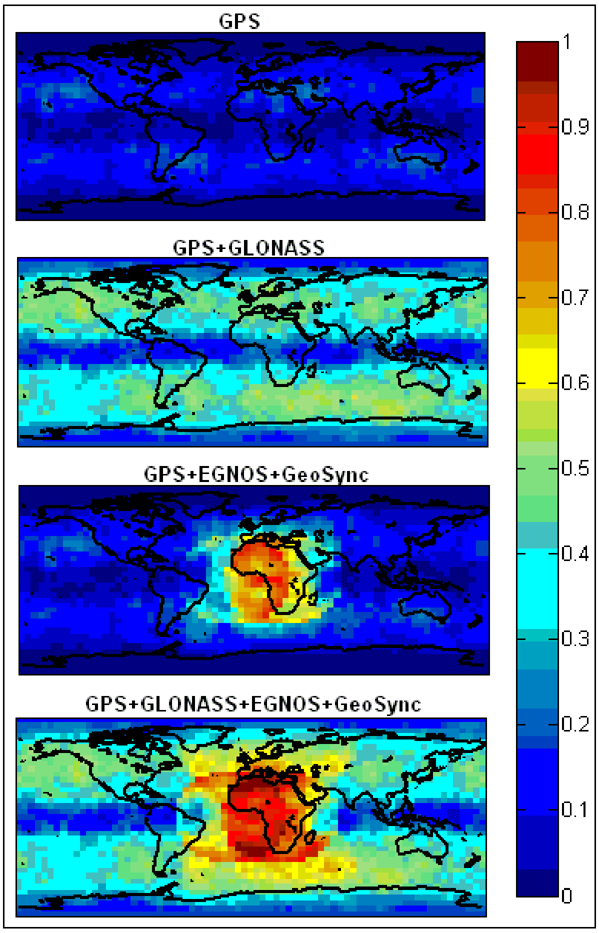

Fig.4 – Joint Probability of VSN≥5 and GDOP<8 (Mask angle 40°)

The simulation carried out shows that the GPS stand-alone is inadequate to provide suitable visibility and GDOP; GPS augmented with GLONASS improves slightly the geometric performances. An enhancement more focused on Europe can be appreciated in the multi-constellation GPS+EGNOS+GeoSync. The last configuration in which GPS is augmented with GLONASS, Geostationary and Geosynchronous space segments provides an adequate joint probability (90% on Southern Europe, 70% on Western Europe) of VSN≥5 and GDOP<8 (fig. 4). It is also noteworthy that the right number of visible satellites is always guaranteed by the super-constellation (fig. 5).

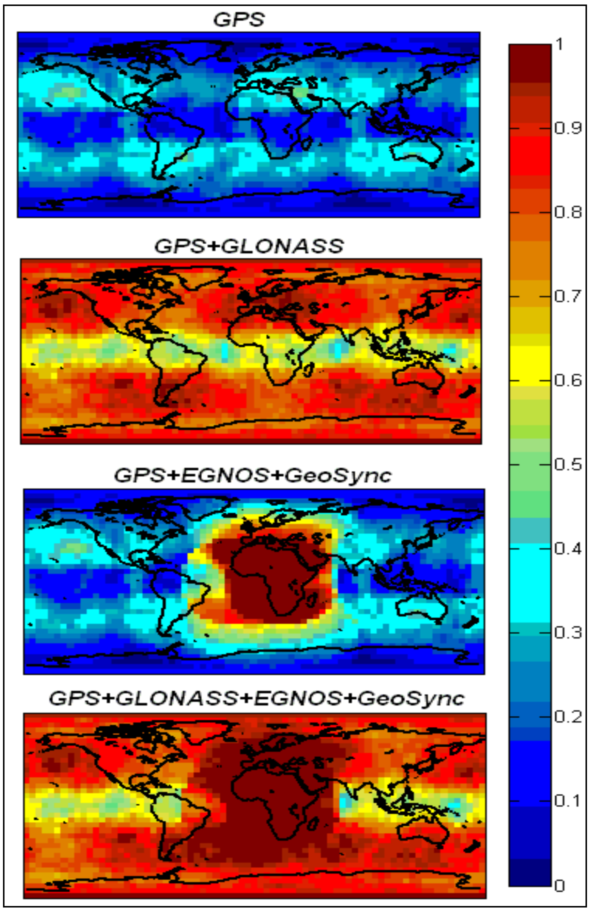

Fig.5–Probability of VSN≥5 (Mask Angle 40°)

For air navigation purpose the fundamental parameter that characterizes the system navigation performance is the integrity, owing to the involved safety of life applications. For this application the sky can be considered free from natural or urban obstacles. So the mask angle is fixed to 15°, because the measurements from satellites below this limit are affected by high propagation errors (ionospheric, tropospheric and multipath) and produce an accuracy decay.

In these conditions of low mask angle the visibility provided by GPS standalone is adequate. The probability of a VSN≥5 is 100% almost everywhere and so the positioning is always guaranteed. Also the probability of GDOP<6 is good with only some areas at 90%. The integration with GLONASS guarantees the 100% globally, while integration with the geostationary and the geosynchronous satellites guarantees it on Europe (fig. 6).

The main metric representing the goodness of a satellite configuration for safety critical applications is the dH. The threshold for the NPA (Non Precision Approach) phase of flight is chosen to test the constellations iDOP (last column of table 3).

The GPS standalone in this case does not provide a satisfying performance, allowing a geometric RAIM availability about 70% at medium latitudes (fig. 7). The multi-constellation GPS+GLONASS improves the performance up to 96% of probability of geometric RAIM applicability (better than geostationary and geosynchronous integration). The super-constellation including all the considered constellations guarantees the 100% of geometric RAIM availability on Europe (fig. 8).

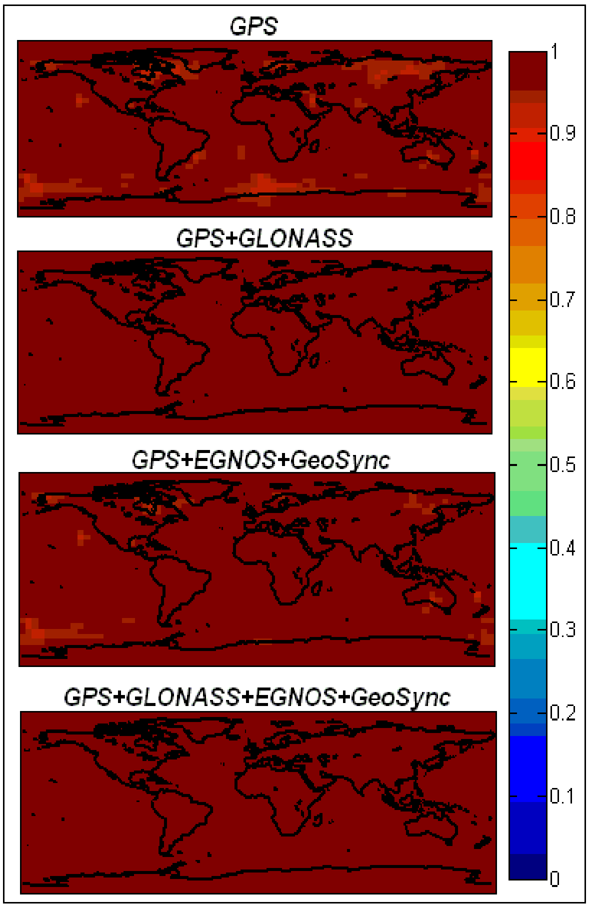

Fig.6–Probability of GDOP<6 (Mask Angle 15°)

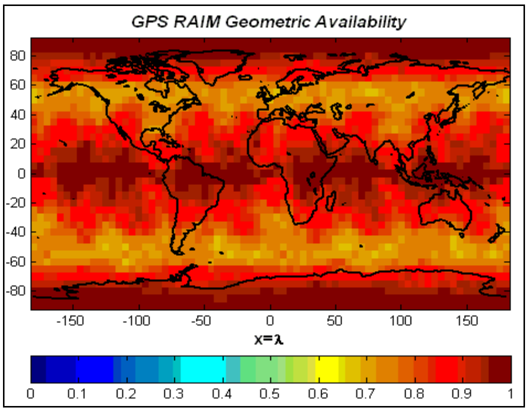

Fig.7–GPS Geometric RAIM Availability for NPA (Mask Angle 15°)

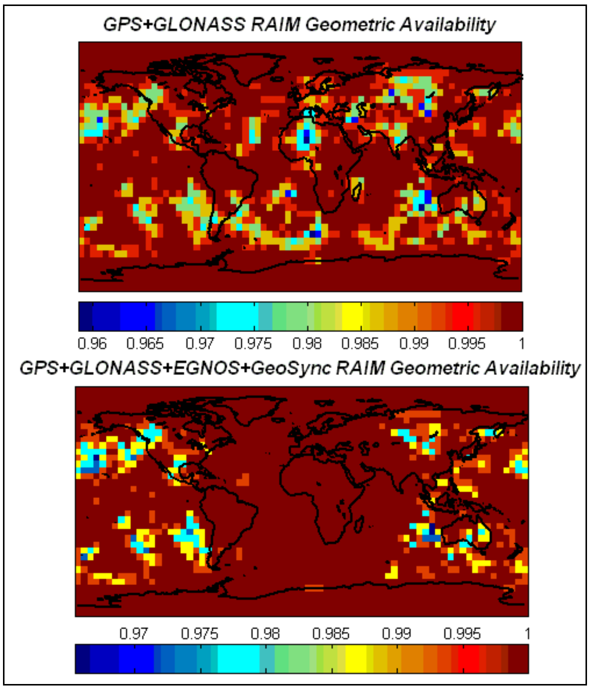

Fig.8–GPS+GLONASS and Super-Constellation Geometric RAIM Availability for NPA (Mask Angle 15°)

CONCLUSIONS

The simulation carried out on GPS, GLONASS, EGNOS GEO and Geosync (similar to QZSS) constellations demonstrates that GPS standalone is inadequate to provide acceptable performances in environments with coarse visibility (urban canyon) or in application with severe requirements (critical phases of flight).

The metrics used to assess the constellations performances are VSN (Visible Satellite Number), GDOP (Geometric Dilution Of Precision) and iDOP (integrity DOP).

In urban canyons the fundamental satellite navigation problem is the continuity of the positioning. In these limited visibility environments GPS, integrated with EGNOS GEO and GeoSync, provides a performance improvement more significant on Europe than GPS+GLONASS. The multi-constellation including all the considered space segments always guarantees the positioning.

In air navigation a fundamental requirement, that a navigation system has to provide, is the integrity.

The GPS+GLONASS integrated constellation works slightly better than GPS+EGNOS-GEO+Geosync one in terms of geometric RAIM availability. The multi-constellation including all the systems guarantees the 100% probability that the integrity is available to be computed in autonomous.

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