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The decade belongs to GNS$

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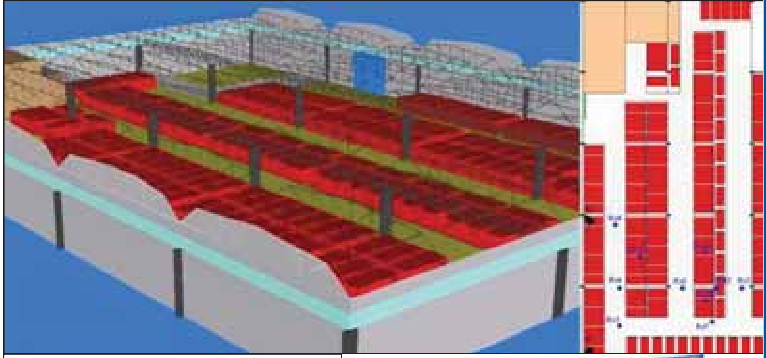

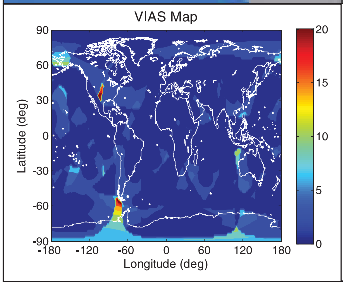

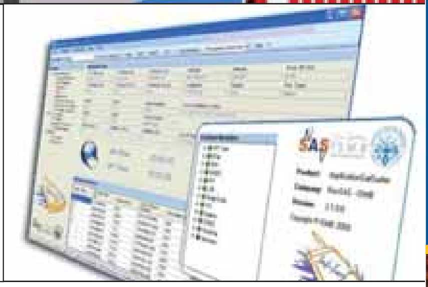

In this issue

Coordinates Volume 7, Issue 1, January 2011

Articles

Columns

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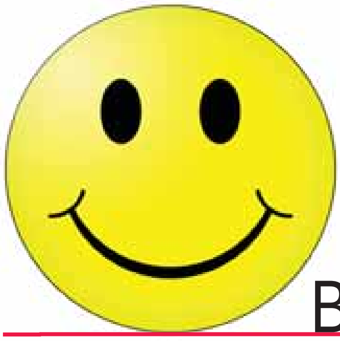


Being optimistic

GNSS and the GNSS market.

Indicates significant growth.

And immense potential,

In different and emerging application segments

In the world that is developed

And also, that is developing.

The technology is setting a stage.

To change our lives.

In the decade,

That, apparently, belongs to GNSS.

Assuming requisite ingredients

remain available.

May all of us have a happy year 2011.

Bal Krishna, Editor
bal@mycoordinates.org

The decade belongs to GNSS

The global market for GNSS will grow significantly over the next decade, reaching about 244 billion euros for the GNSS enabled market in 2020

GNSS market forecasting is of great interest to private and public GNSS stakeholders, for business and strategic planning and policymaking. According to the 2010 GNSS Market Monitoring report published by The European GNSS Agency (GSA), the global market for GNSS will grow significantly over the next decade, reaching some €244 billion for the enabled GNSS market in 2020. Delivery of GNSS devices will exceed one billion per year by 2020. Mobile location based services (LBS) and Road will be the market sectors with the highest revenue generation.

The report covers four market segments: Road, Agriculture, Aviation and LBS that represent the largest volume of users and/or public benefits.

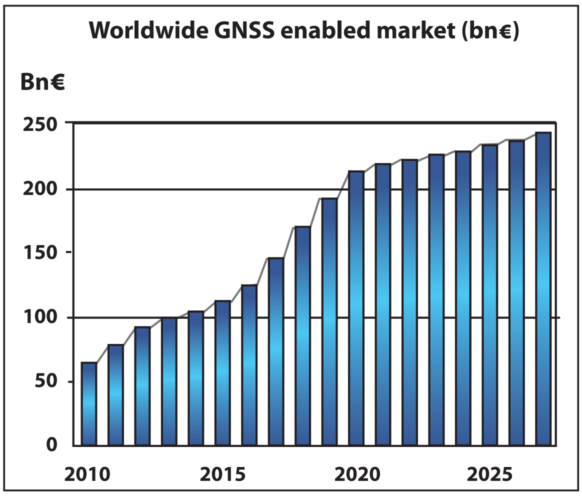
Road leads the way

The road transport sector is facing major challenges, such as the demand for increasing safety and for reduced congestion and pollution. These problems are particularly acute in highly populated zones, including big cities and suburban areas. GNSS represents a powerful tool for improving road transport. Not only does it help get drivers where they want to go more quickly and efficiently, but it also promises fairer road-pricing schemes, for example, to automatically charge drivers for the use of road infrastructure.

The report shows that the road transport sector is still the main GNSS market segment, accounting for a share of more than 50%.

The penetration of receivers in road vehicles, today at 30%, will exceed 80% over the next decade. The Japanese and North American market would reach almost 100% penetrations in next decade whereas penetration in European Union would be around 90%. However, after a period of fast growth, market saturation and competition in the form of 'smartphones', often equipped with free navigation capabilities, have resulted in a slowdown in the car-based navigation market. The estimated global device revenues in road sector by the end of 2020 are €87 bln.

Erosion of device prices has been high, driven by declining costs and strong competition. Vendors are using innovation as a differentiator resulting in 'converged' products with both communication and multimedia functionalities. Some Personal Navigation Device (PND) vendors are also tapping into new distribution channels, including car dealerships and smartphone application stores.



LBS- GNSS in your hands

Mobile location-based services (LBS) are taking off as progress is being made in different areas and innovation is fast in the very competitive mobile industry. More and more mobile phones now have built-in GNSS capabilities and the awareness of consumers and developers is increasing. The hardware, software and content needed for navigation has become cheaper while the user experience has improved tremendously.

All major mobile phone operating system vendors now provide application programming interfaces (API) with location functions. Some of the most popular applications on the various applications stores are based on navigation.

The integration of accurate hand-held positioning signal receivers, within mobile telephones, personal digital assistants (PDAs), mp3 players, portable computers, even digital cameras and video devices, brings GNSS services directly to individuals, making possible a fundamental transformation of the way we work and play. The penetration of GNSS in mobile phones is therefore expected to increase very quickly, from some 20% today to above 50% within the next five years.

Geographically, as of now penetration of GNSS-enabled phones is much higher in North America and Japan compared to the European Union. However, by 2020, the penetration of GNSS in mobile phones will reach 97% in North America and the European Union, almost 100% in Japan and 82% in China. Total annual core GNSS revenues in LBS are expected to grow between 2010 and 2020 from €12 bln to €96bn.

Aviation- high and robust

The aviation market requires the highest possible robustness and integrity. GNSS-based navigation has the potential to greatly complement the traditional systems to locate and track the planes. Moreover, SBAS systems improve the accuracy and integrity of GNSS via a network of ground stations that take measurements of GNSS and broadcast information messages to users via satellite.

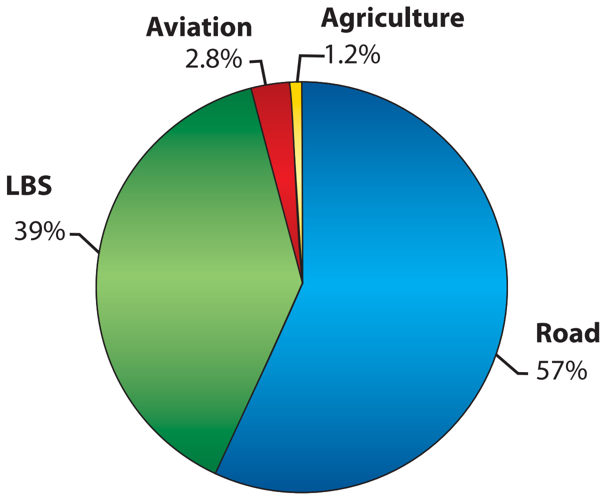
According to the report, the penetration of GNSS in aviation in the European Union will grow to 97% and in North America and the penetration of GNSS in aircraft will reach 78% by 2020. Total cumulated revenues from GNSS in the aviation sector for the period 2010-2020 will be €4.2 bln.

Agriculture – drive on tractors

The report also assesses the market potential in agriculture segment. It has been observed that in agriculture the low technology GNSS solutions are used for low-value crop cultivation, low accuracy operations and for agro-logistic applications. However, high technology GNSS solutions are also used for high-value crop cultivation or precision operations where levels of accuracy achieved are in the range of 2 to 10 cm.

The report says that the annual shipments of GNSS devices in the agriculture sector are expected to grow in all regions to reach 75,000 units by 2020 in the

Galileo market building effect by segment for 4 main segments, 14 bn € in 2010-2027



European Union, 110,000 units in North America and 350,000 units in the rest of the world. It is important to mention that the increased sales are mainly driven by the growth of the fleet and the higher penetration of GNSS in new tractors. Worldwide agriculture revenues will increase over the next decade driven by the increase in device sales from €198 mln in 2010 to €486 mln in 2020.

Galileo and EGNOS

The GSA says Galileo in the future and EGNOS today open up new and exciting prospects for economic growth, benefiting citizens, businesses and governments throughout the EU and beyond.

The road segment has the potential to reap the largest benefits from Galileo. These benefits derive mainly from a reduction in travel time (a result of better navigation), reduced fuel consumption, better congestion management and the development of intelligent services.

The development of LBS, such as GNSS-assisted medical monitoring and other emergency services, will lead to significant benefits due to the reduction of injuries. In agriculture, the use of more accurate positioning technologies will allow rationalisation and increased efficiency in the use of fertilisers and pesticides. In aviation, the integrity information will increase flight safety and reduce fuel consumption.

In 2009, the GSA developed and implemented a GNSS market monitoring and forecasting process which resulted in first issue of the report in question. This process was developed with the support of VVA and LECG, two consulting companies expert in market analysis and forecasting. The Market Monitoring Model takes as input the data from GSA market studies and reliable industry sources. Moreover, the model is based on a tailor-made selection of econometric techniques. An extensive set of variables are defined by key assumptions on the adoption of GNSS and Galileo. This process allows the simulation of different market scenarios. Additionally, a consistency check was performed for each segment by comparing the model's results with the most recent reports from independent GNSS market research companies.

The report may be downloaded free here: *http://www.gsa.europa.eu/go/download_the_gsa_gnss_market-report*

“Significant GNSS market potential and opportunities ahead”

say Boris Kennes and Justyna Redelkiewicz Musial from GSA, while responding to the GNSS Market Report

According to the report……, “Despite significant growth since 2006, significant untapped potential remains.” Would you like to elaborate on this?

According to the forecast based on available information sources and which involved several market experts, the global GNSS revenues are still expected to grow at a double digit CAGR in the 2010 - 2020 period. This growth will come from both new applications and expansion of current products and services. In terms of penetration, the biggest impact will come from LBS since GNSS is still only in a small portion of today’s mobile phones. Regarding new applications, there are countless examples such as ADAS (Advanced Driver Assistance Systems). As for GNSS R&D initiatives in the context of the EU 7FP program of the European Commission, being delegated to the GSA, there is a surge of GNSS technology projects proposing creative applications such as using combined radar and satellite navigation technologies to create maps of coastal areas. Advances in EGNOS and Galileo will accelerate these developments.

According to the report, the Road (56.4 %) and LBS (42.8 %) segments appear to dominate the core GNSS market (cumulative revenues 2010 -2020) whereas agriculture (0.6 %) and aviation (0.2%) would have negligible share in comparison. What could be the reasons?

The relative importance of each market segment is driven by the number of devices being shipped in each segment. LBS handset sales make up the majority, followed by navigation devices used in road transport. In aviation and agriculture unit shipments are much lower due to a smaller addressable market. Nevertheless, aviation and agriculture are important target markets for EGNOS, European satellite-based augmentation system.

The majority of GNSS market share is held by companies having their origin in the developed world (65% in EU, USA, Japan in year 2009 all together). How likely is this going to change, say in a scenario where China and India may emerge as one of the important markets for GNSS, in next few years?

We expect the share of emerging countries to increase as it is happening in other sectors of the economy. The revenues from civil applications of GNSS are dependent on the number of devices being shipped. India and China, being among the largest and most growing countries in the world, are expected to generate very important volume of GNSS devices.

The pace of change in emerging markets may be influenced by specific aspects. Actually, some GNSS applications may require structural changes in emerging countries that usually take time. In agriculture, for example, the addressable market can remain small, if farming is more human than technology-driven. In road, the usage of GNSS devices is correlated with the state of the road network in the country.

At the moment, it is projected that the Global enabled GNSS market (accounting full prices of GNSS mobile phones in LBS sector) will reach 244 bln in 2020. What could be the factors that may hinder the above projected growth?

Building the forecasting process, we made assumptions on a list of key factors like the GDP growth and the evolution of prices of devices which are influencing the GNSS market trend. The projected growth will also depend on other key environmental factors and of course also on GNSS relative advances vs. alternative technologies.

The report has focused on 4 segments - road, LBS, agriculture and aviation. Would you like to name a few more GNSS market segments that may have potential in this decade?

The GSA analyses market opportunities for GNSS in cooperation with industry experts, based on market research information and data available. So far we have focused on LBS and Road, the largest GNSS market segments, as well as agriculture and aviation which are today EGNOS target markets. In the future, we plan to analyse high precision (e.g. mapping, surveying), maritime and public services.

GSA, in the context of the EC Application Action Plan, cooperates and supports the European Commission. The GNSS Market Report will aim at continuing the analysis of GNSS market segments and emerging opportunities.

***Boris Kennes** is responsible for the coordination of the FP7 projects portfolio and market monitoring at GSA Market Development Department.*

***Justyna Redelkiewicz Musial** is responsible for the market monitoring and forecasting process at GSA Market Development Department.*

GNSS spoofing analysis by VIAS

A metric, Vulnerability Index Against Spoofing, is proposed and used to assess the effectiveness of a spoofer

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The GNSS (Global Navigation Satellite System) positioning is known to be vulnerable to interference due to the long distance of radio-signal travel and the resulting low signal power. In the presence of interferences or spoofing, the GNSS navigation performance is likely to be degraded and the navigation function may even be incapacitated. Throughout the years, many GNSS interference mitigation techniques have been developed. A challenge in GNSS interference mitigation is that a wide class of interferences needs to be considered. These interferences range from wide-band noises, narrow-band continuous-waves, frequency modulated interferences, pulsed-type interferences, to PRN (Pseudo Random Noise)-type interferences. Among these interferences, PRN-type interferences originating from pseudolites or re-radiators manifest themselves as GNSS-like signals, bearing the same frequency, format, and code modulation as legitimate GNSS signals. In some navigation applications, pseudolites can be used to enhance accuracy and availability. However, when these devices are used in an adverse manner, they may spoof GNSS receivers. In the celebrated report, it is stated that "A spoofer also can defeat nearly all anti-jamming equipment." Existing mitigation methods against spoofers rely on verification of navigation messages, successive cancellation, and antenna array techniques.

Given that the PRN-type interferers or spoofers are difficult to detect and resist, it is of interest to assess the worst-case position/time deviation when a GNSS receiver is subject to hazardously misleading information from such kind of devices. Essentially in a radio-based navigation system, a set of transmitters broadcast ranging signals to the receiver for the latter to determine its position and time. A spoofer is to augment the existing system with a ranging measurement in a similar form with those of the navigation system so that the receiver will also utilize the augmented signal for position fix. As the augmented signal is subject to misleading information, the resulting navigation accuracy is affected and the navigation function may be denied.

Two types of spoofing techniques can be envisioned. One is to supplement the existing positioning equations with extra range/pseudo-range measurements. The supplement-type spoofing technique employs additional equations together with the original ones for the determination of position and time. Another type of spoofing techniques, which is referred to as the replacement-type technique, is to in-validate some existing measurement equations and replace them with others that are purposely created to alter the resulting position and time solutions. In general, the replacement-type technique may lead to more detrimental effect in GNSS positioning. One way to implement such a spoofer is to broadcast a PRN-like signal that have the same PRN number as that associated with the measurement equation. When the intentional PRN-like signal over-power the satellite signal, the receiver is likely to be forced to track the intentional signal and utilize the message for positioning. Fig. 1 depicts the acquisition diagram of such a scenario in which both the signals of a GPS satellite and a pseudolite are acquired. The two signals bear the same PRN. Yet, the one from the pseudolite is stronger than that from the satellite. Consequently, the receiver can be misled.

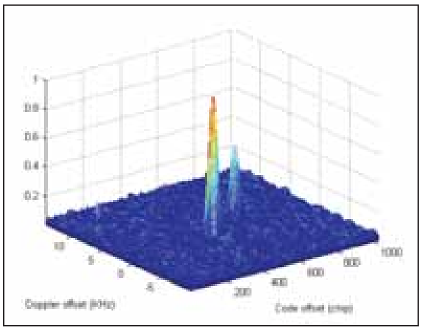

Fig 1. Two signals one (right) from GPS satellite and the other (left) from a pseudolite are acquired

As spoofers may inject erroneous pseudorange measurements to the navigation receiver with false message, it is important to assess the spoofing effect on the resulting PVT solution. In the following, an optimization method is employed to determine the worst-case misleading message of a spoofer to make a GNSS receiver astray. It is shown that the worst-case position error can be expressed as a product of the range residual (or RAIM level) and a geometry-related factor. The geometry-related factor which is termed as the vulnerability index against spoofing (VIAS) reveals the geometric relationship between the GNSS constellation and the broadcast position of the spoofer in affecting the resulting position deviation. The analysis result is expected to be beneficial to the design of spoofers and anti-jam receivers. For the former, the analysis reveals the design of the misleading information in creating the maximal position deviation. For the latter, the maximal position deviation can be assessed and a scheme for the verification of navigation messages is envisioned to protect the receiver from spoofing.

Position deviation under spoofing

Recall that the objective is to assess how the GNSS position solution in the spoofed (perturbed) situation deviates from the unperturbed one. The analysis makes the following assumptions:

- The spoofer is capable of adjusting its broadcast messages and timing offset.
- The spoofer has a prior knowledge on the approximate location of the receiver. Also, information of the GNSS constellation is known to the spoofer.
- The receiver is equipped with certain receiver autonomous integrity monitoring (RAIM) schemes so that a significant range domain residual is excluded.
- The broadcast messages and ranging measurement of the spoofer are used in the receiver for position determination.

In the nominal or unperturbed situation, the equation for the determination of position and time is given by

$$\boldsymbol{G}\boldsymbol{x} + b\boldsymbol{e} = \boldsymbol{z} \qquad (1)$$

where $\boldsymbol{x}$ is the position vector, b is the receiver clock bias, $\boldsymbol{z}$ is the pseudo-range measurement vector, $\boldsymbol{e}$ is the vector of all 1s, and G is the observation matrix. The spoofer is capable of supplementing or replacing the linear matrix equation (1) with an additional measurement equation

$$\boldsymbol{c}^T\boldsymbol{x} + b = d \qquad (2)$$

where $\boldsymbol{c}$ is a unit-length vector and d is a scalar, resulting in position deviations when (1) and (2) are solved simultaneously. In a sense, a spoofer attempts to adjust $\boldsymbol{c}$ and $\boldsymbol{d}$ to create the maximal position deviation which can be measured in terms of the (weighted) distance from the solution of (1) and the solution of the simultaneous equations (1) and (2).

Some assumptions are made for $\boldsymbol{c}$ and $\boldsymbol{d}$. As the vector $\boldsymbol{c}$ is related to the direction from the receiver to the spoofer, its length is constrained to be one. In addition, it is assumed that the receiver is equipped with some integrity monitoring capability so that a significant range residual error will be excluded in the position determination process. In other words, a threshold γ is prescribed to bound the residual error. Such a threshold can be regarded as the RAIM level. Finally, some constraints are further imposed on the vector c. For example, the vector $\boldsymbol{c}$ is required to satisfy $\boldsymbol{v}^T\boldsymbol{c} \geq \alpha$ for some given vector $\boldsymbol{v}$ and scalar α. Suppose that the vector $\boldsymbol{v}$ is in the zenith direction, this constraint is to reflect the practical elevation masking of the receiver in ruling out measurements from satellites at low elevation angles.

Let x_0 and x_1 be, respectively, the nominal and perturbed (spoofed) position solutions, the spoofer is to adjust c and d such that $\|\boldsymbol{x}_1 - \boldsymbol{x}_0\|_W = \sqrt{(\boldsymbol{x}_1 - \boldsymbol{x}_0)^T \boldsymbol{W} (\boldsymbol{x}_1 - \boldsymbol{x}_0)}$ where W is a positive definite weighting matrix is maximized. The analysis of the worst-case position deviation can be stated in terms of the following optimization problem

$$\max_{\boldsymbol{c},d} \|\boldsymbol{x}_1 - \boldsymbol{x}_0\|_W$$

subject to the aforementioned conditions. Let

$$\boldsymbol{Q} = \left(\boldsymbol{G}^T\boldsymbol{G} - \boldsymbol{G}^T\boldsymbol{e}(\boldsymbol{e}^T\boldsymbol{e})^{-1}\boldsymbol{e}^T\boldsymbol{G}\right)^{-1} \boldsymbol{W} \left(\boldsymbol{G}^T\boldsymbol{G} - \boldsymbol{G}^T\boldsymbol{e}(\boldsymbol{e}^T\boldsymbol{e})^{-1}\boldsymbol{e}^T\boldsymbol{G}\right)^{-1}$$

and

$$\boldsymbol{c}_0 = \boldsymbol{G}^T\boldsymbol{e}(\boldsymbol{e}^T\boldsymbol{e})^{-1}$$

It can be shown that through the optimization process, the resulting maximal position deviation is

$$\max \|\boldsymbol{x}_1 - \boldsymbol{x}_0\|_W = \gamma\sqrt{(\boldsymbol{c}^* - \boldsymbol{c}_0)^T \boldsymbol{Q} (\boldsymbol{c}^* - \boldsymbol{c}_0)}$$

where the optimal vector c^* is determined as

$$\boldsymbol{c}^* = -(\mu^*\boldsymbol{I} - \boldsymbol{Q})^{-1}(\boldsymbol{Q}\boldsymbol{c}_0 - \eta^*\boldsymbol{v})$$

where I is the identity matrix and μ^* and η^* are two parameters that depend on the whether the condition $\boldsymbol{v}^T\boldsymbol{c}^* = \alpha$ is met. If $\boldsymbol{v}^T\boldsymbol{c}^* = \alpha$, $\eta^* = 0$ and the variable is solved from

$$\boldsymbol{c}_0^T\boldsymbol{Q}(\mu^*\boldsymbol{I} - \boldsymbol{Q})^{-2}\boldsymbol{Q}\boldsymbol{c}_0 = 1$$

On the other hand, if the condition $\boldsymbol{v}^T\boldsymbol{c}^* = \alpha$ becomes active, the optimal μ^* and η^* are the solutions to the following simultaneous equations

$$(\boldsymbol{Q}\boldsymbol{c}_0 - \eta^*\boldsymbol{v})^T(\mu^*\boldsymbol{I} - \boldsymbol{Q})^{-2}(\boldsymbol{Q}\boldsymbol{c}_0 - \eta^*\boldsymbol{v}) = 1$$

and

$$\alpha + \boldsymbol{v}^T(\mu^*\boldsymbol{I} - \boldsymbol{Q})^{-1}(\boldsymbol{Q}\boldsymbol{c}_0 - \eta^*\boldsymbol{v}) = 0$$

In either case, the worst-case position deviation in the presence of spoofing can be evaluated.

VIAS as an indicator in assessing the spoofing effect

Define the vulnerability index against spoofing (VIAS) as

$$\text{VIAS} = \|\boldsymbol{c}^* - \boldsymbol{c}_0\|_Q = \sqrt{(\boldsymbol{c}^* - \boldsymbol{c}_0)^T \boldsymbol{Q} (\boldsymbol{c}^* - \boldsymbol{c}_0)}$$

A large VIAS implies a larger position deviation. Recall that the variable γ is the level set in the RAIM , the worst-case position deviation can then be rewritten as

(maximal position deviation) = (RAIM level) x (VIAS)

In some applications, the RAIM level is known to the spoofer and the above formula can be used to assess whether the spoofing can successfully lead to the desired position deviation once VIAS is computed. The VIAS is related to the geometry of the satellite/spoofer constellation. By substituting the optimal solution c^*, the VIAS can be expressed as

$$\mathrm{VIAS} = \sqrt{\mu^* + \mu^* \boldsymbol{c}_0^T \left(\mu^* \boldsymbol{Q}^{-1} - \boldsymbol{I}\right)^{-1} \boldsymbol{c}_0 - (\eta^*)^2 \boldsymbol{v}^T \left(\mu^* \boldsymbol{I} - \boldsymbol{Q}\right)^{-1} \boldsymbol{v}}$$

A well known formula in GNSS positioning is to characterize the RMS position estimation error in terms of the product of the standard deviation of the user equivalent range error and the dilution of precision (DOP). The DOP is related to the geometry of the GNSS constellation. Here, the maximal position error (in the deterministic sense) under spoofing is characterized in terms of the RAIM level and the VIAS. The RAIM level is allowable range residual error to meet the desired navigation task and the VIAS depicts the vulnerability of the geometry of the GNSS satellites in the constellation against the false reported position of a spoofer.

Note that although the position deviation analysis is to account for the worst-case position error in the presence of spoofing, the design of c^* can also be used in a homeland security type application. For example, it is possible to broadcast the spoofing information over a zone of security concern. In this case, any unauthorized GNSS receiver may then be subject to the spoofing and the consequential position deviation.

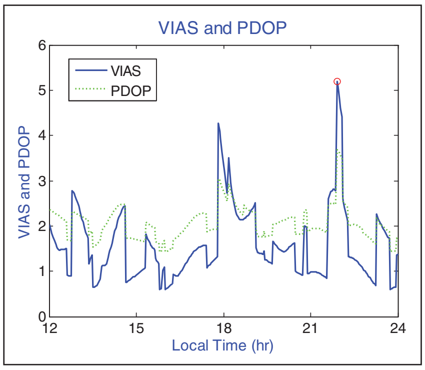

Fig 2 VIAS and PDOP

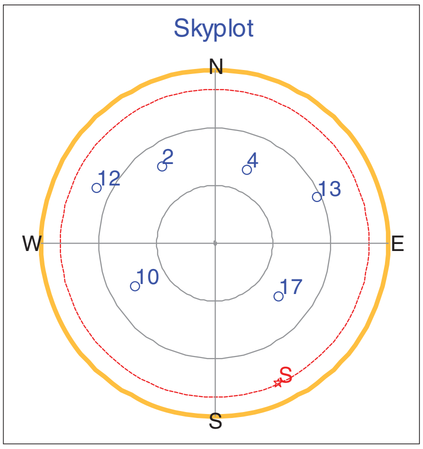

Fig 3 Sky plot of the GPS satellites and spoofer

Simulation result

In the simulation, the location of Tainan, Taiwan is selected as the area of interest. Based on GPS almanac, the observation matrix can be computed. At any particular time instant, the distribution of the GPS satellites can be obtained and, henceforth, the worst-case vector c^* that could potentially lead to a significant position error can be determined by solving the optimization problem. In the optimization problem, the elevation mask is set as 100 and the vector $\boldsymbol{v}$ is along the local zenith direction. Fig. 2 depicts the VIAS for a period of twelve hour. The VIAS varies as a function of the distribution of observable satellites. At those instants when the VIAS is at its peak, the spoofer is more effective in creating a large position deviation. The PDOP is also illustrated in the figure. Not surprisingly, the VIAS is somehow correlated with the PDOP which means that when the satellite geometry is relatively good, it is more difficult to divert the positioning solution.

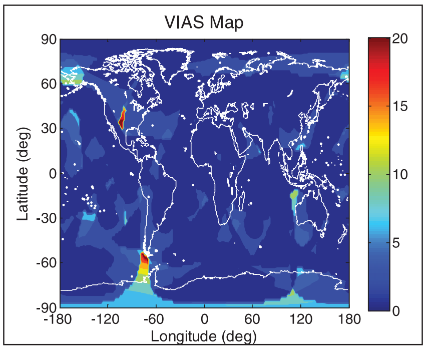

Fig 4 VIAS map (GPS constellation)

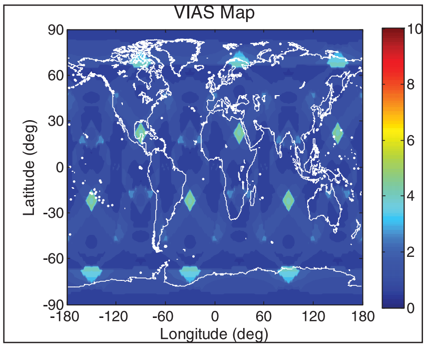

Fig 5 VIAS map (Galileo constellation)

Within this period, the peak VIAS is 5.15 (marked by red circle in the figure) at around 22 o'clock. Fig. 3 depicts the GPS satellites/spoofer sky plot at this time instant. In this figure, six satellites are observable which are marked by blue circles with PRNs 2, 4, 10, 12, 14, and 17, respectively. The spoofer broadcasts its false position vector c^* at the location as marked by the red pentagon symbol (S letter) in the figure. The spoofer reports its false position vector at a low elevation angle in an attempt to shift the balance of satellite distribution.

To see how the VIAS varies at different locations on the Earth, the VIAS map at the aforementioned time instant is presented in Fig 4. At some locations, the VIAS is very large (~20) which implies that the area is susceptible to spoofing. In the figure, the maximal VIAS occurs at longitude -78 and latitude -54.

Since the VIAS map is related to the GNSS constellation, the VIAS analysis approach is applied to the Galileo constellation to assess the susceptibility of the system against spoofing. In this analysis, the 30-satellite Galileo constellation is used. The result is depicted in Fig. 5. Since the Galileo constellation is a Walker constellation, the distribution is more uniform and the worst-case position deviation (assuming the same RAIM level) due to spoofing is not as severe as in the GPS case. In the Galileo case, the maximal VIAS is 5.16. However, the maximal value occurs at several different locations.

Summary

The GNSS position deviation effect under spoofing is analyzed. A metric, VIAS, is proposed and used to assess the effectiveness of a spoofer. It is shown that the worst-case position deviation in the presence of spoofing can be expressed as the product of the VIAS and a term relating to range residual or RAIM level. The use of VIAS is of benefit in assessing the use of GNSS navigation in resisting spoofing. The VIAS which depends on both time and location may also shed light on the design of a robust GNSS constellation.

The analysis also suggests a method to mitigate the spoofing effect in affecting navigation accuracy. To protect the GNSS receiver from the contamination of spoofing messages, the receiver can employ a scheme to rule out or de-weight signals originating from the worst-case direction c^*. In addition, as the worst-case reported position of a spoofer tends to be at low elevations, an elevation-dependent weighting in determining the navigation solution can somehow relax the limitation.

Acknowledgements

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Galileo update

Galileo Control Centre in Italy starts operation

With the first Galileo satellites - Europe's satellite navigation system, due to be launched next August, Fucino in central Italy formally entered into service. It will oversee the running of all the navigation services provided by Galileo. Fucino is one of two Galileo Control Centres – alongside Oberpfaffenhofen near Munich in Germany – to monitor and control the Galileo satellites and ground stations and provide all the information products needed to support the Galileo navigation services. The twin control centres sit at the heart of Galileo's far-flung network of satellites and ground stations distributed worldwide. They have split responsibilities although, with Galileo set to operate continuously, they are fully redundant, meaning that one can step in for the other in case of need. In the initial phase, while the Oberpfaffenhofen centre is in charge of controlling the satellites in space, Fucino holds responsibility for the overall navigation mission. *www.esa.int*

Prague to be Galileo's headquarters

European Union (EU) ministers in Brussels have voted Prague to be the headquarters of Galileo. In an interview with Czech television, Czech Prime Minister Petr Necas said, "This is very good news because this will bring the most advanced technologies to the Czech Republic." Several countries were vying to host the agency and in the final days Prague was competing against the Dutch town of Noordwijk to secure the agency's headquarters. *www.rferl.org*

Galileo and GMES remain the priorities for the EU

Ministers in charge of space activities representing the Member States of the European Space Agency and the European Union met in Brussels for the Seventh Space Council. The Space Council unanimously endorsed a resolution that called for the necessary actions to deliver a space strategy that would enable economic growth, respond to public policy objectives and develop the vocations of science and technology in Europe.

All hands on deck for European space push

High level representatives have weighed in on European space activities, including EGNOS and Galileo, at a recent conference hosted by the European Parliament. European Commission Vice President Antonio Tajani said that Galileo and GMES are "tackling societal and environmental challenges". With a revision of the Commission's budget for space activities expected by the end of 2010, his comments were pertinent. Galileo, he said, in combination with GMES, will be a key tool for agriculture in the future, particularly important in helping to insure food stocks in the developing world. EGNOS, the European satellite navigation augmentation system, is already making great strides in the precision agriculture market. *www.gsa.europa.eu*

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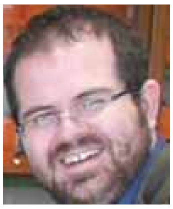
Mass market receiver for static positioning

GPS receivers are able to be employed in the survey field as low cost sensors or for applications where it is necessary to have a good ratio between cost and benefits



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Nowadays, there are several low cost GPS receivers able to provide both pseudorange and carrier phase measurements in the L1band, that allow to have good real-time performances in outdoor condition. The present paper describes a set of dedicated tests in order to evaluate the positioning accuracy in static conditions.

The quality of the pseudorange and the carrier phase measurements let hope for interesting results. The use of such kind of receiver could be extended to a large number of professional applications, like engineering fields: survey, georeferencing, monitoring, cadastral mapping and cadastral road. In this work, the receivers performance is verified considering a single frequency solution trying to fix the phase ambiguity, when possible. Different solutions are defined: code, float and fix solutions. In order to solve the phase ambiguities different methods are considered. Each test performed is statistically analyzed, highlighting the effects of different factors on precision and accuracy.

Goal of the research

The goal of this research is comparing two mass market low cost receivers in static positioning and perform a statistical analysis. The analyses are conducted considering post-processed solutions obtained with two commercial packages devoted to GNSS elaboration data.

Specific tests are carried out, changing the following parameters:

- length of baseline (<1, ≈35 and ≈80 km)
- length of data sessions (10, 30 and 60 minutes)

The low cost receivers considered in this research were selected among chipsets able to provide as output pseudorange and carrier phase measurements. In particular the two commercial chipsets used in the tests are referred to "RECEIVER 1" and "RECEIVER 2" for motives of propriety.

Chipsets under test are hosted in the SAT-SURF hardware platform (one per receiver). The SAT-SURFER software is used to obtain simultaneous and homogeneous data logs. This aspect is described and explained in the following part.

The post-processing of the static sessions is done using two commercial software: Leica Geomatic Office (in the following LGO) made by Leica Geosystems and GRAFNAV made by Waypoint (in the following part called GRAF). LGO is a commercial software devoted to estimate, via post-processing, GPS solutions by means of a single-base analysis, adopting the forward approach. This software is able to work with both pseudorange and carrier phase based solutions. GRAF is also a commercial software dedicated to define post processing solutions, adopting a differential and combined approach, but it is also able to realize a precise point positioning. GRAF achieves in providing a combined solution (forward and reverse), that means to improve the solution quality.

Tests

Each chipset, embedded in the SAT-SURF platform, is connected to a geodetic antenna NovAtel GPS-702 (IGS code NOV702_2.02). In order to simultaneously collect data with a geodetic receiver, a professional splitter is used. For each receiver several hours of data are collected; the resulting datasets are split in many short sessions: lasting 30, 10 and 5 minutes. The post-processing is performed considering different permanent master stations GPS (PMSG), in order to have baselines of different lengths.

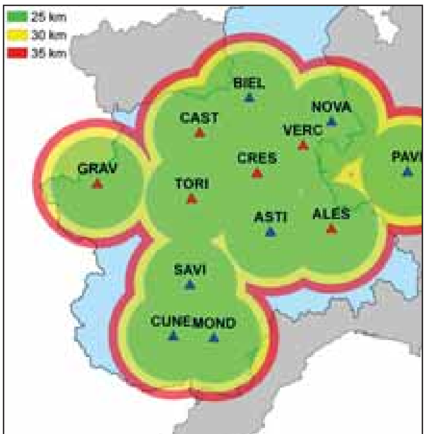

Fig. 1: GPS Test Network of Piedmont (Italy)

This experiment rely on the test GPS network in Piedmont (Italy) (Figure 1). It is a network composed by 15 permanent stations offering both real time services (by means of Virtual Reference Station, Multi-Reference Stations or Master Auxiliary real time products) and raw data.

Three different PMSGs are selected from the list of the available stations, with the intent of having different distances. The pseudonym and the distances of each of the permanent stations used are reported in table 1.

PMSG's name	Distance (from rover) [km]
SPGPS1	< 1
SPGPS2	~ 30
SPGPS3	~ 80

Table1: Name and Distances of Permanent station

Sat surf and sat surfer

SAT-SURF and SAT-SURFER form a suite enabling an easy handling of GNSS data from different chipsets. The two components are respectively a hardware box integrating NAV/COM capabilities and a software application able to control and communicate with the hardware. A graphical image of the hardware/software device is depicted in Figure 2.

The SAT-SURF hardware includes components of the shelf, i.e. mass market GPS and GSM/GPRS modules. The innovation of this platform resides in its flexibility, since it has been designed not for a GPS module made by a single manufacturer, but it is has been conceived with a multiple footprint (i.e. pinout of a GPS module) of different GPS receivers. SAT-SURFER is the software suite running on standard PC that gets and processes data from SAT-SURF (Figure 3.). SAT-SURFER also allows to get the data from a remote receiver via TCP/IP connection. In particular it is capable of getting and logging data from many receivers supporting their own proprietary protocols. In case a protocol is not foreseen a specific adapter can be written in order to expand tool capabilities. At time of writing, there is no Evaluation Kit (EVK) in the market allowing the same degree of freedom.

SAT-SURFER is able to get all the available receiver parameters, data and raw measurements, in addition to conventional positioning information. Such data are displayed in real time on a graphical user interface in order to easily monitor satellites, signals, receiver and user's position. The same data are also logged with the related GPS time stamp and stored in different file formats (ASCII text files, MATLAB®, Microsoft Office Excel®, binary, RINEX 2/3, KML and NMEA) for easy post-processing and analysis purposes.

Results

Each dataset is divided in several independent short datasets, in order to have a large number of solutions and to be able to realize the aforementioned statistical analyses. Each single dataset is elaborated as static, performing relative positioning with respect to the permanent stations reported in table 1. This is done adopting both software mentioned above.

Receiver 1

Considering the 10 minutes datasets, similar results are obtained, in terms of solution accuracy and number of fixes. This holds considering both packages and the different distances. The summary of float and fix solutions is shown in table 2.

PMSG's name	Distance [km]	% float	% fix
SPGPS 1	< 1	12	88
SPGPS 2	35	48	52
SPGPS 3	80	66	34

Table2: Percentage of float and fix solution

This first analysis highlights two interesting results. The first one is that a fix solution is possible when a short dataset (10 minutes) is used, even if a long baseline is considered (80km). The second aspect is concerning the float solution accuracy. In the following diagrams, the residual values obtained comparing the estimated solution and the reference solution are displayed, allowing to appreciate the accuracy factor.

Residual values have a millimetric level in the horizontal and vertical components when a short baseline is considered (a offset is present on the vertical component), as shown in Figure 4. and Figure 5. In this case, float solutions are completely comparable with fix solutions, in term of accuracy.Considering longer baselines (35 or 80 km), the results are reported in Figure 6. Similar results, in terms of accuracy, are obtained considering long baselines (35 and 80 km). For the 95% of observations, a sub-metrical accuracy level is achieved.

On the other hand, doing the same test with a shorter dataset, the results are completely different. Several 5 minutes datasets are considered and elaborated. The results are shown in Figure 7. Only one diagram is shown because a similar behaviour is observed considering different baselines. In this case, the final solution is obviously a code solution: a metrical accuracy is obtained. In conclusion, it is possible to reach a cm-level accuracy, but at least a 10 minutes dataset has to be collected.

Receiver 2

In this analysis, same conditions (dataset length, distance from the permanent station and procedure of post-processing) are adopted. First, the 30 minutes dataset is used to estimate the static positioning with the different PMSGs and both packages. Considering the shortest baseline (< 1 km), i.e. the best condition, the final solution is a float solution, however the accuracy

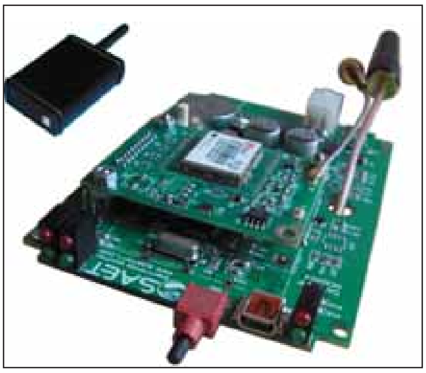

Fig. 2: A naked view of SAT-SURF (hardware)

Fig. 3: SAT-SURFER (software)

of the coordinates has a submetrical level. Several dataset of 10 minutes are considered, as done in the receiver 1 case, but in this case the results are completely different. The summary of float and fix solutions is reported in Table 3.

PMSG's name	Distance [km]	% float	% fix
SPGPS1	< 1	100	0
SPGPS2	35	100	0
SPGPS3	80	100	0

Table3: Percentage of float and fix solution

In this case, each solution is determined as float solution, with an average error in the baseline computation of 4-5 cm. The float solution determined with the "RECEIVER 2" have a completely different quality from the accuracy and precision point of view with respect to the

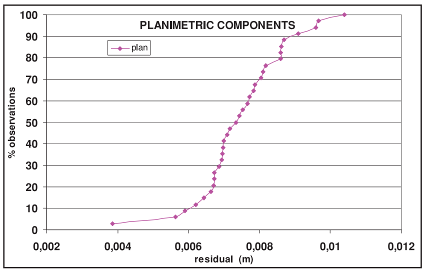

Fig. 4: Planimetric residual considering a short baseline (<1km)

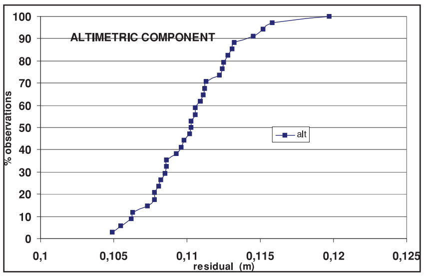

Fig. 5: Altimetric residual considering a short baseline (<1km)

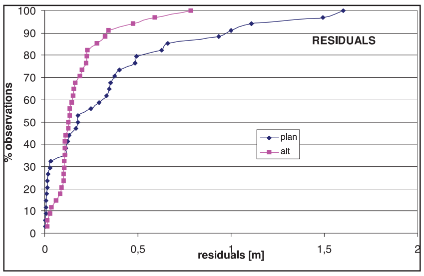

Fig. 6: Plano-altimetric residual considering a long baseline

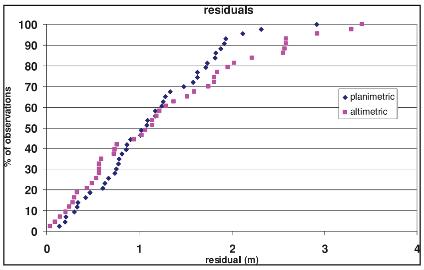

Fig. 7: Plano-altimetric residual considering 5 minutes of data

float solution that was determined above. The planimetric and altimetric components have metrical residuals (Figure 8 a), less than 3 meters in 95% of observations.

As above mentioned, the float solution is not synonymous of fair accuracy; considering the other permanent stations, the results lead to the same consideration. Similar results, in terms of accuracy, are obtained considering long baselines (35 and 80 km) too. The planimetric and altimetric residuals obtained with a different baseline length are shown in Figure 9.. In 50% of observations, a sub-metrical accuracy level is achieved. In this case the test with a longer dataset led to same accuracy of the middle dataset; this aspect has discouraged the Authors from doing tests with shorter lengths, being not necessary to verify the minimum length of datasets in order to obtain a fix solution.

In this test, the accuracy of the solution is similar to a pseudorange solution and it appears that the carrier phase is not even considered for a smoothed solution.

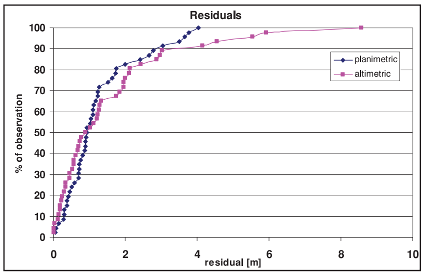

Fig 8: Plano-altimetric residual considering a short baseline (<1km)

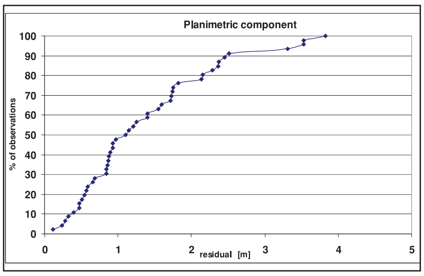

Fig 9: Planimetric residual considering a long baseline

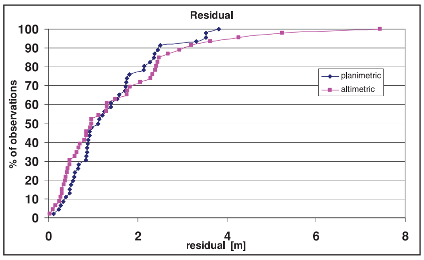

Fig 10: Planimetric residual considering 30 minutes of data

Conclusions

This research highlights and confirms some interesting aspects about mass market GPS receivers. First, there are differences between GPS receivers that have a important impact on accuracy and performance in static positioning. Carrier phase contribute is fundamental in static positioning in order to obtain the best PVT solution (estimated in real time), but this is true only if the carrier phase measurement quality is good enough.

In general, the tests carried out highlight that centimetric accuracy in static positioning is possible even if long baselines are considered, but only using fairly long datasets (10 minutes) recorded with good chipsets. The choice of algorithms employed for post-processing and phase ambiguity resolution is not fundamental in order to obtain a better accuracy in static positioning. Filtered and combined solutions lead to similar results. Results allow to say that some mass market GPS receivers are able to be employed in the survey field as low cost sensors or for applications where it is necessary to have a good ratio between cost and benefits.

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Listen

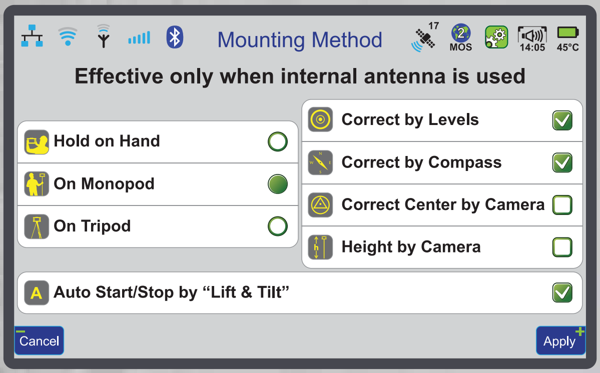
&

Talk

(Sometimes)

LIFT

First, put TRIUMPH-VS in "Lift & Tilt" mode.

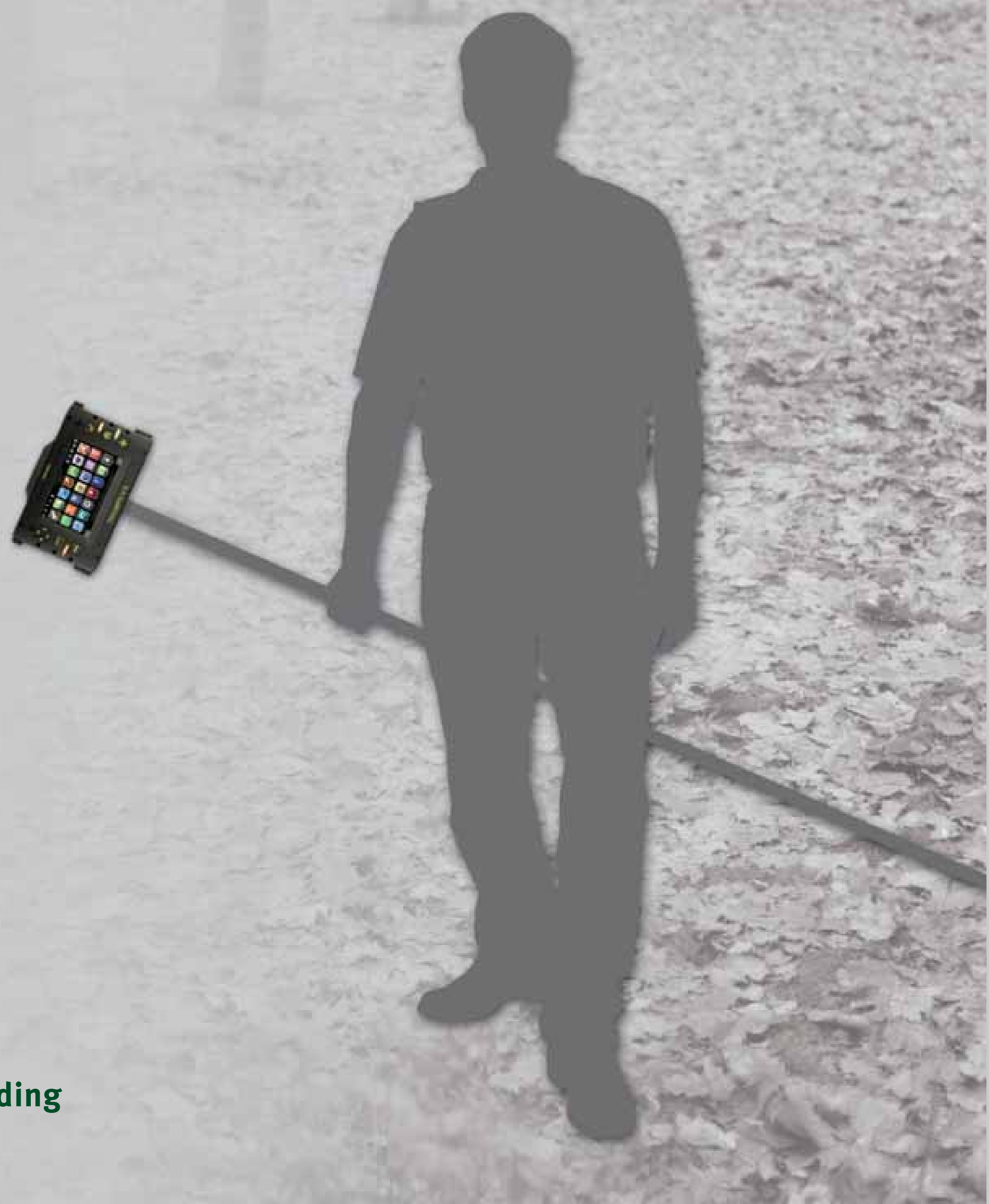


Then, go to the survey mark, lift TRIUMPH-VS to near vertical (better than 5 degrees). Survey will start automatically and sensors continuously compensate for leveling offsets. Audio tones keep you informed of the survey progress. You can use a headset if you are in noisy area. You can also take notes by talking to TRIUMPH-VS.

Patents pending

TILT

When you are happy with the survey result, just tilt the TRIUMPH-VS (more than 15°) and walk to the next point. TRIUMPH-VS will close files automatically.



Patents pending

LIFT

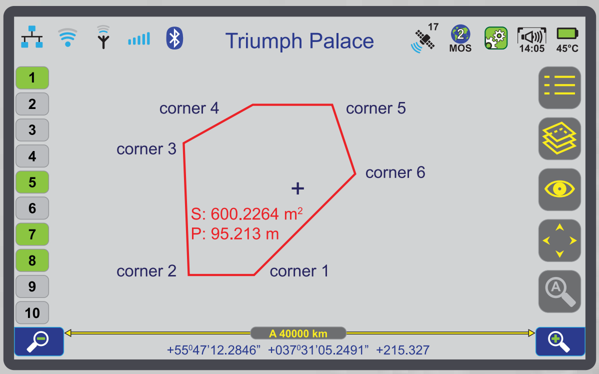
Then go to your next point. Lift it up and do again as you did in the previous survey point: Do Nothing! Just lift it up to near vertical.

Patents pending

Tilt

When you are happy again, tilt it again, and walk to the next point. Points and file names will auto-increment. You can over-write names if you like.

If you are doing a parcel survey (for example) after the last parcel point, push “Parcel End” and see the parcel map, parcel area and parcel perimeter instantly.



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Status of the GNSS transmitter-based approach for indoor positioning

An interesting feature of the transmitter approach is the possibility to locate transmitters underneath the receiver

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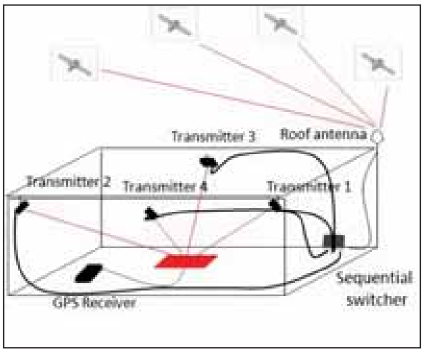

Fig.1: Principle of the GNSS transmitter-based approach

The transmitter-based approach is an indoor positioning method, based on the use of a local infrastructure, aiming to provide accuracies of 1 to 2 meters. The GNSS signals are received by an outdoor antenna located in a place with an unobstructed view of the satellites. Note that another possibility is to use a GNSS signal generator (generating one or 4 satellites) instead of the outdoor antenna. Furthermore, these signals are amplified and transmitted to a set of four antennas located indoors, the so-called "transmitters", which transmit the signals indoors (see Fig. 1).

The four transmitters all broadcast the same signal, but in a sequential way, thus creating a transmission cycle. At the exact instant of the transition from one transmitter to the next, a variation of the distance between the transmitter and the indoor receiver occurs. This variation induces an offset in the phase of the received signal. The principle is to convert this offset (also called phase jump) into a distance in order to obtain the difference of distances between the successive transmitters and the indoor receiver. After a complete cycle, one has four such differences available and may carry out the indoor 3D location computations.

In the current version, an electronic box (see Fig. 2) carries out the amplification, the cycling and the splitting of the signals towards the four transmitters. Please note that the cycling is synchronised to the GPS time through the use of a GPS receiver, included in the electronic box.

The complete transmitter system (shown in Fig.3), composed of the outdoor GPS receiving antenna (or the GNSS signal generator), 4 indoor transmitter antennas, transmission cables and the electronic box, is low-cost and easy to transport and deploy. Current work is focused on replacing the coaxial transmission cables with other techniques (mainly optical fibre), making the deployment of the system even easier.

A very interesting feature of the transmitter approach is the possibility to locate transmitters underneath the receiver. This distribution allows a very good vertical Dilution Of Precision to be provided, as good as the horizontal one. Another important aspect is the "time differential" approach implemented with the transmitters, which allows for an improved theoretical accuracy.

Regulatory framework for GNSS repeaters and pseudolites

Regulations tend to be provided for repeaters and pseudolites. The ECC Report 145 (Electronic Communications Committee) presents some conclusions concerning the use of repeaters [1]. It is recommended that GNSS repeaters be individually licensed, and the technical and operating conditions that should be taken into account for the licensing are specified. ETSI (European Technical System Institute) has also adopted a harmonised standard for GNSS repeaters [2]. In the frequency band under consideration (1559 – 1610 MHz), the protection to non-participating GNSS users has to be ensured by some gain/power limitations.

It should be noticed that there is a fundamental difference between the repeaters mentioned in the ECC Report 145 and the transmitters used in our approach. Indeed, the repeaters are simply receiving the GNSS signals and re-radiating them inside building, in order to provide a usable signal. Thus, they can cause harmful interference to the other GNSS users. The transmitters used in our approach can use any type of signal (e.g. the codes of the non-visible satellites or the PRN codes 33 to 36, reserved to the pseudolites), so interference is dramatically reduced.

Taking into account these considerations, it is more appropriate to apply the pseudolites regulations to our transmitter-based system.

For the moment there are no finalized regulations concerning the pseudolite use, but the restrictions being discussed seem to be less limiting than for the repeaters. Anyway, the only impact on the transmitter-based approach is in relation to the number of transmitters to be deployed in order to ensure full coverage of the environment considered. Simulations performed to this end [3] showed that it is possible to cover in 3D a 4 floors building of 35 x 16 x 13 meters with only four transmitters, if the transmitted power is -63 dBm. If we consider an emission power of -77 dBm (corresponding to the repeater regulations indicated in ECC Report 145), eight transmitters are needed to cover the same building.

Developments and validations

For many years the Navigation Group at Telecom SudParis (TSP) has been working on the transmitter-based approach. Various research and development projects have been oriented in three main directions:

- Multipath propagation simulations and electromagnetic modelling of indoor environments
- Developments of new receiver architectures
- Real implementations of the configurations obtained, and experiments

These themes, briefly discussed in this paragraph, allowed us to develop the transmitter-based approach until the final form it has today and to show the real potential of this method.

Multipath propagation simulations

In order to provide us with a better understanding of the multipath effects and some deployment rules for the transmitters, multipath propagation simulations were performed using Ergospace, a deterministic propagation simulation software. Various indoor environments have been modelled using VRML (Virtual Reality Modelling Language), and are presented in Fig.4:

- the A306 laboratory (6.5m x 6.8m x 3.3m), located on the third floor of TSP
- the main hall of TSP, a large space of 70 meters by 15 meters, with a ceiling height ranging from 4 to 7 meters
- the building A of TSP (4 floors including staircases and elevators, 34.3m x 16m x 13.3m)
- the car-park of Telecom Italia in Turin (34m x 60m) with a height ranging between 7 and 9 meters
- an almost empty metallic hall in the CNES premises, Toulouse (28.8m x 24.5m) with a ceiling height from 4.5 to 5.8 meters

The Ergospace simulations performed in these environments had various goals:

- *Determination of all multipath characteristics at a given receiving position (power, delay, phase, Doppler shift).* Simulations were performed in the A306 laboratory [4] and the main hall of TSP [5] in order to provide us with a better understanding of multipath propagation. Also, the a priori knowledge of multipath characteristics helped us to prepare measurement campaigns.
- *Construction of power maps in buildings.* Power maps were simulated in the building A of TSP in order to evaluate the coverage distance of the transmitters as a function of the emission power and the threshold level of the

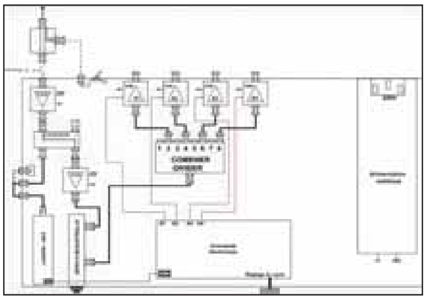

Fig.2: Principle of the electronic box

Fig.3: Current implementation of the transmitter system

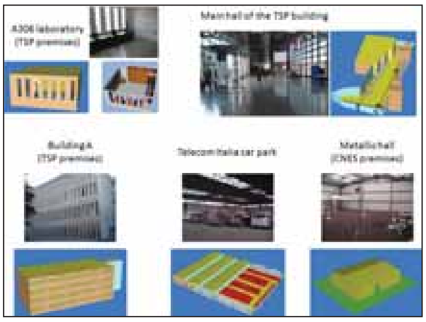

Fig.4: Various indoor environments studied and their VRML models

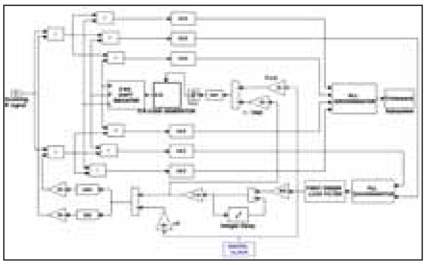

Fig.5: Implementation of the open code loop

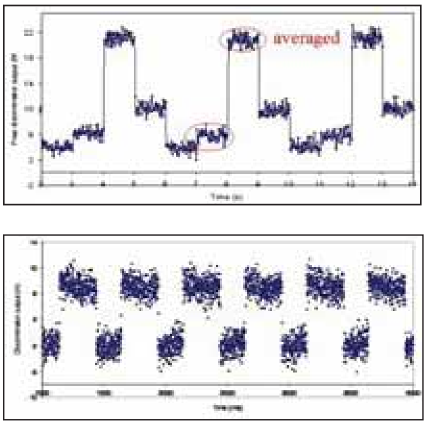

Fig.6: Open loop - discriminator output (top: simulation results bottom: real implementation results)

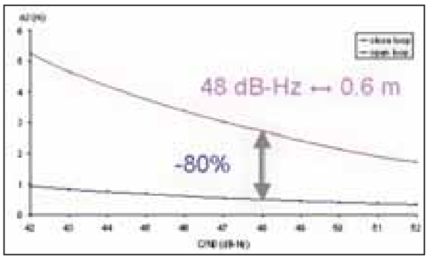

Fig.7: Open loop - Phase jump error as a function of C/N_0

Fig.8: Implementation of the SMICL code loop

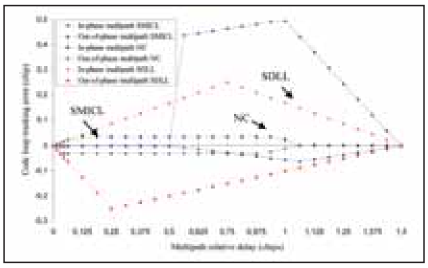

Fig.9: Maximum multipath noise-free tracking error comparison.

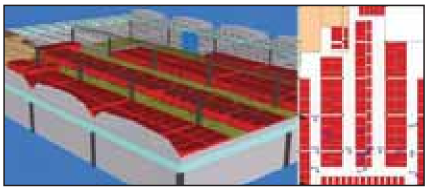

Fig.10: Measurement campaign in Telecom Italia car park, Turin

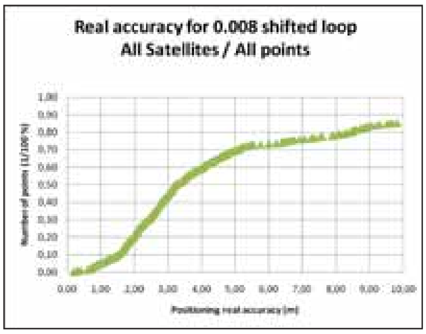

Fig.11: Real accuracy for all the fixes

Fig.12: Comparison of real accuracies obtained for the “non-filtered” and “filtered” approaches

receiver considered [3].

- *Determination of the number of transmitters in visibility.* In order to define the number of transmitters necessary to satisfy the on-going regulations and to provide us with optimal deployment rules for the transmitter antennas, simulations were performed in the building A [3]. To this goal, the number of transmitters in visibility was determined by simulation in each point of the environment.

- *Study the influence of the transmitter antenna pattern.* Two types of antennas were studied in [5], the Macon passive patch antennas, characterized by a maximum gain of approximately 3 dB and a half-power beamwidth of 120°, and the Tecom helical antennas, with a maximum gain of 13.2 dB and a higher directivity (32° half-power beamwidth).

- *Study the effect of limited displacements around a given location, in order to evaluate the small scale variations of the multipath.* Simulations have been performed in the main hall of TSP for various positions of the transmitters and of the receiving antenna in an area of approximately one λ around a considered location [6].

Developments of new receiver architectures

In order to improve the phase jump measurements, especially against thermal noise and multipath, we developed new code loop architectures adapted to the transmitter-based positioning system, but not restricted to it: the “open” loop and the “SMICL” loop.

The open tracking loop discriminator

	Patch antennas		Helical antennas	
	Standard loop	SMICL loop	Standard loop	SMICL loop
Max. error [m]	7.75	1	9.03	1.72
Mean error [m]	2.20	0.23	1.73	0.20

Table.1: Simulated error on the predicted distance

The open tracking loop discriminator, developed in order to reduce the thermal noise is presented in Fig.5. The principle is very simple: the carrier loop is preserved while the code loop is open [7].

Thermal noise is modelled by a zero mean Gaussian process. Thereafter, an effective way to minimize the effect of the noise is to average the output of the code loop discriminator over each transmission time when the code loop is open (see results in Fig. 6). The phase jump is obtained by computing the difference between two successive averages. Fig.7 shows the standard deviation error of the phase jump measurement for the standard and the open loops.

One can observe that the noise effect is dramatically reduced by the open loop (with a noise reduction factor greater than 5). For a carrier to noise ratio of 48 dB-Hz, the error is 0.6 m. The proposed open loop was implemented on a NordNav R30 software receiver, leading to full agreement with the theory.

The SMICL tracking loop discriminator

The SMICL loop [8] - Short Multipath Insensitive Code Loop - was developed in order to mitigate the short multipath (with delays of less than 0.5 code chip), which are the problematic ones indoors. This discriminator traditionally uses the three complex correlators. It is conceived such that it outputs zero when the prompt replica code becomes synchronized to the direct signal, whatever the multipath. The circuit of the new code loop is presented in Fig.8. It has the advantage of being simple and does not require any specific hardware or post-processing of observables.

Tracking error envelopes assuming a noise-free environment are given in Fig.9 for the SMICL loop, the standard DLL (SDLL) and the narrow correlator (NC). Based on these results, SMICL shows a dramatic improvement over the other techniques for multipath having relative delays less than 146.5 meters.

Ergospace simulations performed in the main hall of TSP [9] confirmed the advantages of the SMICL loop:

Real implementations and deployments

Various measurements campaigns were performed. We present here only the results obtained during the last measurement campaign, performed in the car-park of Telecom Italia, in Turin, using an IFEN NavX 10 MHz receiver [10]. The signal was generated by a Spirent GSS6560. The results presented below are based on raw positioning data obtained in the 15 receiving positions studied in the environment (Rx1 to Rx15 in Fig.10).

It has been found that an implementation of the SMICL loop with a shift of 0.008 chips of the horizontal axis (in order to help the loop find the zero crossing point) gives the best results. Fig.11 shows the real positioning accuracy achieved for all the fixes, with no processing of the data, except for removing the fixes located outside the polygon defined by the locations of the transmitter antennas (increased by 1 meter in order to consider a slight error margin). Outside this polygon, the DOP values increase very rapidly and classical positioning computation is of very poor quality.

Some processing approaches were proposed in order to improve the accuracy of the results: it has been found that the results are greatly improved by filtering the fixes with an accuracy standard deviation greater than 3 meters (compared to the mean accuracy obtained by averaging all the accuracies of each individual fix) as well as the ones with fewer than 4 satellites capable of computing a fix. Taking into account these techniques, the accuracy decreases to 2 to 3 meters, results in good agreement with the theoretical expectations for a 10 MHz receiver. Increasing the bandwidth is bound to further decrease the accuracy value, down to 1 to 2 meters (theoretical result). Fig. 12 shows the comparison of real accuracies obtained for the "non-filtered" and "filtered" approaches.

Conclusions & future work

This paper has presented the latest updates of the GNSS transmitter-based approach, highlighting its advantages in terms of performances, cost and simplicity of the infrastructure. It should be noticed that this system, easy to deploy and transport, can be used for instance in a non-equipped building or even outdoors. Such a deployment could be envisaged in a situation of emergency, for fire brigades or police operations, in a building where no indoor positioning equipment is available.

Various research and development projects, validated by measurements or simulations, lead us to a finalized system, proving interesting features and performances for indoor localization. Furthermore, we have reached the step where having a finalised proof-of-concept of the transmitter based approach and implementing the SMICL tracking loop on a suitable receiver requires the technical skills of a GNSS manufacturer.

We are focusing now on a new approach based on the use of "repealites", which is intended to provide sub-metric indoor positioning [11]. The repealites represent a compromise between GNSS repeaters and pseudolites, taking advantage of both techniques in order to allow carrier phase measurements and yet avoid the synchronisation limitations of pseudolites. The first results are very promising and experimental validation is already planned.

Acknowledgements

We want to thank CNES and Telecom Italia for partial funding. An additional thank you to Jenoptec, the French distributor of Spirent, for the loan of a GSS6560.

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FOIF GNSS Receiver A20

More flexible system with following features:

- Fully rugged design with simple "One Button" base setup
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- GPRS data link reconnecting automatically as base station
- Switch from internal radio to GPRS, or both can work together
- RTK Network rover:VRS, FKP, MAC
- Modular design - simple to extend or replace the Bluetooth, radio or GPRS and SD/SIM card module
- Field software: FOIF Survey_GPS or FOIF FieldGenius

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Indian plan for satellite-based navigation systems for civil aviation

A brief outline of the three segments – User Segment, Space Segment and Ground Segment necessary for implementation of an SBAS system over the Indian airspace

Suresh V Kibe
Brahmprakash Professor
ISRO HQ, Bangalore, India

International Civil Aviation Organisation (ICAO) Member States have endorsed Global Satellite Navigation System (GNSS) as a primary future system for aviation. GNSS provides world-wide coverage for seamless aircraft navigation. Satellite transmission along with ground enhancement will enable the users to perform on-board position determination for enroute, terminal, non-precision and precision approaches.

The Airports Authority of India (AAI) have decided to implement an indigenous satellite based regional GPS augmentation system also known as Space based Augmentation System (SBAS) as part of the Satellite based Communication, Navigation, Surveillance (CNS) / Air Traffic Management (ATM) plan for civil aviation. Towards this end, a National Plan for Satellite based Navigation System has been prepared. The Indian SBAS called GAGAN (GPS And Geo Augmented Navigation) System will be implemented jointly by the Indian Space Research Organisation (ISRO) and AAI.

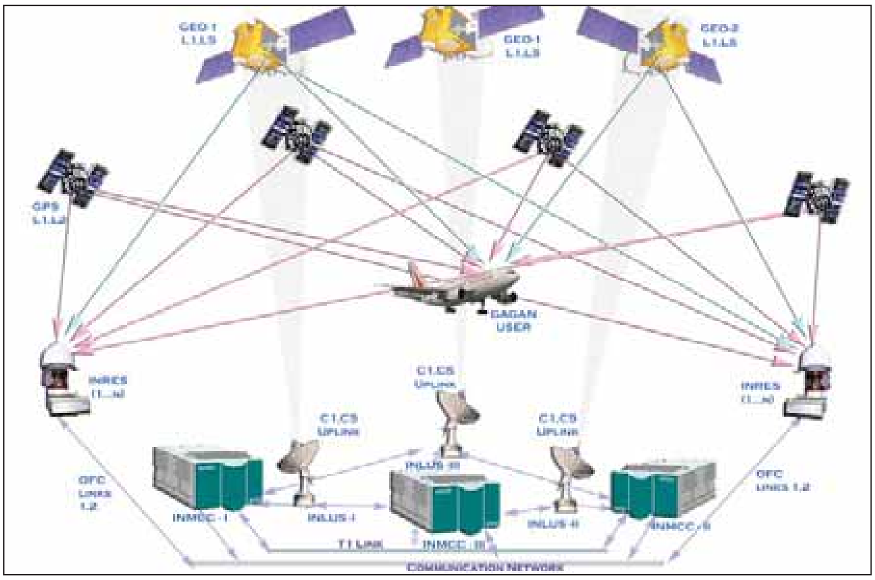

Figure 1: SBAS CONCEPT

The present ATM systems in the Asia Pacific region suffer short comings which include

(a) Lack of surveillance facilities over large areas of region which require relief from congestion.

(b) Air route availability constraints by point source navigation aids resulting in choke points.

(c) Dissimilar ATS procedures and separation standards causing Flight Information Region (FIR) boundary changes to flight profiles.

(d) Un-coordinated provision of present CNS system resulting in duplication of resources and services.

(e) Lack of appropriate parallel ATS route structures to relieve route congestion and,

(f) Poor quality communication facilities and language difficulties.

The first SBAS system was developed by the United States using two INMARSAT-III GEO Navigation payloads (POR & AOR-W) and is called the Wide Area Augmentation System (WAAS). European Geostationary Navigation Overlay System (EGNOS) is being implemented by the European Space Agency since 1996 and was declared operational in the year 2010 for APV 1.0. EGNOS uses the other two INMARSAT-III Navigation payloads (IOR & AOR-E) and ARTES payload. The MTSAT Satellite Augmentation System (MSAS) is being implemented by the Civil Aviation Bureau, Ministry of Land, Infrastructure and Transport, Government of Japan and is expected to be uprgraded soon. All evolving SBASs must comply with Standards And Recommended Practices (SARPs) specified by ICAO to provide seamless navigation to civilian aircraft across the globe. The SBAS implementation over the Indian Air-space will bridge the gap between the evolving EGNOS and MSAS systems.

A mechanism is required where the Indian system becomes a part of an evolving Global Navigation Satellite System (GNSS) consisting of the core constellations and the SBASs.

The Need and types of Augmentation

At present, there are two core constellations which provide satellite-based navigation in the world – The Global Positioning System (GPS) of the United States with 31 satellites and GLObal NAvigation Satellite System (GLONASS) of the Russian Federation with 23 satellites. These core constellations provide position accuracies of the order of 30 meters, Circular Error Probable (CEP) anywhere on the surface of the earth through inexpensive hand-held receivers. Both these systems operate in the L-band. The accuracy available through these core constellations is not adequate for precision approach and landing requirements in civil aviation. A third core constellation of the European Galileo system is under development and is expected to be operationalised 2014-15 with 24 satellites.The core constellations can be augmented in three ways - Aircraft Based Augmentation System (ABAS) augments and/or integrates the information obtained from GNSS elements with information available on-board the aircraft in order to ensure operation according to the values specified in ICAO SARPs.

Ground Based Augmentation System (GBAS) consists of augmenting the core constellation through differential GPS elements implemented close to an airport and transmitting the corrections to the aircraft through a suitable data link. Space Based Augmentation System (SBAS) refers to having GEO satellite based GPS compatible navigation payloads transmitting in L1 and L5 bands over a region supported by the necessary ground segment and uplink earth stations. The User Differential Range Errors (UDREs), improved iono-tropo grid models and improved GPS ephemeris are transmitted to the GEO based navigation payload which retransmits these to modified GPS user receiver also called GNSS Receivers.

Civil aviation requirements for satellite-based navigation are specified in the ICAO SARPs which specifies the Signal-in-Space Performance requirements for civil aviation in terms of accuracy, integrity, time to alert, continuity and availability as follows:

Accuracy (Horizontal)	: 16 m
Accuracy (Vertical)	: 6 m
Integrity	: $1\text{-}2\times10^{-7}$
Time to Alert	: 6 secs.
Continuity	: $1\text{-}8\times10^{-6}$
Availability	: 0.99 – 0.99999

Integrity

Integrity is a measure of trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the users (alerts).

Time to Alert

The maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the equipment enunciates the alert.

Continuity

Continuity of a system is the capability of the system to perform its function without unscheduled interruptions during the intended operation.

Availability

Availability of GNSS is characterized by the portion of time the system is to be used for navigation during which reliable navigation information is presented to the crew, auto pilot or other system managing the flight of the aircraft.

SBAS Concept

The Wide Area Differential GPS (WADGPS) also known as SBAS concept is illustrated in Figure 1. There are five major elements in any SBAS:

- Reference stations (RS)
- Mission Control Centre (MCC)
- Land Uplink Station (LUS)
- The GEO Payload
- User GNSS receivers

Indian Reference Stations (INRESs)

INRESs collect measurement data and broadcast messages from all the GPS and GEO satellites in view and forward it to the Indian Mission Control Centre (INMCC). As per the present planning, 15 INRESs have been located at the following places in India:

New Delhi, Bangalore, Ahmedabad, Kolkatta, Jammu, Port Blair, Guwahati, Trivandrum, Bhubaneswar, Porbunder, Nagpur, Jaisalmer, Dibrugarh, Goa & Patna

Indian Mission Control Centre (INMCC)

The GAGAN INMCC is located at Bangalore and at present consists of

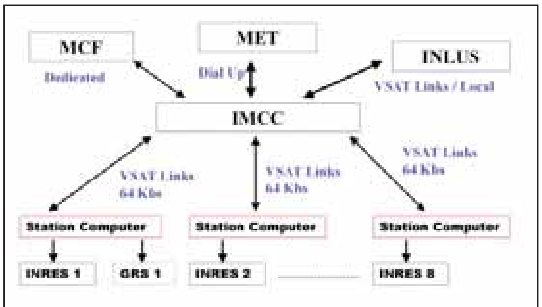

Fig .2 COMMUNICATION INTERFACES

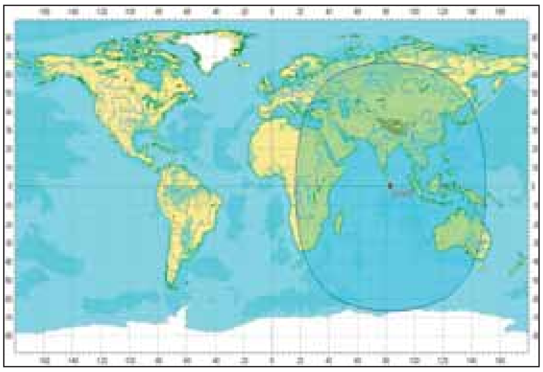

Figure 3: SBAS FOOTPRINT

two INMCCs and two INLUSs. The chief functions of the INMCC are

- Network Management (communication and computer)
- Integrity monitoring
- Iono-Tropo Model delay estimation
- Wide area corrections – separation of errors
- Orbit determination
- Command generation

The INMCCs consist of a main frame computers and a host of secondary computers connected to a network. The communication interfaces of the INMCC with other ground segment elements is shown in Fig. 2.

Indian Navigation Land Uplink Station (INLUS)

INLUS communicates with the Indian Nav. Payload . This earth station receives messages (which contain UDREs and Iono-tropo grid models) from the INRESs through the INMCC, format these messages and transmit them to the GEO satellite navigation payload for broadcast to users. The INLUS also provides GEO Ranging information and corrections to the GEO satellite clocks. Message formats and timing are as per the ICAO SARPs.

Navigation Payload

It is proposed to fly a Navigation payload compatible with GPS L1 frequency (and possibly GPS L5 frequency) on an Indian satellite to be positioned in the Indian Ocean Region between the orbital arc 48 deg. E to 100 deg.E longitude. The salient characteristics of the payload are:

L1D/LEIRP	=	33.5dBW
Receive G/T	=	-5 dB/oK
Power Amplifier	=	40 Watts
Coverage	=	Global
Mass	=	40 Kg
Power	=	300 W

The functions of the Nav. Payload are:

- to relay Geostationary overlay signal compatible with GPS L1 frequency for use by modified GPS receivers.
- to provide a CxC path for ranging by INRESs with an uplink from the INLUS.

The EIRP can be adjusted within a suitable range through on-board attenuator settings. ISRO is looking into incorporating the GPS second civil frequency L2C or the third civil frequency L5.

Several antenna configu-rations for L-band are under study. Some of the candidate antennae are

- Prime focus reflector
- Helix array
- Patch array

The first payload is expected to be made operational in the year 2011 followed by two more payloads in 2012 and 2013. The L1/L5 frequency payload footprint is shown in Fig. 3.

The GAGAN System

Three phases have been identified for reaching the Full Operational Capability (FOC) for GAGAN.

Phase 1:Technology Demonstration System (TDS)
Phase 2:Initial Experimental Phase (IEP)
Phase 3:Final Operational Phase (FOP)

Technology Demonstration System (TDS)

The objective of the Technology Demonstration System (TDS) is to develop indigenous capability in SBAS implementation.

Under the TDS, AAI and the Indian Space Research Organisation (ISRO) has established the necessary ground and space segment for demonstration of SBAS functioning, A successful demonstration was carried out in August 2011. The achieved position accuracies were shown to be better than 7.6 meters on a test AAI aircraft.

Final Operational Phase (FOP)

During the Final Operational Phase (FOP), additional INRESs will be established as required and the communication systems will be established with all redundancies. INMCC and NLES will be augmented with operational hardware and adequate redundancy. INRESs will be augmented with operational hardware. The Preliminary System Acceptance Test (PSAT) was recently conducted and has reconfirmed that the achievable accuracies are much better than the 7.6 meter achieved during TDS. It is aimed to achieve APV 1.5 level of position accuracy by 2012.

Impact of Ionospheric tropospheric multi-path, ephemeris and clock related errors

The ionosphere delays the L-band signals and introduces unpredictable range errors. The ionospheric conditions in the low latitude regions are more difficult to measure and model.

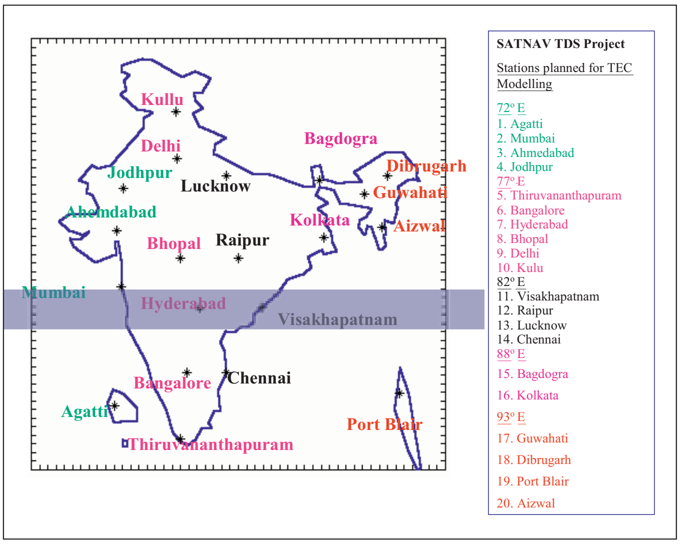

Fig. 4 TEC Stations

The ephemeris error in the data downlinked through the GPS L1 frequency to ordinary GPS receivers is in the vicinity of about 7 – 8 meters. This translates to an equivalent position error. In SBAS a better ephemeris model (through UDREs) is transmitted to the Geo-Stationary satellite which enables a modified GPS receiver to improve the ionospheric and ephemeris related errors resulting in better position accuracies. Clock errors are offset through accurate measurements made at INRESs since this is a one dimensional error.

Ephemeris

Ephemeris stands for the 6 orbital elements of a Keplerian orbit in which the navigation satellites operate. With global ground networks, GPS is achieving sub centimeter level accuracies in orbit determination. In the GAGAN SBAS, the GPS satellite orbits and augmentation payload orbits are redetermined and transmitted to the augmentation payloads.

Iono-Tropo Modelling

(i) Iono-Tropo modelling and scintillation studies in the L-band will be carried out over the entire Indian Airspace as an integral part in the TDS Phase 1.

The following strategy has been adopted to develop suitable grid based ionospheric model over the Indian region.

(a) About 20 total electron content (TEC) receivers shall be located at the Centre of the 25 deg x 5 deg. ionospheric grid points (IGP) over the Indian region as shown in Fig.4.

(b) The data from these receivers shall be logged into a personal computer and the logged data shall be delivered to all academic and scientific institutions on which contracts are placed to carryout the necessary studies.

(c) All receivers and PCs shall have an uninterruptible power supply (UPS) and necessary housing at all the 20 sites. The instrumentation at all the sites shall be identical. A suitable Ionospheric Scinti-llation and TEC monitor receiver equipment which is best suited for these studies shall be deployed at all the sites.

Data from the TEC stations is being collected for almost 8 years now. This is a vast amount of data for better iono tropo models. ISRO and AAI engineers have developed accurate iono tropo models over the Indian Flight Information Region (FIR).

International Coordination

Advanced Publication Information (API) for the Indian Nav. Payloads has been filed with the International Telecommunications Union (ITU). During the FOP, international assistance would be sought for the definition of inter-operability for the Indian SBAS, system validation, testing and certification.

Asia Pacific Region

For civil aviation traffic estimates, the world is divided into 6 regional systems – Africa India Ocean (AFI) region; Asia/Pacific region, Caribbean/ South American (CAR/SAM) region, European (EUR) region; North Atlantic (NAT) region; Middle East (MID) region & North America (NAM) region. The Asia-Pacific region is further divided into five regions – Central, Northeast, South, Southeast and South Pacific.

Indian SBAS GAGAN in the Asia-Pacific region

The GAGAN satellite based augmentation system is expected to be implemented by the Airports Aurhority of India (AAI) and Indian Space Research Organisation (ISRO) by 2012 and made operational after certification by 2014. The Ministry of Civil Aviation and the Airports Authority of India are therefore in a position to cater to increased flow of traffic and demand for ATS over India.

The US National Airspace has implemented the Wide Area Augmentation System (WAAS) over the US National Air Space (NAS) with a position accuracy of Approach Vertical-2 (APV-2) by 2008. The Federal Aviation Administration of US is working towards achieving CAT-I accuracies in the near future. The European Commission (EC) has implemented the European Geostationary Overlay System (EGNOS) over the European Civil Aviation Council (ECAC) region shown below with a accuracy of APV-1.0 by 2010-11. The Japanese MTSAT Augmentation System (MSAS) is expected to reach higher levels of accuracy in the near future. It is aimed to achieve APV-1.5 level accuracy for GAGAN which is primarily for civil aviation over the Indian Airspace. These four augmentation systems provide around the globe seamless GNSS based navigation system for civilian aircrafts.

The lead taken by the Ministry of Civil Aviation in implementing GAGAN and possible certification by 2014 will propel India as only the fourth country with the most modern airspace in the world.

The Indian Flight Information Region (FIR) falls between Europe and South Asia, Europe and South East Asia and Europe and the South Pacific. A modern Airspace is important from the point of view of providing ATS to civil aviation aircraft used to flying in regions where such modern CNS/ATM facilities are available.

Vietnam, India ink deal to deploy GIS

A delegation from the Vietnamese Ministry of Science and Technology has signed deal with India for the deployment of GIS technologies. The GIS deal aims to spot areas vulnerable to droughts in service of agriculture and forestry and extracting substances from starfish in service of the pharmaceutical industry. The two countries will also cooperate in designing and developing aerial technology for 3G and 4G wireless services as well as photoelectric cell technology for turning solar power into electricity. *www.english.vovnews.vn*

Monitoring woodpeckers

An Idaho University team is developing techniques to monitor woodpeckers from space. The team has been using a satellite-borne laser to try to predict in which part of a State forest the birds might be living. Initial work has shown maps built from such data can locate areas favoured by North American pileated woodpeckers. The scientists want to know where these birds are because they are seen as good indicators of overall bird diversity in a forest. *www.bbc.co.uk*

USD 140 million order for substations deploying GIS

ABB has won an order for USD 140 million from the Qatar General Electricity and Water Corporation for building 4 new transmission substations and upgrade 4 existing substations to help meet the growing residential and commercial demand for electricity in the region. *www. albawaba.com*

Brunei now in 3D

Brunei Survey Department, has successfully completed one of the National Development Plan (2007-2012) projects, 3D Digital Terrain Model. The LiDAR instruments used close range-infrared from the electromagnetic (1064nm) spectrum of light to collect data. Data measured on the ground was at every one-meter distance apart in areas including forest areas. This endeavor has made Brunei among the best mapped countries in the world. *www. brudirect.com*

Singapore rolls out marine biodiversity survey

Singapore's National Parks Board (NParks), in partnership with experts from tertiary institutions, non-governmental organisations and individual enthusiasts, has started comprehensive survey of marine ecosystem. Sites with coastal and marine habitats around Singapore have been identified and mapped, using satellite images. *www.channelnewsasia.com*

Bentley to join consortium for clean energy

Bentley Systems has been selected to join the consortium, led by the US Department of Energy's Lawrence Berkeley National Laboratory, for a US-China Clean Energy Research Center (CERC) focused on building energy efficiency. It will develop technologies for low-energy residential and commercial buildings, as well as work on the commercialization of those technologies and research how human behavior affects building energy use. *www.bentley.com*

France's national mapping agency selects Intermap

Intermap Technologies announced a USD 804,518 contract with the national mapping agency of France, the Institut Géographique National (IGN). It will supply IGN with DTMs, generated as part of its completed NEXTMap Europe countrywide mapping programme. *www.intermap.com*

OS working on Olympic site map accuracy

To facilitate navigation at Olympic site for spectators, security staff and emergency services and athletes, Ordnance Survey (OS) is improving the accuracy of Olympic site map close to 2.6cm, according to Dave Wareham of OS. The OS measures the complexity of its job in what it calls "units of change" and has a target of recording 96% of all changes made in the country within six months. *www.bbc.co.uk*

Shoreline maps of Gujarat released

Jairam Ramesh, Minister of State for Environment and Forests, Government of India launched the shoreline study maps of Gujarat and Puducherry. These maps are approved by the respective state governments. The shoreline study was assigned to Institute for Ocean Management (IOM), Chennai. *PIB*

Indian archaeologists discover prehistoric maps

An archaeological team, led by T M Keshava from Bangalore, discovered maps that date back to 1500-2000 BC. The place is located around Tungabhadra River near Hampi in Karnataka, India. Unlike modern maps that rely on technology, ancient men banked on their eyesight and memory. The map was depicted on the roof of caves of Chikramapura village. What was once thought to be a megalithic burial site with just paintings of animals and humans; is proof of the prehistoric man's cartographic skill. *www.bangaloremirror.com*

GPS tracking of criminals

Nepal Police is likely to use GPS frequently to track suspected criminals, though no existing law warrants its use. The police have recently made an experimental use of GPS. *www.myrepublica.com*

PCI Geomatics to deliver GXL satellite processing system

PCI Geomatics has been awarded a contract, worth USD 700,000, to deliver GeoImaging Accelerator (GXL) Satellite processing system to a key customer in the Asia Pacific region. *www.pcigeomatics.com*

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Taiwanese technology reads damaged GPS chips

Taiwan has developed a technology to retrieve information from damaged GPS chips, used in helicopters and other vehicles. Japan's Transportation Safety Board (JTSB) sought Taiwan's Aviation Safety Council's (ASC) help to determine the cause of a helicopter crash, according to Kuan Wen-lin, Director, ASC laboratory. *www.focustaiwan.tw*

Glonass-K launch postponed

Launch of Russia's new-generation Glonass-K satellite has been postponed until 2011, according to the Russian Defense Ministry. The satellite was about to blast off from the Plesetsk Space Center on December 28. *RIA Novosti*

Big blow to Glonass

Three satellites – part of GLONASS system crashed into the Pacific Ocean on December 5, according to Russian Federal Space Agency (Roscosmos) officials. The satellites were the last of the batch of 24 Glonass satellites. They went off course and crashed about 1,500 kilometres northwest of Honolulu, Hawaii, after blasting off from the Russian-leased Baikonur launch pad in Kazakhstan. *www.themoscowtimes.com*

Two satellites join GLONASS

The number of functioning satellites in Russia's GLONASS navigation system has been increased to 22. One of the two newly introduced spacecraft rejoined the constellation following technical maintenance and another one was withdrawn from reserve. According to Russia's Roscosmos space agency, both satellites have reached their planned orbit and started operation.

7th Compass/BeiDou-2 Launch

China is preparing for launch of another satellite in its Compass/BeiDou-2 GNSS system in the "coming days," according to an unnamed spokesperson at the Xichang Satellite Launch Center in southwest China's Sichuan Province.

High precision data in epidemiology

British scientists have developed a software package that can record and playback location data with high-precision. The software then uses SIR modeling (S for susceptible, I for infectious and R for recovered) and the epidemiological technique of contact tracing in order to predict the spread of a disease through a network of people. According to William John Knottenbelt of Imperial College London and his team which includes members from Edinburgh Napier University, the precision of location tracking technology has improved greatly over the last few decades. They demonstrated that by tracking the locations of individuals in a closed environment, it is possible to record the nature and frequency of interactions between them. *www.sciencedaily.com*

Tracking of infra development

Bihar State Road Development Corporation (BSRDC), under the Road Construction Department (RCD), will deploy GPS-enabled Android phones to help executive engineers keep an eye on road construction from district headquarters, while the RCD Secretary will do so from the Patna office. The initiative will be launched on January 2011. Earlier, Bihar State Bridge Construction Corporation had successfully used GPS-enabled phones to help mobile inspectors track engineers on duty. The latest mobile operation system supports all Google applications in 3G mobile phones. *www.indianexpress.com*

Wi-Fi will outstrip other technologies

Wi-Fi location will outstrip all other location technologies including GPS, cellular and MEMs, with shipments reaching more than 1 billion by 2015, according to ABI Research's new study, Alternative Positioning Technologies. *www.ABIResearch.com*

NSDI 10: National Geospatial Ecosystem – The Road Ahead

"Restriction of information is disempowering and it does not serve the national interest" said Kapil Sibal, Hon'ble Minister for HRD, Telecom, Science & Technology and Earth Science, Government of India, while inaugurating the NSDI 10 conference held in New Delhi during Dec 23 – 24, 2010. Mr Sibal called for a policy on information dissemination and need for all government departments to come together and provide data. He also emphasized on the need of a regulatory framework in this sector that is more facilitative and not restrictive. The theme of the conference was "National Geospatial Ecosystem – The Road Ahead".

Dr Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India mentioned the need of multilingual and online information system as that would best serve the need of the country. He also highlighted the need of maps at larger scale at local level.

KK Singh, Chairman Rolta India Ltd expressed that geospatial technology has significantly transformed the world and governments all across the globe are becoming aware of the potential of this technology. He also mentioned about the enormous growth potential with several mega projects.

Subba Rao, Surveyor General of India highlighted the importance of industry participation. He said that Survey of India will focus on evolving strong IT component incorporating GIS.

A geo portal of the Prakasam district in Andhra Pradesh was released during the inaugural session. Also, a Report of Task Force on 1:10,000 Mapping was also presented.

Prof V S Ramamurthy, Director National Institute of Advanced Studies elaborated in his vision address how the geospatial segment is yet to reach the common man. The common man of this country is yet to feel the need and benefits of the technology. The technology as of now still appears to be on threshold only.

NEWS REMOTE SENSING

ISRO to set up ground station to relay RS data

The Indian Space Research Organisation (ISRO) will have an exclusive ground station in Hyderabad to collect and relay remote sensing data from multiple low-earth orbit satellites to customers all over the world. This is expected to come in handy to manage the huge amount of remote sensing data relayed to ground stations as India plans to launch at least 30 such earth observation satellites within the next 10 years, according to V Jayaraman, Director, National Remote Sensing Centre (NRSC). *DNA India*

DG's satellite imagery for Chinese navigation companies

DigitalGlobe (DG) is supplying the digital imagery for enhanced navigation solutions from three Chinese companies: China Mobile, YF International and Hazens. The opportunity to supply imagery to China Mobile is a significant development for the company and for next generation mobile navigation solutions in the region, according to Rafay Khan, DigitalGlobe's Senior VP of Commercial Sales. *www.digitalglobe.com*

China, Pakistan ink deal on RS

China and Pakistan signed a number of trade deals worth about USD 10 billion, said Wen Jiabao, Chinese Premier. One of them is on remote sensing satellite between the Pakistan Space and Upper Atmosphere Research Commission and the China Great Wall Industry Corporation. *http://news.xinhuanet.com*

GeoEye to buy SPADAC for USD 46million

GeoEye has agreed to purchase 100% of the stock of SPADAC Inc., a geospatial predictive analytics company, for USD 46 million in cash and stock. SPADAC provides geospatial predictive analytic solutions to over 40 customers in defence, intelligence and homeland security. *www.geoeye.com*

NEWS LBS

GLONASS-enabled phone by March 2011

Russian company Sistema is likely to launch GLONASS-enabled phones in March, 2011. The company plans to make 500,000 GLONASS chips by then. In addition, the country is likely to introduce duties of around 25% by 2012 on the import of mobile phones without the GLONASS navigation system, as part of efforts to encourage worldwide adoption of the technology. *Reuters*

China experiencing boom in LBS market

China's location-based services (LBS) market boasted three to four million active users by the end of the third quarter this year, according to a report from Beijing-based market research firm Analysys International. According to industry analysts, China is already home of more than 30 LBS companies, many of which are growing at a decent clip.

Mobile GIS for renewable energy

TC Technology has announced a strategic partnership with The Hightower Energy Company to bring to market mobile information management solutions for the renewable energy sector. The first offering planned for 2011 is the Renewable Energy Extension to GO! Sync Mobile GIS. *www.tctechnology.com*

HP Navigator on Spime's Hybrid LBS platform

Powered by Spime's Hybrid LBS platform and Navteq content, HP is the first multi-device original equipment manufacturer (OEM) to launch a competitive location based solution under its own brand – HP Navigator – for Netbook, Notebook and Tablets PCs. *www.spime.com www.wsj.com*

NEWS INDUSTRY

FARO laser scanner aid in heritage restoration

Art Graphique & Patrimoine (AGP), a specialist in dimensional drawings of buildings and works of art, has used FARO laser scanner to create virtual mock-ups, which in turn have been used to create spectacular enhanced reality applications. This new technology, which enables the superimposition of virtual elements onto reality, opens up new options for presenting sites and works of art. *www.faroasia.com*

FOIF launches new products, moves to a new location

Suzhou FOIF Co.,Ltd, recent organized its new products release conference and domestic distributor conference in XiaoShan Hangzhou, China. The new 500m reflector less total station from FOIF was released during the same. It is the reflectorless total station made in China. The company has also moved to the new location in Suzhou. *www.foif.com.cn*

CHC X90 obtains ISO 17123-8:2007 certification

CHC has announced its X90 GPS receiver has obtained ISO 17123-8:2007 certification. The validation process was performed by the Center for Applied Geomatics (CAG), Military University of Technology, Warsaw, Poland. This ISO certification specifies the field procedures for determining and evaluating the precision of GNSS field measurement systems in real-time kinematic (GNSS RTK). *www.chcnav.com*

New processing point clouds software from Leica

Leica Geosystems announced distribution of RealityLINx Model 5.4 - powered by Leica point cloud Engine (pcE) technology. It speeds and simplifies the processing of as-built laser scans into intelligent models that feed into popular 3D plant design software and into INOVx plant asset management software. *www.leica-geosystems.com*

Leica survey equipment chosen by Swisscom AG

Swiss telecoms company, Swisscom AG, opted for a Leica Viva GNSS when it was searching for survey equipment to pinpoint positions in its fixed-line network telecommunications infrastructure.

Trimble buys Indian vehicle tracking, telematics company

Trimble acquired Tata AutoComp Mobility Telematics Limited (TMT), a wholly-owned company of Tata AutoComp Systems Limited, Pune, India. TMT is a provider of telematics solutions and Mobile Resource Management (MRM) services in India and serves large customers such as Bharat Petroleum Corp. Ltd. as well as Tata Group companies such as Tata Motors. *www.trimble.com*

Trimble releases eCognition version 8.64

Trimble eCognition 8.64 is an advanced image analysis software suite available for geospatial applications. It sets a new standard for native 64-bit object based image analysis—an important technical milestone for the processing of very large image datasets.

NAVTEQ's Global R&D Center now in Mumbai

NAVTEQ set up its R&D Global Development Center (GDC) in Mumbai, India. The centre will employ 150 R&D team members and significantly enhance NAVTEQ's R&D capabilities which support map and content design and development activities for the global NAVTEQ product portfolio. *www.navteq.com*

Astrium bags billion dollar military contract

DGA, the French arms procurement agency, awarded EUR 795 million (approx. USD 1billion) contract to Astrium for two satellites for the optical space component (CSO) that will replace the current HELIOS 2 military observation satellites. *www.astrium.eads.net*

TopSURV 8 sets new industry standards

Topcon Positioning Systems' TopSURV 8 is the newest version of its field controller software series. It has enhancements to increase productivity on a variety of survey jobs. It provides significant new functionality on cross-section staking on roads, import and export of road strings, graphical user interface, multiple new map views, file import/export, in-field status reporting and much more. *www.topcon.com*

NavCom announces new capabilities

NavCom Technology has announced new capabilities for the SF-3050 multi-frequency GNSS receiver and Sapphire GNSS OEM board. The SF-3050 and Sapphire now support single frequency, multi-constellation operation, heading and moving base station RTK operation that enables coordinated vehicle applications. *www.navcom.com*

CORE Geospatial and DAT/EM announcement for DVP Users

CORE Geospatial and DAT/EM Systems International have teamed together to offer DVP users a unique opportunity to revitalize their 3D photogrammetric workstations. CORE Geospatial has arranged an exceptional offer with DAT/EM Systems International to exchange each DVP workstation license for a DAT/EM Systems SUMMIT EVOLUTION 3D digital photogrammetric workstation license. *www.datem.com*

RapidEye German mosaic available

RapidEye first large-scale mosaic is now available for purchase. Consisting of 750 tiles covering 25 x 25 km² areas, this contiguous satellite image covers Germany in its entirety. *www.rapideye.de.*

Software GPS receiver for mass-market applications

GMV will be releasing SRX-10, a software GPS receiver for mass-market applications, soon. It is a fully hosted software GPS receiver; developed with mass-market applications in mind, especially urban scenarios. As a fully hosted solution, a general purpose CPU can host all receiver functions, even signal acquisition and tracking, with the only requirement of adding on a low cost RF front-end. *www.gmv.es*

SuperGeo develop dynamic bus info & transit system for Taichung City

SuperGeo Technologies develop a system for Taichung City Hall. Through the system, the public can query estimated arrival time of the bus when waiting for the bus and know how to transfer to required destinations effortlessly. The GIS application would eventually bring convenience and save time for the citizens and tourists. *www.supergeotek.com*

u-blox launches LISA 3G modules optimized for M2M

u-blox has extended its LISA wireless module family by including the LISA-H100 (for the USA) and LISA-H110 (for Europe and Asia). The UMTS/HSDPA data modems are dedicated to telematics and telemetry applications that typically require only data and not the full 3G bandwidth. www.u-blox.com

NovAtel wins 2010 Alberta Export Award

NovAtel Inc. was presented with the 2010 Alberta Export Award for Advancing Technologies, an award which recognizes companies who "have effectively harnessed the powers of intellectual property and value-added know-how". The award was given out as part of the Alberta Export Awards competition, which celebrates excellence and innovative approaches to exporting by Alberta-based companies. *www.novatel.com*

Weihai Emergency Operations Centre Wins 2010 China City Information Application Award

Weihai Municipal Government has won the 2010 China City Information Application Award for its implementation of the Intergraph® Incident Management solution for its emergency operations centre (EOC) at the recent 2010 China Development Forum on City Informatisation held in Suzhou, China. *www.intergraph.com*

GPS Mobile Mapping used to resolve Kosovo private property claims

Forty-nine Ashtech® MobileMapper® 6 GPS/GIS field terminals have been purchased by two key Republic of Kosovo agencies, the Kosovo Property Agency (KPA) and the Kosovo Cadastre Agency (KCA), to map property boundaries to help resolve private property claims. *www.ashtech.com*

Chronos leading a Consortium to develop a service to detect jamming

Chronos Technology is leading a Consortium, SENTINEL, which is a 24 month project to research and develop a service to establish the extent to which GNSS – in particular GPS and Galileo and/or eLoran Positioning, Navigation and Timing (PNT) signals can be trusted by users on a 24x7 basis. SENTINEL will research the detection, quantification and location of interference to GNSS and eLoran signals at point of use by deploying IDM (Interference, Detection & Mitigation) probes in the vicinity of critical infrastructure. Detecting and discriminating between accidental, deliberate and natural phenomena including multipath, jamming or space weather to protect safety, mission-critical, security or revenue generating services, enabled by PNT signals A SENTINEL network of IDM probes will provide real-time alerts to discriminate natural events and enable the location of deliberate jamming and to provide timely detection and mitigation by the appropriate agencies. *www.chronos.co.uk*

MARK YOUR CALENDAR

February 2011

ILMF 2011
7 - 9 February
New Orleans LO, USA
www.lidarmap.org/ILMF.aspx

16 International Geodatic Week
13 - 19 February 2011
Obergurgl, Austria
http://geodaesie.uibk.ac.at/obergurgl.html

March 2011

The Munich Satellite Navigation Summit 2011
1-3 March
Munich, Germany
www.munich-satellite-navigation-summit.org

GEOFORM+2011
15-18 March
Moscow, EcoCenter Sokolniki
www.geoexpo.ru/defaulteng.stm

April 2011

6th National GIS Symposium in Saudi Arabia
24 – 26 April
Khobar, Saudi Arabia
www.saudigis.org

Geo-Siberia 2011
27-29 April
Novosibirsk, Russia
www.geosiberia.sibfair.ru/eng/

May 2011

ASPRS 2011
1-5 May
Milwaukee, Wisconsin, USA
www.asprs.org/milwaukee2011/

Gi4DM 2011
3-8 May
Istanbul, Turkey
www.gi4dm.org

FIG Working Week 2011
18-22 May
Marrakech, Morocco
www.fig.net

June 2011

Trans Nav 2011
15-17 June
Gydnia, Poland
www.transnav.am.gdynia.pl

South East Asian Survey Congress
22 - 24 June
Kuala Lumpur, Malaysia
www.seasc2011.org

2011 Cambridge Conference
26 June - 1 July
Winchester, England UK
www.cambridgeconference.com

July 2011

Survey Summit
7 - 11 July
San Diego, California
www.thesurveysummit.com/

ESRI International User Conference
11 - 15 July
San Diego, USA
www.esri.com

August 2011

XXV Brazilian Cartographic Congress
21-24 August
Curitiba - State of Paraná, Brazilia
sbc.tatiana@gmail.com

7th International Symposium on Digital Earth
23-25, August
Perth, Australia
www.isde7.net

XXII ISPRS Congress
25 August - 1 September 2011
Melbourne, Australia
http://www.isprs2012.org

September 2011

ION GNSS 2011
20-23 September
Portland, USA
www.ion.org

INTERGEO
27 - 29 September
Nuremberg, Germany
www.intergeo.de

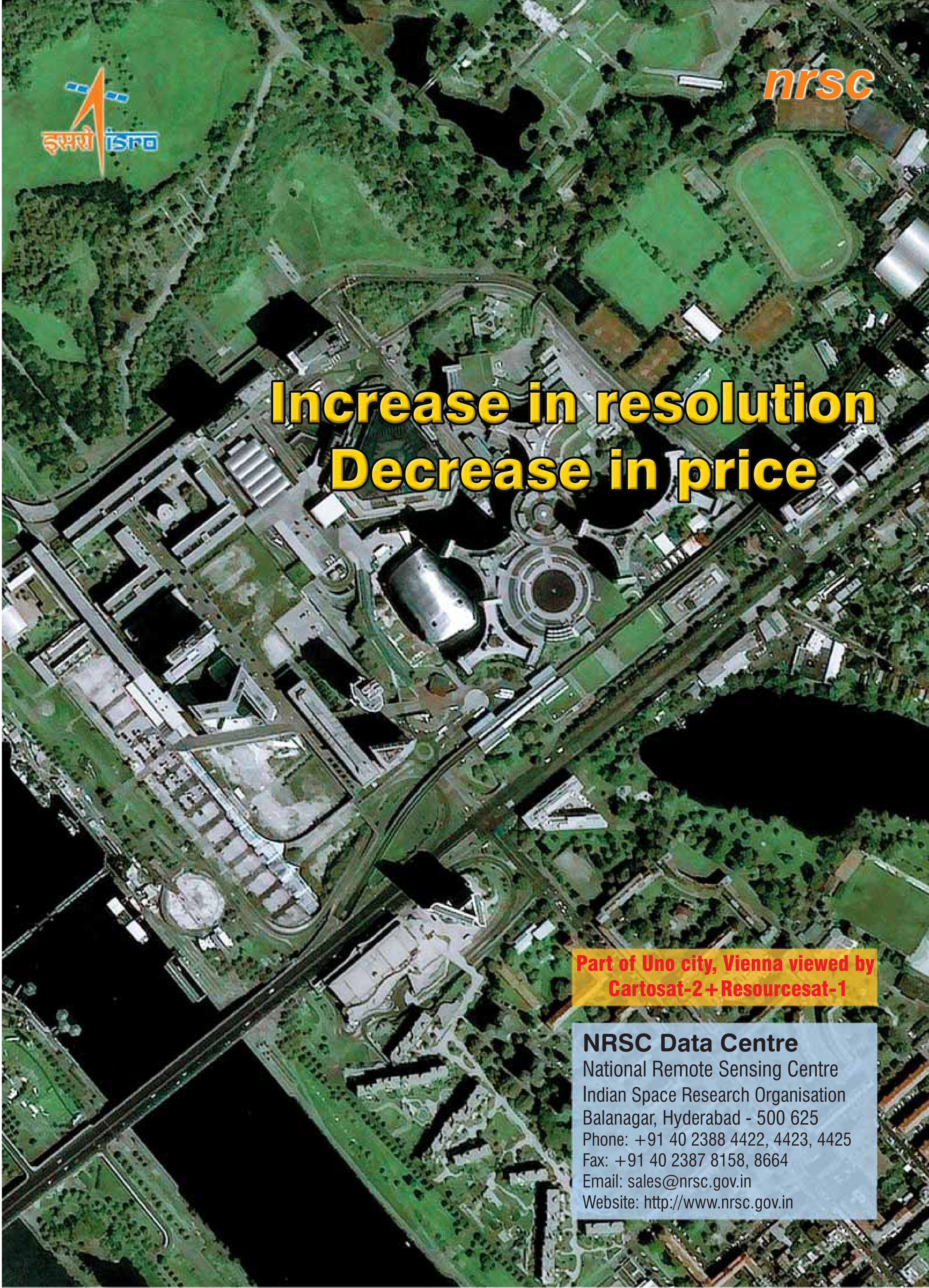
October 2011

ACRS 2011
3 – 7 October
Taipei, Taiwan
www.acrs2011.org.tw

AfricaGIS 2011
10 – 14 October
Cairo, Egypt
www.eis-africa.org/EIS-Africa

November 2011

Regional Geographic Conference – UGI 2011
14-18 November
Santiago, Chile
www.ugi2011.cl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