

IGNSS 2006

Presenters List

Ordered by paper number



First Name	Surname	Organisation	Speakers Paper Title	Paper No.
Peter	Mumford	The University Of New South Wales	A time-synchronization device for tightly coupled GPS/INS integration	5
Peter	Mumford	The University Of New South Wales	An open GNSS receiver research platform	6
Martin	Hale	Department Of Sustainability & Environment	Validating a CORS Network Management Model Using A Case Study	7
Toshiaki	Iwata	National Institute Of Advanced Industrial Science And Technology	Design of Tools and Plan for Remote Synchronization System for Quasi-Zenith Satellites	8
Cristian	Gordini	Department Of Geomatics	Testing and Evaluation of a GPS CORS Network for Real Time Centimetric Positioning? The Victoria GPSnet? Case Study	9
Camden	Fitzgerald	University Of Sydney	Processing GPS Data for Travel Surveys	11
Joel	Barnes	The University Of New South Wales	Locata: A new positioning technology for classically difficult GNSS environments	12
Sharzil	Yousufi	RMIT University	Temporal variation of the Victorian GPSnet base stations	13
Anuj	Pahwa	The University Of New South Wales	Locata: Interoperability with RTK-GPS and DGPS Radios in the ISM Band	14
Chris	Rizos	The University Of New South Wales	Mitigation of Distance-Dependent Errors for GPS Network Positioning	15
Rob	Lorimer	Position One Consulting	GPS to improve the safe operation of vehicles	17
Hiroshi	Isshiki	Institute Of Mathematical Analysis (IMA)	Estimation of Ionospheric Delays in Dual Frequency Positioning	18
Keith	McPherson	Airservices Australia	Beta GBAS Category 1 Installation and Certification in Australia ? Lessons Learned	19
Keith	McPherson	Airservices Australia	Ground-based Regional Augmentation System (GRAS)	20
Laura	Connolly	BAE Systems	Error Analysis of An Integrated Inertial Navigation System and pSLAM (pseudoSLAM) During GPS Outages	21
Jose	Lorga	TU Delft (Delft University Of Technology)	Assisted Multi-Antenna GPS Altitude Determination	23
Stefan	Cacon	Agricultural University Of Wroclaw	Monitoring of ground surface changes following the end of mining with satellite GPS technique	24
Jan	Blachowski	Wroclaw University Of Technology	Integration of GPS and GIS in bicycle trail planning	25
Thomas	Yan	The University Of New South Wales	GNSS Data Protocols: Choice and Implementation	26
Peter	Terrett	Rapid Map Australia	Economical DGPS for spade width accuracy	27
Yong	Li	The University Of New South Wales	Time Synchronization Analysis of an FPGA based GPS/INS Integrated System	28
Mark	Hardman	OmniSTAR Pty Ltd	Wide Area Carrier Phase Positioning - Comparison of the Two Alternate Methods	29
Usman	Iqbal	The University of New South Wales	A Privacy Preserving GPS-based Pay-as-You-Drive Insurance Scheme	31
P.M	Grgich	University Of Melbourne	Atmospheric Bias Interpolation for Network RTK GPS	32
Mark	Elsegood	Australian Communications And Media Authority	Regulating GNSS ? Present Strategy, Future Challenges	33
Weidong	Ding	The University Of New South Wales	Stochastic Modelling Strategies in GPS/INS Data Fusion Process	35
Falin	Wu	RMIT University	An Investigation of Precise Point RTK Positioning Application for Airborne Geophysical Survey	36

IGNSS 2006

Presenters List

Ordered by paper number



First Name	Surname	Organisation	Speakers Paper Title	Paper No.
Jinling	Wang	The University Of New South Wales	Performance Analysis of the Ultra-Tight GPS/INS Integration Based on an Improved Kalman Filter Design for Tracking Loops	38
Fabrizio	Tappero	The University of New South Wales	Remote Control System for the Quasi-Zenith Satellite Crystal Oscillator Based On the Two-Way Time Transfer Method	39
Andrew	Dempster	The University Of New South Wales	A-GPS for Firefighting	40
Jacqueline	Denham	Department of Sustainability and Environment, Spatial Information Infrastructure	Contemporary Position and Navigation Needs of Precision Agriculture and Victoria's GPSnet CORS Network	41
Peter	Cooke	University Of Adelaide	Experimental Evaluation of a Dual Polarized Patch Antenna Array	42
Andrew	Dempster	The University Of New South Wales	The application of GPS Multipath Mitigation techniques on BOC signals	43
Rajneesh	Gupta	Isro	An Adaptive Kalman Filter Algorithm for Real Time Estimation of Receiver Clock in SBAS	44
Minghai	Jia	Geoscience Australia	Plate motions determined by CGPS in South Pacific region	45
Troy	Bruggemann	Qld University Of Technology,	Chip Scale Atomic Clocks: Benefits to Airborne GNSS Navigation Performance	46
Roger	Fraser	Department of Natural Resources & Mines	Code-Carrier Phase Smoothing via the Least Squares Observation Equations Model	47
Murray	Dolling	Department Of Land Administration	An investigation of CORS networks for Western Australia	48
Asghar	Tabatabaei Balaei	The University Of New South Wales	An application of Post-Correlation GPS Receiver Interference Detection and Characterization	49
Andrew	Dempster	The University Of New South Wales	Wireless Signal Map Matching for NLOS error mitigation in mobile phone positioning	51
Duncan	Greer	Queensland University Of Technology	Simulation Results for High-Performance Navigation System Utilising the Ground Based Regional Augmentation System for General Aviation Aircraft	52
Jianguo Jack	Wang	The University Of New South Wales	Designing a Neural Network for GPS/INS/PL Integration	54
Sang Hyun	Park	Korea Ocean R & D Institute	Pseudolite-augmented Precise Positioning System for Vessel Berthing	55
Susumu	Yoshitomi	Japan Aerospace Exploration Agency	GNSS Augmentation using Quasi-Zenith Satellite System (QZSS) and its benefits for satellite navigation applications	56
Bernd	Eissfeller	University FAF Munich	FFT Based Acquisition Algorithm in a Multi-Frequency Software Receiver	58
Peter	Mumford	The University Of New South Wales	Improving signal quality in FPGA based GPS receiver designs	59
T	Sakai	Electronic Navigation Research Institute	Implementation of Prototype Satellite-Based Augmentation System (SBAS)	60
Goetz	Kappen	Chair Of Electrical Engineering And Computer Systems	Mapping of multioperable GNSS receiver algorithms to a heterogeneous ASIP based platform	62
Bilal	Amin	The University Of New South Wales	Sampling and Jitter Considerations for GNSS Software Receivers	64
Gary	Johnston	Geoscience Australia Earth Monitoring Group	The Australian Regional GPS Network Real time and Beyond	65

IGNSS 2006

Presenters List

Ordered by paper number



First Name	Surname	Organisation	Speakers Paper Title	Paper No.
Jorge	Woods	Civil Aviation Safety Authority	The Use of GNSS for Aviation in Australia	66
Gary	Einicke	Mining Automation Research Group	Improved mining navigation via pseudolites	68
Werner	Enderle	Queensland University Of Technology	The Proposed Australian Galileo Test Bed	69
Gary	Einicke	Mining Automation Research Group	Improved Mining Navigation via Pseudolites	70
Werner	Enderle	Queensland University Of Technology	The Australian GNSS Joint Undertaking (AGJU) ? Concept and Objectives	71
Werner	Enderle	Queensland University Of Technology	A Regional Galileo Integrity Concept for Australasia	72
Zd	Qin	Nokia	Phase Adaptive Integration for GNSS Signals	73
Yanming	Feng	Queensland University Of Technology	A new receiver autonomous integrity monitoring strategy for multi-fault exclusion using GPS and Galileo Constellations	75
Yanming	Feng	Queensland University Of Technology	Exploring GNSS performance benefits from multiple satellite systems and multiple carrier signals using existing GPS constellation and measurements	76
Yi	Zheng	Queensland University Of Tecnology - CRCSS	Regional GNSS Satellite Orbit Monitoring for Improved Real Time Zenith Tropospheric Delay Estimations	77
Scott	Wyllie	RMIT University	An analysis of the temporal correlation of the ionospheric bias affecting GPS carrier phase	79
Kefei	Zhang	RMIT University	Sparse or dense: challenges of Australian network RTK	80
Ashley	Mallia	GPSat Systems Australia Pty Ltd	Communications Management and Automation in Distributed GNSS Applications	81
Patrick	Oppenlander	GPSat Systems Australia Pty Ltd	E-Trakka A fully integrated GPS system to assist with horse training	82
Liam	Densley	RMIT University	High fidelity 3-D urban model-based signal performance simulation of the current and future GNSSs in Australia	84
Kefei	Zhang	RMIT University	Positioning case studies using RFID and GNSS: indoor and outdoor	85
Neil	Harper	Andrew Corporation	An analysis of the position calculation accuracy for GPS status aiding of an A-GPS server.	88
Ge	Li	Institute For Automation	An Architecture for Satellite Navigation Signal Simulation	90
Yukihiro	Kubo	Ritsumeikan University	Carrier Phase and Pseudorange Based GPS/INS Integrated Navigation System for Land Vehicles	91
Seigo	Fujita	Ritsumeikan University	Precise Point Positioning based on GR Models ?Further Results in Single Frequency Applications	92
Yukihiro	Kubo	Ritsumeikan University	Detection of Abnormal Pseudorange and Carrier Phase Measurements in GPS Precise Point Positioning	93
Argenis	Da Silva	Louisiana State University	Relativistic GPS and quantum approaches to clock synchronization. How these could be combined?	95
Jing Yuan	Zhang	Victorian University	Geographic Information Mapping for Email Services	97
Jan	Weiss	University Of Colorado	Improved Multipath Model Validation in Semi-Urban, Aircraft, and Shipboard Environments	98
Garry	Cislawski	Department of Natural Resources & Mines	SunPOZ : Enabling Centimetre Accuracy GNSS Applications in Queensland	100
Jeff	Tullberg	Control Traffic Farming Solutions	Agricultural Opportunities of Precision (2cm) Navigation	102

0005

A time-synchronization device for tightly coupled GPS/INS integration

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To successfully integrate data from navigation devices and other sensors, reference time stamps are required in the collected data. While this can be achieved relatively easily for devices that provide timing pulses, it is more difficult in the general case when only serial data streams with no reference time stamps are available. The time-synchronization device presented in this paper is being developed as part of the Cooperative Research Centre for Spatial Information (CRC.SI 1.3) "Integrated Positioning and Geo-referencing Platform" project. The device uses the precise one-second timing pulse from a GPS receiver as reference to time-stamp incoming serial data streams. The data is then logged to a compact flash card for post-processing on a computer workstation. The hardware used in the device is based around an Altera Field Programmable Gate Array (FPGA) development board, with custom logic and a Nios soft-core processor that do most of the work residing in an Altera FPGA chip. The firmware is built around the Embedded Configurable Operating System (eCos) real-time operating system, which supports compact flash access and multi-thread applications. Testing of the device with GPS and INS sensors has revealed good results and reliable performance. The test setup and results are presented in this paper. In addition, the hardware design is described and an overview of the firmware is provided. Further development is planned to enhance functionality and the user interface and to move some of the post-processing functions onto the device.

0006

An open GNSS receiver research platform

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This paper presents results from the open GNSS receiver platform that has been under development since mid 2004. The aim of the project is to create the first open source GNSS receiver design based on Field Programmable Gate Array (FPGA) technology for research and development. Currently, an L1 GPS receiver design running on custom hardware is complete and functioning correctly. It is hoped that eventually the hardware components, along with the FPGA design files and GPS firmware, will become available as a development kit. In addition, it is envisioned that the baseband processor design could become available from one of the FPGA providers as an integrated IP block. The platform consists of a custom circuit board, a baseband processor design and application firmware. A circuit board has been built and tested, confirming the low noise operation of its GPS L1 RF front end and correct functioning of the Altera FPGA chip and support components. The baseband design is complete and shown to operate correctly both in simulation and real-time testing. The application firmware has been ported to the new platform; testing and tuning are on-going. The main aspects of the design and results from each component are discussed in this paper, followed by some ideas for the future.

0007

Validating a CORS Network Management Model Using A Case Study

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Continuously Operating Reference Station (CORS) networks are accepted by many national and state jurisdictions around the world as a means of improving the accuracy and reliability of Global Navigation Satellite Systems (GNSS), user determined positions, in terms of a datum relevant to each nation. CORS networks and related Network RTK (NRTK) services for instance, are being used to address the high accuracy needs of spatial professionals and para-professionals. Many new, non-traditional spatial information users however do not necessarily have a spatial background or extensive understanding of satellite positioning and are making increasing use of CORS network services for applications such as precision farming and emergency services. Most users however, regardless of background, training and application, have high expectations of CORS networks including optimal service delivery and performance. A CORS Network Management Model is being developed to address institutional, commercial, operational and legal arrangements for CORS network establishment and operation. The Model will help ensure that CORS networks can take their place in an increasingly information-based society as fundamental spatial sciences infrastructure. This paper discusses the status of a user gap analysis and Model validation process using a state government managed, jurisdiction wide, real time CORS network as a case study.

Design of Tools and Plan for Remote Synchronization System for Quasi-Zenith Satellites

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The Quasi-Zenith Satellite (QZS) System (QZSS) is a Japanese project that was started in 2003 and consists of a multi-mission system that will include positioning capability. Two experiments of the new timekeeping method of the QZSS are planned by the AIST. In “experiment one,” the remote synchronization system for an onboard crystal oscillator of the QZS is investigated for its ability to synchronize time information received from the ground station that is equipped with accurate atomic clocks (QZSS-Time). Based on the measured time difference between the uplinked time information and the onboard crystal oscillator, the voltage to be applied to the crystal oscillator is calculated on board. In “experiment two,” the remote synchronization method is investigated by uplinking controlling voltage of the crystal oscillator calculated on the ground based on the results of time comparison between the onboard crystal oscillator and QZSS-time, conducted by the NICT. To realize these experiments, tools, including apparatuses for the ground station and onboard software, are designed, namely, a transmitting time adjuster, a PN code generator, a QZSS/GPS receiver, a controller, a data processing computer and a frequency transformer. The specifications of these apparatuses and the interfaces among these apparatuses and other related apparatuses at the ground station are discussed. Since communication is sometimes interrupted, in order to avoid interference with geostationary satellites when the QZS approaches the equator, some control modes are included in the onboard software. The plans for these experiments are also presented.

Testing and Evaluation of a GPS CORS Network for Real Time Centimetric Positioning – The Victoria GPSnet™ Case Study

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Real time kinematic (RTK) GPS techniques are now commonly adopted to achieve centimetric position accuracy requirements. The classical RTK methodology allows for an operational distance between the reference station and the user, within a range of 10-15 kilometres, due to the correlation of some GPS errors with distance. By adopting a Network RTK (NRTK) approach, this operational range can be extended to many tens of kilometres. As a result, regional networks of Continuously Operating Reference Station (CORS) are now being routinely established as the primary infrastructure to support user needs for real-time, centimetre level positioning. For many countries, the cost involved in establishing the required density of CORS sites for nationwide NRTK coverage is fully justified. However, for countries like Australia, with large areal extents and widely spaced population distributions, a nationwide NRTK coverage is not viable economically. In such instances available resources are only able to support the establishment of sparse CORS networks over wide areas in combination with higher density sub-networks in locations that fully justify the investment, for example over major cities such as Melbourne, Sydney, Brisbane and Darwin in Australia.

This paper presents an evaluation of NRTK technologies that enable operation over large areal extents previously restricted due to the nature of GPS errors. In particular, through the use of a case study undertaken to test and evaluate available NRTK systems, this paper describes the GPS CORS network (GPSnet™) established in Victoria, Australia, the procedures adopted in evaluating its performance and the practical results obtained.

Key Words: GPS, Network RTK, Continuously Operating Reference Stations, GPSnet™

0011

Processing GPS Data for Travel Surveys

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Using GPS devices to measure individuals' travel has become increasingly popular over recent years. In particular, passive, unobtrusive GPS devices have become the device of choice. The authors, in conjunction with a GPS manufacturer, have developed a lightweight device the size of a mobile phone with an antenna/receiver capable of measuring people's travel on all transport modes. This paper describes the problems associated with processing these data and the solutions that are in place. The data need to be cleaned and separated into trips, repaired for cold starts, and signal drop-out when travelling through tunnels, urban canyons, etc. Determination of transport mode and trip purpose is also required for travel behaviour analysis. In the past, one method of obtaining mode and purpose information was to return to the survey participant after their travel period, with tools such as maps and tables as a memory aide, and ask them how and why they went to each destination. To reduce respondent burden the authors have developed a set of heuristic rules to automate procedures for producing a complete description of the travel without needing to have participants respond to questions after using the GPS device. As technology advances and we change from one GPS receiver to another, the data output also changes and new rules need to be developed to suit the particular device. The intent, however, is to be able to develop this technology to the point that it becomes the method of choice for travel surveys.

0012

Locata: A new positioning technology for classically difficult GNSS environments

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GPS is undoubtedly the most popular and widely used three-dimensional positioning technology today, but despite this, cannot provide the positioning requirements in many everyday environments, such as urban and indoors. Locata's solution to these "challenging" environments is to deploy a network of terrestrial based transceivers that transmit ranging signals. These transceivers form a positioning network called a LocataNet that can operate in combination with GPS (such as in urban environments) or entirely independent of GPS (for indoor applications). One special property of the LocataNet is that it is time-synchronous, potentially allowing single point positioning with cm-level accuracy.

The LocataLites transmit their own proprietary signal structure in the 2.4GHz ISM band (license free) to ensure complete interoperability with GPS. This allows enormous flexibility in the system design due to complete control over both the signal transmitter and the receiver. In this paper key aspects of the Locata system will be described and discussed. In Q1 of 2006 the Locata technology will be deployed for the first time in 'real-world' applications that are challenging for GNSS positioning technologies. This paper will discuss the LocataNet design issues for specific application deployment and present results and analysis of the first 'real-world' trials.

Temporal variation of the Victorian GPSnet base stations

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Many applications of Global Navigation Satellite System (GNSS) technology, such as surveying, mapping and precise navigation, require real-time positioning accuracies to centimetre level. To support these applications, space and ground based augmentation systems are required to supplement and enhance the capability of GNSS systems. One important development of this augmentation is the establishment of regionally dense, continuously operating reference station system (CORS) networks, with stations positioned typically a few tens to hundreds of kilometres apart. In Australia, both national (ARGN) and regional (eg GPSnet in Victoria, SydNet in New South Wales and SunPos in Queensland) CORS network infrastructures have been established. Victoria's GPSnet has been used by a wide community of GPS users and is regarded as an integral part of state-wide geodetic framework. The positional accuracy of the stations over medium (monthly) to long (annual) terms have been established. To meet the needs of increasing reliance on GPSnet, this paper attempts to investigate the stability of the GPSnet stations in very short (hourly and diurnal) terms using Bernese GPS processing software. Particular interests are the effects of sharp temperature changes, strong wind gusts, and surrounding environments of the GPSnet stations (eg antenna mounting on tall buildings, reflection, multipath etc.) It is anticipated that the outcome of this research will provide a significant guidance to the establishment and maintenance of the CORS network. This will also contribute significantly to the developments of the prestigious ARC project (on network RTK) endorsed to a research consortium led by RMIT and DSE.

0014

Locata: Interoperability with RTK-GPS and DGPS Radios in the ISM Band

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Locata is a new technology which has been developed for reliable positioning in challenging environments (both indoors and outdoors) where satellite coverage is poor or not available. This is achieved through a time synchronised network (LocataNet) of ground-based transceivers (LocataLites) that envelop an area with strong signals suitable for single-point, accurate positioning. Locata's current design incorporates its own proprietary signal transmission structure that operates in the 2.4GHz Industry Scientific and Medical (ISM) band. Considering, that many radios that are used for RTK-GPS or DGPS applications, transmit the position corrections and/or other position related data in the same ISM band, interoperability between these transmissions and those of Locata is an obvious concern. This paper addresses this concerns by presenting interoperability results between the Locata signals and those of the Freewave radios used by Leica for their RTK installations.

0015

Mitigation of Distance-Dependent Errors for GPS Network Positioning

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A network of GPS reference stations provides autonomous, accurate and all-weather observations at low cost that can be useful for capturing information on the effect of the neutral atmosphere as known as tropospheric delay. GPS-derived tropospheric delay provides absolute and relative ZTD. Absolute delay is crucial for meteorological study, however, relative delay is more important for GPS positioning. For high precision GPS RTK positioning the delay needs to be estimated in some way, and furthermore it must be estimated in (near) real-time. This paper discusses the estimation of the relative tropospheric delay using a network of GPS stations for the benefit of positioning purposes. First part of this paper shows that different network size and satellite elevation cut-off angle have no significant impact on the relative ZTD calculation. To verify this fact, a regional GPS network and a local network are used to calculate the relative delay. The regional network is a part of the ARGN contributing to the IGS. As for the local network, the SydNET is employed. Results from the two networks are compared to obtain an understanding of the relative delay. Second part of the paper discusses the estimation of the relative tropospheric delay in SydNET in the form of GPS non-dispersive corrections. The non-dispersive corrections should be applied to RTK positioning with an expectation that it can assist long-range RTK ambiguity resolution and therefore improve the positioning results. To evaluate this proposition, a vehicle RTK experiment has been conducted within the SydNET coverage area and the data was post-processed in simulated RTK mode. The vehicle trajectory is computed with the network-based RTK technique (aided by the non-dispersive corrections) and verified by single-reference RTK using the nearby reference station. The RTK trajectories from both techniques are compared to assess the performance of the non-dispersive correction in the network-based RTK.

0017

GPS to improve the safe operation of vehicles

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Knowledge based safety management (KBSM) is a commitment to automatically collect quantifiable data regarding the safe operation of equipment and vehicles. In an industrial workplace KBSM is used as a supplement to inspections and subjective techniques to help determine the true state of safe working practices.

This paper introduces a novel application for GPS in implementing a knowledge based safety management system on a large open cut mine site. The system under discussion monitors the safe operation of haul trucks and light vehicles on an individual operator basis by monitoring the man-machine interaction.

The paper further discusses the technology integration used in monitoring man-machine interaction which includes GPS, Biometrics, Mesh Wi-Fi, RFID and Terrain and Driver Sensing modules.

The paper concludes with a discussion of results obtained on a large Gold and Copper mine and the use that is made of the data by occupational health and safety and human resource managers to improve overall mine safety.

0018

Estimation of Ionospheric Delays in Dual Frequency Positioning

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The correct estimation of the ionospheric delays is very important for the precise kinematic positioning especially in case of the long baseline. In case of triple frequency system, the ionospheric delays can be estimated from the measurements, but, in case of dual frequency system, the situation is not so simple. The precision of those supplied by the external information source such as IONEX is not sufficient. The high frequency component is neglected, and the precision of the low frequency component is not sufficient for the long baseline positioning. The high frequency component can be estimated from the measurements, but the low frequency components must be estimated by using the external information source or pseudo range measurements. The estimation using the pseudo range measurements is not sufficient at present because of the poor accuracy of the measurements. However, if the accuracy of the pseudo range measurements is improved in future, the method would become very promising.

0019

Beta GBAS Category 1 Installation and Certification

in Australia – Lessons Learned

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A beta Ground Based Augmentation System (GBAS) Category 1 satellite landing system was installed at Sydney Kingsford Smith International Airport in 2005. A group of companies worked together to achieve this milestone; consisting of a service provider, regulator, airline operator, airline manufacturer, the GBAS manufacturer, and the airport owner. Qantas has B-737NG aircraft fitted with certified GBAS avionics and first flew approaches on 29 October 2005. The system underwent acceptance testing to allow revenue earning flights to use the approaches, under certain constraints. This paper describes some of the issues involved in the siting, installation, procedures design, operational approvals, operational procedures and constraints imposed. The paper also covers the planned certification process to have the system upgraded and certified to be the world's first system approved for unrestricted Category 1 commercial operations.

0020

Ground-based Regional Augmentation System (GRAS)

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Airservices Australia has embarked on the development of an operational Ground-based Regional Augmentation System (GRAS) following several years of operating a test bed. The International Civil Aviation Organisation (ICAO) has approved the GRAS international Standards And Recommend Practices (SARPs). GRAS provides departure, enroute, terminal area, arrival and approach navigation with high integrity. This paper explains the final operational architecture, the uses of GRAS and that it can possibly reduce controlled flights into terrain. An Asia Pacific Economic Cooperation GNSS Study included GRAS and the outcomes relevant to Australia are discussed. The proposed certification process for GRAS is also discussed.

Error Analysis of An Integrated Inertial Navigation System and *p*SLAM (*pseudo*SLAM) During GPS OutagesBEN K.H. SOON¹, S. SCHEDING¹, L. CONNOLLY²

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Recent rapid technological developments have created a number of revolutionary integrated navigation system, often supported by the Global Positioning System (GPS) and an inertial navigation system (INS), for direct geo-referencing of airborne mapping systems. In fact, the GPS/INS platform orientation systems are rapidly emerging as a primary component of modern airborne mapping and remote sensing systems. With full operational GPS capability, it has been recognised that an optimal combination of GPS with inertial navigation system brings a number of advantages over standalone inertial or GPS navigation. GPS contributes its high accuracy and stability over time, enabling continuous monitoring of inertial sensor errors. Implementation of closed-loop INS error calibration allows continuous, on-the-fly error update that bounds INS errors, leading to increased estimation accuracy. On the other hand, INS contributes immunity to GPS outages over short period of time, continuous attitude solution, and reduction of the GPS ambiguity search volume/time. However, operation over a long period of time in a GPS-denial environment due to obstructions or jamming or when operating in cluttered environments such as urban canyons, the accuracy of ground features being tracked by the integrated mapping system degrade over time due to the unbounded positioning errors caused by the uncompensated gyro and accelerometer errors affecting the INS measurements.

This paper presents an integrated INS and *p*SLAM (*pseudo* Simultaneous Localisation And Mapping) system, using the principle of SLAM which enables simultaneous navigation and estimation of unknown features/landmarks. The estimated ground features will provide relative position aiding to reduce inertial error drifts. In this paper, the basic concept of SLAM will be introduced and a comparison between the direct approach of total state estimation in general SLAM algorithm and indirect approach of error state estimation in integrated INS/*p*SLAM will be discussed. With the mechanisation of INS error states of position, velocity and attitude augment with error states of unknown ground features using the INS *Psi*-angle error approach; error analysis is performed by simulating a flight profile. A linear error analysis is used to characterise and understand the tracked feature position estimation of an arbitrary sensor system. The error analysis process is a rigorous, quantitative examination into how a family of systems performs. Its power comes from the fact that it can be used to examine the total family of systems, as well as individual systems, subsystems, and single components. The process involves identifying all elements that introduce error, tracing the propagation of these errors throughout the system, and quantifying their effect on system performance.

0023

Assisted Multi-Antenna GPS Attitude Determination

JFM Lorga, Q.P. Chu, J.A. Mulder

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Nowadays, GPS systems using multi-antenna for attitude determination are common in land, maritime, and space applications. One of these systems using a GPS receiver with multi-antenna capability was installed in a laboratory aircraft, a Cessna Citation twin engine business jet. A two hours flight-test took place in May 2005 during which several high-dynamic manoeuvres were performed, for instance, several strong 35 degrees pitch oscillations and coordinated turns with 30 and 60 degrees roll angles. During these high-dynamic moments, severe changes in the GPS satellites that were in line-of-sight were constantly forced. Consequently, new carrier-phase integer ambiguity problems were continually being created and had to be solved under these adverse dynamic conditions. Results show that this was not always possible and fixes to the wrong integers also had a higher chance of occurring. To improve the integer ambiguity estimation and validation problems, attitude information from the tightly integration of an inertial measurement unit with the dual frequency range data from the main antenna of the GPS attitude system were used. The IMU aided GPS attitude data show that the integer ambiguity estimation and validation problems were successfully helped with the attitude information from the external integrated navigation system. Improvements are considerable, especially in the period of the high-dynamic manoeuvres, and less than 10 seconds of unfixed or wrongly fixed integers were verified during the complete flight-test. In the authors opinion, the achieved promising results, together with the continuous development of solid state inertial sensor, will make the used aiding techniques a common feature in GNSS receivers for attitude estimation in a near future.

0024

Monitoring of ground surface changes following the end of mining with satellite GPS technique

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In the paper the problem of ground surface deformations after the end of underground mining activity in a large urban area is presented. It focuses on accurate assessment of the changes at the surface of the ground as well as indicating stable areas suitable for new industrial and residential development. For this purpose it is important to analyze the area in relation to stable, in terms of geology, regions located, often, at considerable distances. On the example of an object in SW Poland the advantages of satellite GPS technique to solve this problem are shown.

0025

Integration of GPS and GIS in bicycle trail planning

J Blachowski

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The Dolnoslaskie Voivodeship is a region in SW Poland with rapidly growing number and length of tourist bicycle trails. In order to systematize the existing paths, collect information on planned projects and develop an integrated network of trails, including international, regional and local ones a Study of Tourist and Recreational Bicycle System in the Dolnoslaskie Voivodeship has been started by regional planning authorities.

The paper describes a method used for bicycle trail inventorying, marking and planning based on GPS positioning and a mobile GIS system. The methodology has been tested on selected parts of existing and planned trails. It solves the problems of collecting large sets of attribute data, e.g. related to: shape of the trail, tourist attractions along them, guide-signs, waypoints and other in an standardized numerical database designed to meet the specific regulations. It significantly improves the process of bicycle trails development providing accurate position and feature properties and can be used for decision-making associated with spatial planning. The information collected can also be distributed e.g. via internet in the form of data files to be used for navigation by cyclists equipped with GPS receivers.

0026

GNSS Data Protocols: Choice and Implementation

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The increasing number of Continuously Operating Reference Station (CORS) installed in Australia and other countries combined with the ability for worldwide dissemination of GNSS data via Internet and cell-phone network has highlighted the important role of GNSS-specific data transmission protocols. This paper reviews the choices available to both CORS network operators and GNSS users and analyses the similarities and differences between those protocols. In providing examples, this paper specifically looks at the implementation that CORS network operators in Australia have taken and subsequently their usage by local GNSS users.

0027

Economical DGPS for spade width accuracy

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StarFire, a decimeter DGPS system is being used by the pipeline industry to accurately locate maintenance issues on buried infrastructure by workers in the field. The implications for other industry concerned with mapping and locating other buried objects, be they cables, pipes, ordinance, forensic or archeological etc are wide reaching.

As GPS technology advances it becomes more pervasive. Extraordinary results can be achieved using sophisticated equipment by maintenance workers due to the familiar and friendly windows environment.

Point in case - buried pipelines.

Over years these "not seen" assets can corrode, crack or fracture without physical evidence on the surface until it is too late. New technology allows the use of "intelligent pigs" which are sent through the pipeline and can detect corrosion, cracks etc. By use of a dead reckoning on the pig, these faults can be positioned. However an above ground (RTK) survey must be undertaken to remove precessive errors in the pigs dead reckoning system such that positioning errors of faults can be adjusted to the correct GDA location.

Maintenance works are scheduled and the maintenance staff use a field computer interfaced to the StarFire DGPS system and simply move the antenna to the location of the fault and dig at that point. Feedback indicates a typical accuracy of better than 100mm

0028

Time Synchronization Analysis of an FPGA based GPS/INS Integrated System

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The integration of GPS and INS can overcome the defects of INS or GPS standalone systems, and benefits from the complementary characteristics of the two systems. Time synchronisation of GPS and INS data is crucial for such an integrated system to achieve an accurate solution. This paper describes progress on the development of a GPS/INS integrated system based on a field programmable gate array (FPGA) platform. It addresses the time synchronisation issue of the system, discusses timing accuracy and presents test results. The research is conducted under the Australian Cooperative Research Centre (CRC) for Spatial Information (CRC-SI) project 1.3 "Integrated Positioning and Geo-referencing Platform". The aims of the project include: (1) to develop a generic integrated positioning/geo-referencing platform system based on FPGA technology, that can be subsequently reconfigured for optimised positioning and spatial data acquisition applications; and (2) to develop a suite of software that allows for precise, time-synchronised measurement logging, sensor control, real-time data processing, and sundry operations necessary to support mapping applications. The current work focuses on development of software and algorithms, and a FPGA-based GPS/INS data logging system. A tightly-coupled GPS/INS integration system has been designed and implemented. A preliminary version of the FPGA based data logging system has been completed and further debugging and testing are underway. The system records the GPS and INS data onto a compact flash card. The data is then further processed by software for the time synchronisation and estimation of the INS errors via the integrated Kalman filter. Further planned developments will be outlined.

Wide Area Carrier Phase Positioning - Comparison of the Two Alternate Methods

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In recent years new dual frequency carrier phase based real-time DGPS services have emerged to provide decimetre level positioning accuracy over wide areas. These services use geostationary satellite links to provide wide area coverage. The new positioning methods bridge the accuracy and coverage gap between metre level code-based DGPS and expensive centimetre level Real-Time Kinematic systems.

In order to assure the highest level of integrity of the inherently ambiguous carrier phase positioning solution Fugro has developed two independent wide area carrier phase positioning methods. The first method uses the corrections from the multiple reference stations to mitigate the influence of the GPS satellite orbit and clock errors. The second method, instead of eliminating the orbit and clock errors along the line of sight from the reference stations, explicitly uses the satellite orbit and clock corrections without the reference stations.

Both methods can provide decimetre accuracy positioning. The paper reviews both carrier phase positioning methods. It describes the implementation of the methods in the operational real-time positioning services. It also presents the comparison results of the testing of the two methods.

The results show better performance of the multiple reference station method. However both multiple reference station and precise orbit and clock methods can achieve decimetre level positioning accuracy. The paper also illustrates the application of these services within Australia and discusses their relevance to emerging GNSS systems.

0031

A Privacy Preserving GPS-based Pay-as-You-Drive Insurance Scheme

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The emergence of low cost GPS receivers has spurred the development of an increasing number of satellite-based positioning applications. In the automobile industry, satellite-based vehicle tracking offers promising services. One such application is Pay-as-You-Drive (PAYD) insurance. The aim is to design mobility-based insurance policies that would potentially reduce the premiums of car owners who do not travel often and/or long distances. The premiums can be estimated by the total kilometres travelled, the zones where travel was made, the times of the day that the vehicle was used, and the average speeds. Although PAYD offers cost reduction for the motorists, there are serious privacy concerns surrounding the application due to its ubiquitous tracking capability. The insurance providers can know a lot more than just how many kilometres you drove in a billing period. If tracking is continuous, they can estimate the risks of a particular driver being on the road, and how often, and of what nature, were offences made on the road. The ultimate control of this information should be in the hands of the driver. This has to be mandated through regulation or other means. Since PAYD is in its infancy, and no specific legislation exists, its acceptance depends on a technological solution that preserves driver privacy. We propose a privacy preserving PAYD system that promises cost reduction incentives for the driver yet still preserves their right to privacy. Implementing privacy mechanisms on onboard units, only required information for calculating PAYD premiums are transferred, thus ensuring a measure of privacy.

0032

Atmospheric Bias Interpolation for Network RTK GPS

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Network Real Time Kinematic (NRTK) GPS enables positions at centimetre level accuracy to be obtained almost instantaneously using a network of continuously operating reference stations (CORS). The method is both economical, accessible, quick and highly accurate. Accordingly, the uptake of NRTK GPS in such fields as precision farming, property set outs, and machine control has increased markedly in recent years. As a result, productivity gains have been immense. However, NRTK GPS is limited to locations within some tens of kilometres of the surrounding CORS sites. In the Australian case, there is a vast area to cover, with only sparse networks currently in place, e.g. Victoria's GPSnet and Sydney's SydNet. The cost of placing additional reference stations at intervals that would enable coverage across entire states would be prohibitive. For this reason a mathematical solution would be preferable. The main reason for the range limitation of NRTK GPS is errors in the estimation of atmospheric biases at the rover position. This research aims to increase the range of NRTK GPS by improving the estimation of these biases. One estimation technique is Least Squares Collocation (LSC), which requires a functional and a stochastic model to effect the estimation. This paper outlines a method that will improve the models used in LSC and as a result, potentially offer significant increases in the accuracy of the interpolated biases. Consequently, the range of NRTK GPS will be greater and it will have improved accuracy. In addition, ambiguity resolution will be both faster and more reliable.

0033

Regulating GNSS – Present Strategy, Future Challenges

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An essential resource for the operation of GNSS is use of the radiofrequency spectrum (spectrum). The Australian Communications and Media Authority (ACMA) is Australia's spectrum regulator. As such, ACMA facilitates access to the spectrum for GNSS services by applying international and domestic regulatory policies and frameworks, as well as examining the technical specifications associated with the latest examples of GNSS. ACMA consideration includes assessment of interference potential with other services, for example, Defence's Joint Tactical Information Distribution System (JTIDS). In addition, ACMA has declared RNSS jammers to be prohibited devices. ACMA aims to: maximise, by ensuring the efficient allocation and use of the spectrum (by services such as GNSS), the overall public benefit derived from using the spectrum; provide a responsive and flexible approach to meeting the needs of users of the spectrum; and to encourage the use of efficient radiocommunication technologies so that a wide range of services of an adequate quality can be provided. The regulatory framework which ACMA applies to GNSS includes the work of the International Telecommunication Union (ITU) – a United Nations specialised agency; the Australian Radiofrequency Spectrum Plan (which reflects international arrangements with local variations); Band Plans; and Licensing arrangements. Considering the obvious future public benefits of GNSS, ACMA will continue to endeavour to accommodate GNSS advances within an increasingly complex regulatory environment. Through its involvement with the Australian GNSS Coordination Committee (AGCC); Galileo Inter-Departmental Committee (IDC); and Australian Government Space Forum (AGSF), ACMA supports & encourages industry involvement in services associated with GNSS.

Stochastic Modelling Strategies in GPS/INS Data Fusion Process

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To achieve optimal performance of Kalman filter, a correct evaluation of the covariance of the process noise and measurement errors is necessary. The two parameters are normally referred to as Q and R in the Kalman filter terms. The values of Q and R affect the calculation of the Kalman gain K , which implies the weight the filters apply between the existing historical measurement data and the latest measurements. However, the proper definition of Q and R is not a trivial task, and requires intensive empirical analysis. Once the evaluation process is finished, they are used as fixed parameters in the data fusion process. This kind of off-line stochastic modelling works well in situations where the stochastic features of the error process appear constant. But the solution is unlikely to be always optimal due to changes of the error characteristics associated with GPS/INS system models and measurements made under different conditions. Hence adaptive or self-tuning algorithms are needed to deal with this drawback. However, when reviewing the literature for the adaptive estimation of Q and R , one shortcoming was noticed. The derivation of such adaptive methods is largely based on the assumption that the estimated object has stationary stochastic characteristics. Such methods must be used cautiously for non-stationary stochastic cases, otherwise significant performance degradation or even divergence may occur. In the covariance method, estimation of the Q and R is based on the covariance estimation of either the innovation sequence or the updating residual sequence. This is equivalent to estimation of the power spectral density (PSD) of the corresponding data sequence, which has to meet certain requirements for data sampling frequency and total data length. When the estimation is attempted for a strong non-stationary stochastic process, convergence may not be guaranteed. This paper evaluates the adaptive estimation performance of the error stochastic properties Q and R , and their impact on integration results under different application dynamics. Based on the test results, strategies are proposed for its application in the GPS/INS data fusion process.

0036

An Investigation of Precise Point RTK Positioning Application for Airborne Geophysical Survey

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A typical airborne geophysical system consists of the following main components: a time-domain electromagnetic system, a high-sensitivity cesium magnetometer, a GPS navigation system, a radar altimeter and a cesium magnetometer base station. To date, precise real-time GPS positioning has only been possible using differenced carrier phase observations and the RTK or network-RTK method over local areas. The critical limitation of this technique is the availability of expensive user ground-based infrastructure. However, the new developments of precise International GNSS Services products, the advances in receiver technology and the advent of new space infrastructure have given GPS users an innovative way to eliminate GPS errors and to performance high precision point positioning without a user ground-based infrastructure. This research investigates a robust Precise Point RTK Positioning technology that can offer high-precision positioning using single receiver observations for airborne geophysical survey. The primarily results demonstrate that the Precise Point RTK Positioning technology provides robust technology for easy positioning at the centimetre level of accuracy without the need for expensive independent user ground infrastructure for airborne geophysical survey applications.

0038

Performance Analysis of the Ultra-Tight GPS/INS Integration Based on an Improved Kalman Filter Design for Tracking Loops

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Compared with loose and tight integration, ultra-tight GPS/INS integration offers improved performance under exposure to high dynamics, jamming and interference by employing the advanced Kalman filter design methods. The ultra-tight configuration delivers unique advantages by aiding the GPS tracking loops with velocity estimates derived from the Kalman Filter. In this manner, only the errors in the aiding velocity need to be tracked by the receiver as opposed to the absolute motion. Hence, the code & carrier tracking loop measurements, i.e. the pseudorange & pseudorange-rate measurements are correlated with the inaccuracy of the estimated velocity derived from Kalman filter. Due to these correlations, between the tracking loop measurements and estimated velocity errors, it is necessary to consider the correlations of not only the code tracking loop but also the carrier tracking loops in the design of the Kalman filter. In this way, accurate pseudorange-rate measurements and finally the optimal velocity estimation may be achieved.

In this paper, the performance of the ultra-tight system which takes into account the correlations of both the code and carrier tracking loops is analyzed. Various simulation testing scenarios are examined to comprehensively evaluate the proposed Kalman filter configuration, particularly under situations with low satellite visibility and high dynamics. Experimental testing results indicate that the mitigation of the correlations of tracking loops and therefore minimizing the tracking loop errors does, in fact, lead to more accurate pseudorange-rate and pseudorange measurements and therefore velocity estimations, which in turn enhance the tracking performance and the stability of the ultra-tight Kalman filter.

Remote Control System for the Quasi-Zenith Satellite Crystal Oscillator Based On the Two-Way Time Transfer Method.

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The Quasi-Zenith Satellite System (QZSS) is a three satellite positioning/augmentation system to be launched by Japan in 2008. Although the original QZSS scheme includes the employment of space-born atomic clocks for the on-board time signal generation, each QZS will be equipped with an additional time comparison unit (TCU) aimed to measure the phase shift between each on-board clocks (atomic clocks and VCXO) and the ground station time standard. The on-board clock phase shift information is then sent to the management station (TMS) on the ground by means of a two way time transfer method. Using this scheme, time uncertainty between the on-board VCXO and the time standard on the ground can be contained below 1 ns. In this paper, we propose a new time keeping method where the control voltage that steers the remote VCXO is based on the time difference available on the ground. This method does not require any on-board atomic reference. Fundamental issues like data processing delay, remote control voltage generation and ground-satellite communication delays will be fully considered. This scheme will be realized by the cooperation of three institutes: the Japan Aerospace Exploration Agency, the National Institute of Information and Communications Technology and the National Institute of Advanced Industrial Science and Technology.

0040

A-GPS for Firefighting

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Fighting fires in vast areas of bush can be a challenge for control centres to establish the location of fire units, however, determining the position of a GPS receiver under foliage is an almighty task, since the GPS signal is greatly attenuated by any object it passes through. Assisted GPS (A-GPS) is a relatively new technology that uses a network to transmit assistance data to the mobile receiver, where the network is usually a mobile phone network such as GSM. Emergency services in NSW have access to a wireless data network that has coverage in areas that these services normally access (such as bushland). GPS testing at the University of New South Wales showed that the attenuation through various types of foliage was no more than approximately 20dBHz, with acquisition time increases of no more than approximately 30 seconds. Through further investigation and field tests of attenuation of GPS signals through eucalypt foliage, it was found that the A-GPS system could circumvent this attenuation through its increased sensitivity. An A-GPS system was designed for this data network, using an existing standardised protocol that is used for the equivalent system designed for the GSM network. Performance testing showed the initial assistance data would take less than a second to transmit to the receiver.

0041

Contemporary Position and Navigation Needs of Precision Agriculture and Victoria's GPSnet™ CORS Network

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In Victoria, Australia, advanced arable land management practices that implement contemporary precision farming techniques now typically require high accuracy, and ideally sub 20mm positioning and navigation solutions. Practices such as inter-row sowing, controlled traffic farming, precise banded and precise shielded spraying techniques depend on reliable and accurate positioning solutions over large areas and to be repeatable from season to season.

Across cropping districts in Australia, and in particular in Victoria, agricultural practitioners are taking advantage of the latest Real Time Kinematic (RTK) solutions to increase yield, reduce inputs, maximise sustainability and improve occupational health and safety outcomes for machine operators. High accuracy, automatic machine guidance is at the heart of much of these techniques.

Appropriately configured, Continuously Operating Reference Station (CORS) networks can provide a consistent framework within which precision farmers can conduct contemporary precision farming practices. This paper reviews the application of Networked RTK (NRTK) services using Victoria's GNSS CORS network GPSnet™, internet enabled radios, and autosteer technologies at Balliang in south east Victoria as a case example.

0042

Experimental Evaluation of a Dual Polarized Patch Antenna Array

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We recently obtained two dual polarized patch antennas from Pharad and placed them a distance of 20.0 cm apart. They were aligned and levelled in the horizontal plane in an unobstructed area. We used four preamplifiers and RF front ends driven by the same local oscillator. The IF was sampled by four coherent A/D's in an Canadian Interactive Circuits and Systems unit model DAQ – PC 554/117. We saved a number of 30 sec sets of data to disk at 12.5 MS/s. Two different Matlab codes were employed on the data, one using circular correlation over 12500 points, and the other using correlation across two or more chip lengths in order to make the correlation peak independent of the data. The resultant phase angles from the two methods agreed to one or two degrees. The four channels were calibrated. Satellite elevation and azimuth were obtained concurrently using a GPS Genius receiver. The logged data is also used to determine the effectiveness of a dual polarized antenna array for interference rejection using null steering. To do this, one of the GPS signals is treated as an interference and the array is adapted to reject this GPS signal, while still attempting to receive the other GPS signals. The anti-jam performance of the dual polarized array is then compared against a standard adaptive array where each antenna is forced to have circular polarization.

0043

The Application of GPS Multipath Mitigation Techniques on BOC Signals

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The future of satellite navigation undoubtedly envisions use of both the GPS and Galileo systems. Though the use of BOC modulation on Galileo signals improves accuracy, its multiple peak nature also makes tracking more complex. This problem is particularly severe when there are external sources of error present. A major source of tracking error in satellite navigation is multipath. There are several techniques available for multipath mitigation on GPS signals. One of the most successful techniques is the Double Delta Correlator, which comprises of "narrow" and "wide" correlators used in parallel. For any future combined receiver to be successful, it is imperative that the error minimizing techniques employed are compatible for both GPS and Galileo signals. This paper analyses the effectiveness of the Double Delta Correlator on BOC modulated signals using MATLAB simulations. When the algorithm used on BPSK signals is applied to BOC modulated signals, it appears at first that the technique is far less effective for Galileo receivers. Further examination, however, reveals that the values of "narrow" and "wide" chip spacing cannot be used prima facie. Unlike conventional GPS chip spacings (usually 0.1 and 0.5 chips), for the technique to be effective the chip spacing on BOC correlators must be decreased as the offset carrier frequency increases. By incorporating this fact into the preliminary algorithm, it was discovered that the Double Delta Correlator can in fact be successfully employed to provide multipath mitigation on BOC modulated signals.

0044

AN ADAPTIVE KALMAN FILTER ALGORITHM FOR REAL TIME ESTIMATION OF RECEIVER CLOCK IN SBAS

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There are different techniques and models to estimate and remove the errors in a GPS based system like SBAS. The reference station clock constitutes a major source of error in measurement. Further, the measurements do suffer from instantaneous receiver noise. It is necessary to estimate and remove the reference station clock errors and receiver noise from the measurements in real time. This paper provides a new insight into the development of a two step procedure for estimating receiver clock error and receiver noise from the corresponding measurements. As a first step, the algorithm employs an instantaneous batch least square technique on the real time measurements from a selected reference station to various visible GPS satellites. This provides a fairly good and initial estimate of the receiver clock error and its variance instantaneously. In the second step, an adaptive Kalman filter is developed to estimate four parameters i.e. the receiver clock, the clock rate, the noise and the noise rate. The two step algorithm is an elegant method to estimate the receiver clock error, since the uncertainties associated with the measurement noise and the process model noise are resolved effectively. The algorithm results are verified by comparing the computed measurement residues as against the expected residues. The procedure was repeated for different line of sights, by choosing a GPS PRN visible across various participating reference stations. The measurement data source for evaluating the algorithm performance was based on a standard dual frequency code and carrier phase measurements at 1 Hz rate.

0045

Plate motions determined by CGPS in South Pacific region

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CGPS data of 5 years in South Pacific region have been processed and combined with a global CGPS network in the ITRF2000 reference frame. Velocity field determined from the 5 years CGPS coordinate time series shows some very complicated plate motion and micro-plate rotation patterns in this region. This paper will address details of these geodetic and geophysical issues.

0046

Chipscale Atomic Clocks: Benefits to Airborne GNSS Navigation Performance

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Advances in Micro-Electro-Mechanical Systems (MEMS) fabrication promises cheap, micro-miniature, low power atomic clocks to be available within the next five years. The use of such technology to replace less stable crystal clocks in GPS receivers would improve the achievable navigation performance. For airborne GNSS navigation, the clocks could enable greater performance in accuracy and integrity monitoring over currently used crystal oscillators. Furthermore, the clocks may be used to augment the GPS receiver during failures or outages of augmentation systems such as Airservices Australia's proposed Ground Based Regional Augmentation System (GRAS). This paper explores the potential benefits of using micro-miniature atomic clocks with airborne GPS navigation by presenting computer simulation results. Comparisons of GPS accuracy and integrity monitoring performance are made with standard crystal clocks. In addition, results are presented for augmenting the GPS by clock coasting with micro-miniature atomic clocks, for flight through SBAS, GBAS and GRAS outage areas.

Code-Carrier Phase Smoothing via the Least Squares Observation Equations Model

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Code-carrier phase smoothing (in the form of an averaging technique known as the Hatch filter) has been implemented within many low-cost GPS receivers as a means for minimising the shortcomings of low-quality (high noise) code correlators and antennas with high multipath susceptibility. Whilst providing a simple and efficient means for minimising noise, the averaging technique is not completely rigorous since the effect of multipath bias may be carried over successive smoothed pseudoranges. A further limitation exists in that no consideration is given to the precision of either the code pseudorange and carrier phase measurements. A continuous lock on the signal over (n) epochs must also be maintained.

This paper examines the use of a simple observation equations model for smoothing epochal positioning solutions using a combination of code pseudorange and carrier phase measurements in a modified Kalman filter. The observation equations model presented in this paper is proposed as an equally rigorous, yet much simpler technique over the traditional condition equations model for combining the carrier phase and code pseudorange measurements. The influence of multipath and receiver noise is minimised statistically, thus providing a rigorous approach to smoothing the epochal positioning solution.

In the paper, the full observation equations and the modified Kalman filter are developed. Both static and dynamic platforms are considered. Results based on data obtained from CORS network and high-quality roving receivers are provided with graphs to illustrate the effectiveness of the modified filter.

0048

An investigation of CORS networks for Western Australia

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This paper discusses the benefits of expanding the existing CORS network throughout Western Australia, to support the geodetic infrastructure and realisation of GDA and AHD across the State. The options and issues related to this expansion will be discussed and a number of simulated case studies presented, representing potential designs for Western Australian CORS networks. Network quality is assessed using a series of statistically simulated design parameters. This paper also addresses the likely impact of GPS modernisation and the introduction of the Galileo system on the performance of an expanded Western Australian CORS network.

0049

An application of Post-Correlation GPS Receiver Interference Detection and Characterization

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Narrowband interference can severely degrade the performance of GPS receivers. Different narrowband interference suppression techniques also degrade this performance correspondingly. Detecting the presence of interference and then characterizing it can either lead to its removal or we can reconfigure the receiver to change its focus to satellites that are less vulnerable to that interference at that time. In this work, using the post processing capability of a software GPS receiver, CW interference is detected and characterized. This is achieved by passing the GPS signal and the interference through the correlator. Then, using the conventional definition of C/No as the squared mean of the correlator output divided by its variance, the actual C/No for each satellite is calculated. A different method leads to a mathematical expression for C/No. If this value falls below a given threshold, the satellite will be "excluded" due to the interference. An "exclusion zone" in carrier frequency exists for each satellite and can be calculated. Finally by monitoring the Doppler frequency of each satellite and also having the actual C/No of each satellite using the traditional definition of C/No and actual data from a software GPS receiver, the reconfiguration decision for the receiver to track other satellites is made.

0051

Wireless Signal Map Matching for NLOS error mitigation in mobile phone positioning

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Angle of arrival (AOA), time of arrival (TOA) and time difference of arrival (TDOA) are widely used for mobile phone positioning. However, these measurements experience degradation of location accuracy due to localised non-line-of-sight (NLOS) signal propagation, especially in urban or suburban area. NLOS error is well known to be a major source of error in mobile phone positioning and is simply caused by buildings blocking the line-of-sight propagation of the RF signal. Hence mobile station (MS) appears further away from the base transceiver station than it actually is. This significantly increases the positioning error. To mitigate the effects of NLOS error in terrestrial wireless location systems, a wireless signal map-matching (WSMM) concept was recently introduced. WSMM is based on using a database method to generate the NLOS error correction map, and then use the correction map to correct the measurements. Therefore, a more accurate MS location can be estimated. Furthermore, WSMM can automatically extract the relationship between an electronic map representing the ideal world and the fully-populated anonymous user distribution representing distorted world. After the concept was verified by simulation, an experiment was carried out in a typical suburban area. The test result shows the proposed database method based on universal kriging can improve the accuracy of position estimate using the TDOA technique if the reference points can be identified.

0052

Simulation Results for High-Performance Navigation System Utilising the Ground Based Regional Augmentation System for General Aviation Aircraft

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It is now widely established that high performance navigation can be achieved by integrating GPS and low-cost Micro-Electro-Mechanical Sensors (MEMS) Inertial Navigation System measurements. However, the high noise and drift rates of these low-cost sensors, and the subsequent inability to coast for sufficient periods during GPS outages has hampered their widespread uptake in general aviation aircraft. The Ground Based Regional Augmentation System (GRAS) will bring high-integrity GPS navigation to General Aviation aircraft, however the potential exists that the GRAS signal could be lost for seconds or minutes at a critical time due to terrain masking or aircraft manoeuvres. A system is therefore needed which can coast through short GRAS outage periods, whilst taking advantage of the superior integrity provided by the GRAS Signal in Space (SiS) when it is available. This paper presents simulation results for a high performance navigation system utilising low-cost MEMS inertial sensors and the GRAS. The system utilises the high accuracy and integrity of GPS navigation when the GRAS SiS is available to calibrate the inertial system parameters, and is then able to coast the navigation solution with high-integrity for short periods if the GRAS signal is not available. An analysis of the availability of integrity is presented demonstrating the performance of the system whilst flying through GRAS outage regions.

0054

Designing a Neural Network for GPS/INS/PL Integration

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Although Kalman filtering is an optimal real-time data fusion method for GPS/INS integration, it has some limitations in terms of stability, adaptability and observability, etc. A Kalman filter can perform optimally only when its dynamic model is correctly defined and the noise statistics for the measurement and process are completely known. As a Kalman filter's predictions may diverge rapidly without measurement update, GPS/INS system performance could degrade rapidly if GPS signals are unavailable. Neural networks, on the other hand, can map input-output relationships without apriori knowledge about them - hence this technique can be applied to overcome the limitations associated with a Kalman filter.

The design of a high accuracy and high-rate airborne GPS/INS/PL (pseudolite) integrated system is presented, which combines Kalman filtering and neural network algorithms to estimate the accelerometer and gyro measurement errors, plus the position and attitude parameters, as well as the PL troposphere delay modelling errors. Kalman filtering is the primary integration method when GPS signals are available, and the neural network provides the navigation solution when GPS/PL signals are obstructed. While GPS/PL signals are available, a multilayer neural network is trained to map the INS measurements with the corresponding Kalman filter predictions at the update rate of the INS. Then the neural network can be used to provide accurate solutions when only INS measurements are available, i.e. between the (1Hz) GPS/PL samples and during receiver dropouts caused by antenna shading or other reasons. Both simulation and real field test data are processed to evaluate the proposed hybrid method.

0055

Pseudolite-augmented Precise Positioning System for Vessel Berthing

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We have known that AIS, ECDIS use standalone GPS or DGPS technology to get a vessel position. But unfortunately, it is not a precise position. If so, don't we have need of a precise vessel position? The answer is absolutely yes! A good example of that is "Laser Docking System," which provides a centimeter-level accuracy distance from the jetty mounted laser sensors in order to help a vessel to approach to a pier. It is very accurate & useful, whereas there are too many considerable problems. That is, laser sensors need to be correctly positioned and installed on the jetty to allow for full range of vessels to be berthed and to consider loading condition and tidal variations. Above all, the laser docking system is expensive and its service coverage is limited.

In order to solve these problems, this paper proposes a pseudolite-augmented precise positioning system for vessel berthing. In this paper, pseudolite is used to aid in CDGPS positioning in 2 ways. First, it is used to augment the GPS satellite constellation by providing additional ranging sources when the natural satellite geometry is inadequate. Second, pseudolite is used as an aid to carrier-cycle ambiguity resolution.

This paper presents that the proposed system can provide continuous centimeter-level positioning accuracy through comparison analysis of RDOP simulation result of the GPS satellite constellation and the pseudolite-augmented GPS satellite constellation. And this paper describes the test bed for performance evaluation of the proposed system. Furthermore, it is shown that the proposed system satisfies the positioning accuracy required for vessel berthing at the test bed.

0056

GNSS Augmentation using Quasi-Zenith Satellite System (QZSS) and its benefits for satellite navigation applications

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Quasi-Zenith Satellite System (QZSS) is a constellation consisted of several satellites orbiting different high inclined orbital planes with geosynchronous period. Each satellite is allocated on the orbit so as to pass over same ground track at constant intervals.

QZSS will transmit navigation signals, which have complete compatibility and interoperability with current and modernized future GPS, on L1, L2 and L5 band to whole visible earth surface from the satellite including not only Japanese neighbors but also East Asia and Oceania region. The signal, called L1-Sub meter class Augmentation with Integrity Function (SAIF), will be planned to provide WDGPS correction message based on SBAS message format adding to above mentioned signals.

“More stars” is a primary essential requirement for GNSS applications from geodesy to navigation use of handheld equipment. The constellation design of the QZSS leads the improvement of availability effectively as less as number of satellite. Especially, the satellite with high elevation angle is highly important for land mobile users in the urban canyon and mountainous terrain.

Moreover, the effect of acceleration to Initial Operational Capability (IOC) of modernized civil signals in Asia Oceania region is considered in the paper as well as fundamental benefits such as availability and GDOP improvement.

This paper describes what QZSS is and its benefits for satellite navigation and introduces our current design status for QZSS as a regional GNSS augmentation system. It is emphasized that the same benefit for navigation users is to be provided in the Oceania region as well as Japan.

0058

FFT Based Acquisition Algorithm in a Multi-Frequency Software Receiver

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Acquisition is one of the crucial and the most time consuming process which estimates the received code delay and Doppler frequency in a software receiver. In this paper, we evaluate the performance of the acquisition process in a multi-frequency software receiver which receives L1CA, L2CS, L5 and Galileo signals. In such a complex receiver, if the acquisition processes of all signals are performed simultaneously in separate units, then this lowers the performance of software receiver seriously. Moreover, this also causes interference between different GPS and Galileo signals. Taking into account this case, our main purpose is to reduce the time consuming computation of acquisition and to perform the acquisition process in one step for all signals.

In this study, we analyse the performance of the FFT based signal acquisition algorithm in one common unit for all received signals in a multi-frequency software receiver. The FFT based acquisition algorithm is based on one coherent integration taking into account the data bit boundary. With this efficient acquisition algorithm, fewer resources are required and the receiver quickly acquires generic GNSS signals with little memory consumption in such a complex system.

For further investigations, we consider differential acquisition algorithms which give a sensitivity gain over the time domain standard squaring acquisition algorithm.

0059

Improving signal quality in FPGA based GPS receiver designs

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The design of a new FPGA based GPS receiver platform for research purposes is described with emphasis on the efforts to reduce low level signal contamination from the nearby digital circuitry. A key objective is to acquire the highest quality low interference GPS signal at the front end to allow signal processing research. The receiver uses a front end ASIC to convert the GPS signals to a suitable IF in the normal way, followed by an FPGA to perform the base-band processing functions. The digital noise generated by the FPGA creates some challenges when operated alongside the RF front end when receiving GPS signals at very low levels. The focus of this paper is on the architecture used and the electronic design methods used to reduce interference.

0060

Implementation of Prototype Satellite-Based Augmentation System (SBAS)

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A prototype Satellite-Based Augmentation System (SBAS) has successfully been implemented. It generates wide-area augmentation information based on RINEX observation input so providing integrity information and differential corrections applicable to GPS users within wide-area service coverage. The complete SBAS messages are output one by one every second. Currently the prototype is running in offline mode for various evaluation activities; the distribution and number of monitor stations are variable and the historical severe storm ionospheric conditions might be tested.

The SBAS messages output by the prototype were tested by SBAS user receiver simulator with the observations at various user locations. It was verified that the prototype was fully functional and providing wide-area differential corrections achieving the position accuracy of submeter-class. For nominal ionospheric conditions, the user positioning accuracies were within 0.3-0.6 meter horizontal and 0.4-0.8 meter vertical, respectively, both in 1-sigma RMS, over the mainland of Japan using only 6 monitor stations. The protection levels provided by the prototype protected users completely.

Such a prototype could be the practical tool for evaluation of new algorithms and/or parameters for SBAS. One could evaluate the effects of additional monitor stations quantitatively and the new algorithm of ionospheric correction might be tested. The prototype will work as a testbed for improvement of the MSAS and development of the quasi-zenith satellite system (QZSS).

0062

Mapping of multioperable GNSS receiver algorithms to a heterogeneous ASIP based platform

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This paper presents the concept of a reconfigurable hardware macro to be used as a generic building block in low-power, low-cost Systems-on-Chip (SoCs). The macro will allow for multioperable Global Navigation Satellite System (GNSS) positioning and simple integration into existing SoCs.

In contrast to state-of-the-art GNSS receivers, the proposed target architecture features an Application Specific Instruction Set Processor (ASIP) instead of a standard embedded microprocessor as a central processing unit. By optimising the ASIP instruction set and architecture for multioperable GNSS algorithms, the power efficiency (Performance/Power Dissipation) can be significantly increased.

For a sufficient performance the ASIP is accelerated by tightly coupled co-processors. To ensure low power consumption and high flexibility two implementation styles are used for the co-processors. On the one hand side finally specified signal processing blocks are mapped to weakly configurable ASICs to ensure lowest power consumption. On the other hand an embedded FPGA (eFPGA) optimised for arithmetic structures is utilised as a platform for signal processing blocks which may likely change in future receiver generations (e.g. changes in standards).

To show the potential of the ASIP/co-processor architecture for multioperable GNSS positioning, the results of a first mapping are presented. In this approach the correlator control is mapped to the ASIP and the correlator channels are realised as a weakly configurable ASIC (e.g. switchable between GPS and Glonass). Since the generation of Code Correlation Reference Waveforms is the current research subject of several GNSS groups and moreover not finally specified, they will be realised on the eFPGA to offer sufficient flexibility.

Sampling and Jitter Considerations for GNSS Software Receivers

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This paper examines the sampling and jitter specifications and considerations for GNSS software receivers. Software radio (SWR) technologies are being used in the implementation of communication receivers in general and GNSS receivers in particular. With the advent of new GPS signals, and a range of new Galileo signals soon becoming available, GNSS is an application where SWR and software-defined radio (SDR) are likely to have an impact. The sampling process is critical for SWR receivers, where it occurs as close to the antenna as possible. This requires a high-performance Analog-to-Digital Converter (ADC). Important to the specification of both the ADC and Phase-Locked Loop (PLL) is jitter. Aperture jitter effects have usually been modeled as additive noise, based on a sinusoidal input signal, and limits the achievable Signal-to-Noise Ratio (SNR). Jitter in sampled signal has several sources: phase noise in Voltage-Controlled Oscillator (VCO) within the sampling PLL, jitter introduced by variations in period of the frequency divider used in the sampling PLL, aperture jitter effects in ADC, clock line running parallel to the signal-line and harmonic distortion that occurs through the quantization process. Jitter in the sampling process directly acts to degrade the noise floor and selectivity of receiver. Choosing an appropriate VCO for a SWR system is not as simple as finding one with right oscillator frequency. Similarly, it is important to specify the right jitter performance for the ADC. In this paper we will investigate the sources of jitter, shaping of jitter and phase noise by loop filter is discussed and a basic jitter budget is calculated that could assist in the design of SWR GNSS receivers. We examine different ADCs available in the market and compare know performance with the calculated budget. The results obtained are therefore directly applicable to SWR GNSS receiver design.

KEYWORDS: GNSS software receiver, Software Radio (SWR), Software-defined Radio (SDR), Bandpass Sampling, Quadrature Sampling, Analog-to-Digital Converter (ADC), Phase-Locked Loop (PLL), Jitter, Phase Noise, Voltage-Controlled Oscillator (VCO), Signal-to-Noise Ratio (SNR).

0065

The Australian Regional GPS Network Real time and Beyond

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The Australian Regional GPS Network (ARGN) consists of twenty permanent, geodetic quality Continuous Operating Reference Stations (CORS), on geologically stable marks, in Australia and the Australian Antarctic Territory. The ARGN serves two main purposes – Provides and maintains the fundamental Reference Frame for the spatial data in Australia and to provide data for Australia's contribution to Global Geodesy in the study of earth processes such as crustal dynamics, sea level rise and atmospheric research. The ARGN provides data to the International community via the International Global Navigation Satellite Systems (GNSS) Service (IGS). It is this service that Geoscience Australia (GA) provides GNSS data in many different packets, with the latest development in the area of high rate data in near/realtime., for instance the project is now moving into a pilot project phase.

The ARGN has been contributing to a prototype project, Real Time IGS (RTIGS), with over 18 stations streaming the RTIGS format in real time. A by product of this new data stream is that high-rate data is now available to the general public at a 1Hz rate. It is anticipated the availability of higher data rate data from the ARGN will be beneficial to many users.

This paper will talk about recent developments made in the ARGN, detail the products that are now available to the general public, and detail any likely future directions of the ARGN.

0066

The Use of GNSS for Aviation in Australia

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This presentation will cover the background of the development of standards, approvals and training requirements in the use of GPS (GNSS) in Australia and the surrounding region. It will also look at international activities that were used to support the now wide spread acceptance of GPS by the aviation community and highlight the human factor and technical issues uncovered during this work. The use of GNSS as the navigation basis for ADS-B will also be examined.

Some attempt will also be made to predict the way ahead for GNSS based aviation in Australia.

The Proposed Australian Galileo Test Bed

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Galileo, the global navigation satellite system under European control, will consist of a satellite constellation – 27 satellites plus 3 active spare satellites in three orbital planes (space segment), as well as a ground segment for control of the satellites and monitoring of their performance.

The first Galileo Test satellite - GIOVE-A (Galileo In-Orbit Validation Element) - was launched in December 2005 and sends successful Galileo signals to the Earth. The second Galileo test satellite is expected to be launched mid 2006. Given that appropriate equipment is available Galileo signals could be received.

In order to monitor and analyse the Galileo signals in the near future, the Cooperative Research Centre for Satellite Systems (CRCSS) at the Queensland University of Technology (QUT) has proposed a Galileo System Test Bed for Australia, located in Queensland. As key elements, several pilot projects have been identified in order to analyse and demonstrate the Galileo/GNSS performance for specific applications, which are important for the industry in Australia. In October 2004, the Queensland University of Technology and the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) through its Mining Automation Research Group, have together with their European partner EADS Astrium, submitted a proposal for a Galileo pilot project in the context of the European 6 Framework Program (FP6). A decision for this proposal is expected during the first quarter of 2006.

This paper will outline and discuss the concept and aims of the proposed Australian Galileo System Test Bed. It will also briefly describe the associated pilot projects.

0070

Improved mining navigation via pseudolites

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A reliance on GPS-only technology limits the opportunities for automation of mining and transport industries. For example, in a project concerned with the introduction of autonomous haul trucks encountered problems with a lack of GPS satellite availability around a bench and highwall caused stoppages. Further, it was observed that the number of available satellites was observed to decrease as the truck descended down a ramp, and the wall height increased, and the ramp width limited the view of the sky. This was associated with an increase in dilution of precision. When six or more satellites were visible and differential corrections were received, the GPS accuracy was typically less than 30 mm. However, when the minimum number of satellites available to the truck was four, autonomous operation had to be stopped. The advent of the Galileo system will significantly reduce this satellite availability problem. The presence of two satellite constellations will significantly improve the performance of navigation systems within urban canyon scenarios. To date, many investigations into the performance benefits offered by hybrid-Galileo-GPS receivers have been based on modelling and simulation studies. This paper reports on some measurements that were undertaken within Europe and Australia employing pseudolite equipment developed by EADS Astrium GmbH. It is argued that the measured data goes some way towards predicting the availability and accuracy that will prevail when the Galileo system commissioning is completed. The impact of improved availability and accuracy on automation applications is also discussed.

0071

The Australian GNSS Joint Undertaking (AGJU) – Concept and Objectives

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The Queensland University of Technology (**QUT**), the State of Queensland through its Department of Natural Resources and Mines (**NR&M**) and the Australian Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) through its Mining Automation Research Group have signed in January 2006 a Memorandum of Understanding to promote and facilitate the establishment of the Australian GNSS Joint Undertaking (AGJU) as a cooperative arrangement to coordinate opportunities within Australia for exploitation of Galileo. Other research and key industry bodies have already expressed their interest in involvement in the AGJU.

The Australian GNSS Joint Undertaking (AGJU) is the first initiative within Australia, which have already established links to Galileo and European key players. The AGJU aims to provide a focal point within Australia to facilitate maximisation of benefits to Australia from the next generation Global Navigation Satellite Systems and in particular the European Galileo system.

This paper will outline and discuss the concept of the AGJU and its main objectives. Potential stakeholders and key strategic partners have been analysed. The conceptual development and integration process will be described in detail. Finally an overview of initiatives and activities will be given.

0072

A Regional Galileo Integrity Concept for Australasia

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Galileo, the global navigation satellite system under European control will consist of a satellite constellation – 27 satellites plus 3 active spare satellites in three orbital planes (space segment) and a ground segment for monitoring and control of the satellites and their performance. As an integral part of the Galileo design an integrity function has been implemented. This means to have the capability for detection of satellites or system failures and malfunctions and broadcast an integrity information in real-time to the end users. The integrity information will be available for dedicated Galileo services, for instance the safety of life service (SOL) and the public regulated service (PRS) based on a global concept.

Beside the Galileo global integrity concept it is also foreseen that Galileo will support External Regional Integrity Services (ERIS) by dissemination of integrity data via the Galileo satellite constellation. The regional integrity data will be generated by independent external regional integrity service providers. This concept allows regions to generate integrity information, which can be tailored towards specific requirements derived from dedicated applications typical and important for this particular region.

This paper will outline the theoretical background of the Galileo global integrity concept in general. Further, a regional Galileo integrity concept for Australasia will be developed and explained in detail. Based on simulations for the Galileo safety of life service, results for Integrity information based on an Australasia region will be provided and discussed. The paper will finally provide recommendation for the relevant infrastructure for the proposed Australasia region.

0073

Phase Adaptive Integration for GNSS Signals

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When comparing the traditional integration methods of GNSS signals, coherent integration has good sensitivity but high complexity if wide Doppler frequency coverage is needed, while non-coherent integration has low complexity but also lower sensitivity. Also, it is difficult to use long coherent integration if the signal to be integrated is not coherent from time to time.

In our study we found a new method for the GNSS signal integration. The integration process adapts to the shape as well as to the phase of the signal to be integrated. It differs from the pure coherent integration in that it simply integrates the signal without taking care of the phase changes, especially the irregular phase changes. When dealing with the signals from different time intervals, the phase errors and drifts are first corrected based on the signal shape distribution and then the integration is performed. The method can be used to combat frequency drift, and of course, frequency error or Doppler frequency as well.

Computer simulations show that the performance of the method is between that of coherent integration and non-coherent integration. The method converges very fast when the SNR goes up over zero decibel. It means that for nominal level signal, the performance of this method is comparable to coherent integration while the data structure is as simple as that of non-coherent integration. The method is much more robust for long time integration, especially when there is a frequency error or any irregular oscillator drifts.

This method is a complement for the integration process in the GNSS signal acquisition. By using this method, significant hardware savings can be achieved without degrading receiver performance.

A New Receiver Autonomous Integrity Monitoring Strategy for Multi-Fault Exclusion Using GPS and Galileo Constellations

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One of the significant benefits that the dual use of the Global Positioning System and the prospective Galileo can provide is the apparent improvement of integrity performance for safety-of-life and other critical applications. For a user, the doubled number of satellites in view enables simultaneous detection of multiple faults autonomously and robustly.

The existing Receiver Autonomous Integrity Monitoring (RAIM) strategies are to detect and/or exclude the failures, either single or multiple. The method is based on least-square estimation, called fault detection/exclusion (FDE) method. The proposed new strategy is to identify the group of quasi-accurate measurements. The method is also based on least-squares estimation, known as quasi-accurate identification (QAI) method. The philosophy is, if we can identify a group of the “:best” satellites/measurements, which can satisfy the performance requirements for the navigation solution, then we could leave alone the “worst” satellites, regardless of being really problematic or not.

After the new concept is established, the next is the development of the efficient algorithms for identification of the group of quasi-accurate measurements, which is an iteration process, involving the criteria. Possible exclusion of real-accurate measurements would lead to loss of accuracy for the positioning solutions. The question is whether what the level of the cost is and whether the cost is affordable. The paper gives a theoretical answer to this question.

The paper also attempts to demonstrate the above concept and theory using real GPS measurements. To simulate the situation of the future hybrid GPS/Galileo system, the concept of Virtual Galileo Constellation (VGC) is used. Numerical results from several 24-hour GPS RINEX data sets are obtained. It concludes that the QAI method usually excludes more measurements from the navigation solutions, but the solution may not be optimal in terms of positioning accuracy. The FDE may exclude fewer measurements, but the solution may potentially suffer from effects of missed-detection failures. Overall speaking, the QAI method gives more conservative solution, but could lead to a safer integrity decision, whereas the existing FDE method results in more accurate solutions, but could lead to a less safer integrity decision.

Exploring GNSS performance benefits from multiple satellite systems and multiple carrier signals using existing GPS constellations and measurements

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The next generation GNSSs, such as the modernized GPS, the revitalised Glonass and the planned Galileo systems, offer three or more carrier frequencies for civilian use. As far as Real Time Kinematic (RTK) positioning is concerned, significant benefits of three-frequency signals, and multi-GNSS technology and applications, can be expected:

- 1) Allowing ambiguity resolution to be performed at global and regional scales.
- 2) Ensuring correct integers are fixed with much shorter periods of observations.
- 3) Achieving reliable integer solutions using hybrid GNSS constellations.
- 4) Realising RTK positioning in restricted urban areas to support lane-level road navigation.

While the first two potential benefits are dependent on the distance-independence (or distance insensitivity) of future three carrier ambiguity resolution methods, the latter two naturally result from the combined use of all GNSS signals. This paper presents results from theoretical and numerical analyses, demonstrating, to large extent, the abovementioned capabilities using existing GPS measurements. In the analysis, a "Virtual Galileo Constellation" method allows use of GPS data at two separated epochs for performance analysis.

As a result of the studies, the authors establish a theoretical framework for the next generation global, regional and local GNSS services. We also explore the significant impacts of the above technological advancements on future GNSS positioning and scientific applications.

0077

Regional GNSS Satellite Orbit Monitoring for Improved Real Time Zenith Tropospheric Delay Estimations

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Normally only predicted GPS orbit solutions can be made available for real time applications, including GPS broadcast ephemerides. Thanks to the collective efforts in the International GPS services (IGS) community, the predicted part of ultra-rapid GPS orbits can easily achieve the 3D RMS accuracy of 10 cm or better over the prediction arcs from 3 to 9 hours. Because of unpredictable forces, factors and initial state errors, errors in meters and even 10 meters in these predicted orbits are inevitable. In the case of satellite manoeuvre, the orbit biases could be up to hundreds even thousands of metres. These errors must be considered in regional precise applications, such as wide area differential positioning, water vapour estimation and integrity monitoring

The paper develops a short-arc sliding-window orbit estimation strategy to identify larger orbit errors in the IGS predicted orbit solutions in near real time, using the GPS tracking data from a regional GPS network. The idea is to precisely predict the uncertainty estimate of each orbit over a short orbit arc in near real time, which allows users to down-weight the problematic satellites and reduces the effects of orbits errors for improved real time applications. Instead of all parameters, we estimate 6 orbital elements for each satellite. The initial constraints on these parameters are derived from the IGS predicted orbits used. The corrections of the orbit parameters are compared to the default constraints, which are updated and propagated through the data arc used and 1 hour beyond for use in applications in real time.

The paper conducts extensive tests using the GAMIT software, with varying data arcs over the regional GPS network around Australia. Results are evaluated with the final GPS orbits, and zenith tropospheric estimation solutions, to show the improvement compared to the solutions without using the proposed strategy.

It is suggested that the proposed orbit monitoring strategy is a cost-effective solution for regional GNSS positioning services, because fewer organizations in the world can afford to set up a global real time GNSS tracking network, to monitor the GNSS satellites worldwide. In summary, the research provides a technical basis for development of operational strategies for real time ZTD estimation, regional precise positioning services and other applications, including regional integrity monitoring.

0079

An analysis of the temporal correlation of the ionospheric bias affecting GPS carrier phase observations

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Ionospheric effects significantly impede the performance of real-time high-precision Global Positioning System (GPS)-based positioning techniques. The ionosphere is a dispersive medium located between 50 and 1000km above the earth. In this region, ionising radiation from the sun causes fluctuations in free electrons that in turn introduce a frequency-dependent bias on radio signals that pass through it. GPS range measurements made on two frequencies allow for direct correction of the ionospheric bias for point-positioning applications. For precise positioning, where carrier phase measurements are involved, the presence of ionospheric biases limit the operating range of equipment, increases carrier phase ambiguity resolution times, and reduce the reliability of the ambiguity resolution process. Precise positioning performance could be improved with accurate ionospheric models. A number of ionospheric models have been developed over the past few decades. Most models consider the seasonal, diurnal and spatial variation of the ionospheric delay in a global sense, but unfortunately the models are not well suited for precise positioning applications.

Research has been undertaken to quantify the temporal correlation of the ionospheric bias over a regional (150 x 150km) area in Victoria. Seventy-two-hour GPS data sessions were collected at three permanent reference station (GPSNet) sites over four seasons during 2001 and 2002. The Bernese Version 4.2 GPS software was used to process the three baselines, resolving the phase ambiguities and fixing the station co-ordinates. The L4 linear combination known as the Geometry-Free Combination (L1-L2) was used to isolate the double-differenced ionospheric bias values, for each baseline. The ionospheric bias values were then analysed in terms of their temporal correlation. The correlation information provides a better understanding of how well predictive ionospheric models can work. The diurnal and seasonal variation of the ionospheric correlation was also studied and is presented.

Sparse or dense: challenges of Australian network RTK

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This paper introduces recent developments of an Australian Research Council (ARC) project involving researchers from RMIT University, University of New South Wales, University of Melbourne, Land Victoria and the NSW Department of Lands. The aim of the project is to enhance the utility of continuously operating reference station (CORS) networks in the states of Victoria and New South Wales by developing regional atmospheric correction models to support high precision, real-time positioning. The main challenge is that Australia has a large and sparsely populated landmass and dense CORS networks cannot be justified economically. It would be a major step forward if a real-time, high precision positioning service could be reliably deployed over a large area without significantly increasing the density of reference stations.

This paper will describe the current developments in CORS network infrastructure in Australia, in particular *GPSnet* in Victoria and *SydNet* in New South Wales. Major research components of the project will be outlined, addressing both technical and practical challenges. Some methodologies to be investigated will be discussed. The envisaged 'roadmap' of the project and the critical issues associated with appropriate models and algorithms required for network RTK over a large area will be outlined. In addition, various practical solution components, such as software and hardware platform, atmospheric characteristics pertinent to the Australian context, communications, system integration, security, and geodetic reference framework, will also be discussed.

0081

GEMS - GNSS Environment Monitoring System

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GNSS services are used in many critical industrial applications including navigation, positioning, machine control and timing. Applications reliant on GNSS services are vulnerable to failures unless they proactively monitor the GNSS service and take risk-mitigating actions.

A GEMS (GNSS Environment Monitoring Stations) System provides a solution by continuously monitoring GNSS services in a spatial region through a network of collection units. Collected data is sent to a control station for real-time fault, failure, quality and reliability analysis. The control station then issues status information about the GNSS environment.

This paper will describe the GEMS System implementation and test results, including:

- *Hardware Architecture* of the distributed GEMS Slave Units (GSUs) and Master Control Station (MCS) with emphasis on hardware selection to ensure reliability of operation in harsh environments.

- *Software Architecture* of the MCS with emphasis on configurability, extendibility and security.

- *Design, operation and Test Results* from two implemented GEMS Processing Modules (GPMs) – The Signal Quality Monitor (SQM) and Deformation Monitoring System (DMS).

Applications with a critical reliance on GNSS services will use GEMS status information to detect failures, allowing them to take risk-mitigating actions. The use of GEMS status information has the potential to improve the overall safety, reliability and quality of the underlying application despite interruption to critical GNSS services.

0082

E-Trakka

A fully integrated GPS system to assist with horse training

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The horse-racing industry has long been without an effective metric for determining and analysing a horse's performance in the field. Making sure that horses perform to their peak potential requires training sessions that are specifically tailored to their current condition. Issues such as the onset of lameness or illness need to be identified as early as possible to minimise possible harm to the animal. Currently many trainers use heart-rate monitoring equipment for such a purpose; however the data is not able to be easily analysed in the context of the training session. To resolve this issue a system has been developed that uses GPS in conjunction with a heart-rate monitor to enable fast and reliable analysis of each workout.

The horse heart-rate/GPS tracking system comprises of a saddle-blanket unit, rider display unit and a central monitoring station. These components combine to provide both real-time feedback to the rider and trainer, whilst continually logging all data and allowing a full training session to be retrieved and analysed upon completion. Post-processing of this data results in a performance metric that may then be analysed across a number of sessions. Trends in this data can reveal the effectiveness of a training scheme, signify the race readiness of an animal, or give an early indication of injury or illness.

This paper presents an overview of the aforementioned system and examines the key components and the design methodology behind them. System verification and validation results are shown including GPS, radios, compliance, firmware and software. The real-world performance is also examined by comparing the training performance data of a few horses. To date this system has generated a large amount of interest and subsequently has made its way well into the marketplace.

High fidelity 3-D urban model-based signal performance simulation of the current and future GNSSs in Australia

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With the rapid development of spatial infrastructure in US, Europe, Japan, China and India, there is no doubt that the next generation Global Navigation Satellite Systems (GNSS) will improve the integrity, accuracy, reliability and availability of the position solution. GNSS is becoming an essential element of personal, commercial and public infrastructure and consequently part of our daily lives. However, the applicability of GPS in supporting a range of location-sensitive applications such as LBS in an urban environment is severely curtailed by the interference of the 3D urban settings. No investigation has been carried out to accurately quantify and reliably evaluate these improvements in typical 3D Australian urban context, where most human activities are taking place.

To characterize and gain in-depth understanding of such interferences and to be able to provide location-based optimization alternatives, a high-fidelity 3D urban model of Melbourne CBD built with ArcGIS and large scale high-resolution spatial data sets is used to support a comprehensive simulation study of current and future GNSS signal performance, in terms of signal continuity, availability, strength, geometry, positioning accuracy and reliability based on a number of scenarios. The design, structure and major components of the simulator are also outlined. Useful time-stamped spatial patterns of the signal performance over the experimental urban area have been revealed which are very valuable for supporting location based services applications, such as emergency responses, the optimisation of wireless communication infrastructures and vehicle navigation services.

Positioning case studies using RFID and GNSS: indoor and outdoor

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Positioning people and objects is crucial for people mobility and asset tracking, emergency services (e.g. search and rescue), and security and defense applications. These applications may be as simple as continuously tracking the location of a valuable shipping carton or as complex as helping someone (fire-fighters or miners) to find his or her way around an unfamiliar building/underground mining passage.

Wireless positioning techniques have attracted much interest and research recently, since they represent a core enabling technology for a continuously increasing number of mobile locating applications. Indoor location estimation is particularly challenging as GNSS signals are too weak to penetrate into buildings and underground mining passages. Tracking people and objects using alternative techniques is, therefore, desirable for the safety (protection and potential rescue) of the workers/operators.

This paper will investigate the emerging Radio Frequency Identification technology for location determination in combination with GNSS. Typical RFID systems consist of transponders (called tags) with antennas and readers. Long range RFID tags can be placed at known locations and a user who carries a reader can retrieve the tag information (e.g. the 3-D coordinates of the tag) within the read range. The position of the user can be then located using the network of the tags. The read range depends on the type of tag (active or passive). Long range tags are usually active tags with their own power supply and have a possible read range of up to 100 m. To achieve a higher positioning accuracy than 100 m for location determination, the read range can be limited by reducing the sensitivity in the reader.

This paper will present the concept of RFID positioning and their application in two case studies. The integration of RFID with GNSS technology for both indoor and outdoor trackings will be discussed. RFID will be tested in an indoor localization testbed at the Vienna University of Technology and some conclusions will be given.

0088

An analysis of the position calculation accuracy for GPS status aiding of an A-GPS server.

NL HARPER

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Assisted-GPS is an accurate positioning technology that is used for handset location in cellular networks and is gaining traction in the market. When running in MS-Assisted mode, our A-GPS server provides GPS assistance data to a cellular handset. The handset makes the code phase measurements and sends these measurements back to the server to perform the position calculation. The A-GPS server has the opportunity of accessing additional information to improve the position calculation that the handset may not have.

This paper describes a series of experiments that show the impact on the accuracy of the position calculation by including outage information from the United States Coast Guard (USCG) Navigation Center. The USCG Navigation Center reports on the GPS constellation by providing status messages and a web page that reports satellite outages.

An antenna on the roof of our laboratory is connected to a NovAtel GPS receiver. Software connects to the GPS receiver and logs GPS measurements each second. The software also connects to the USCG site and logs the status message each hour. We can then analyse the data off-line.

The analysis consists of pruning satellites from the GPS measurements that the USCG indicates are undergoing maintenance or Delta-V maneuvers and comparing the accuracy of that to other pruning methods. Note that this is not the intended use of the status messages but in this study we decided to look at them to see if they could help.

In this study we have found that during times of reported outage, the RMS error for the satellite increases and it is better to prune satellites based on the measured RMS error than to use the GPS status information.

0090

An Architecture for Satellite Navigation Signal Simulation

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To facilitate the satellite navigation signal simulation, we propose a four-layered architecture: the non real-time layer, the weak real-time layer, the strong real-time layer and the rigid real-time layer.

The top layer is the non real-time layer which has no time constraint. It performs off-line operations such as modeling and model capsulation, data base operations, test task configuration and post data process. This layer operates on PCs connected by LAN so that it is compatible with simulation modeling platforms such as MATLAB; The weak real-time layer provides the user a feeling of real time operation. It includes modules such as simulation management and control, on-line man-machine interaction, data logging, 2D/3D visualization, diagram display and system evaluation. This layer is also based on networked PCs so as to provide user with a powerful user interface by Windows/C++ tools, data base, visualization software; The strong real-time layer has strict real-time constraint. It includes real-time simulation modules such as satellite orbit, user receiver movement, signal transmission link, space environment, navigation message generation, and data transfer module, equipment control module, signal test module. It operates on high speed reflective memory network and Vxworks real-time operating system. It outputs high frequent data of model calculation and simulation result; The bottom layer is the rigid real-time layer. It refers to the modules related to signal generation, including signal generation and delay control, Doppler frequency shift control. The signal output to RF signal modulation. DSP, FPGA and parallel signal processing algorithms are used in this layer.

0091

Carrier Phase and Pseudorange Based GPS/INS Integrated Navigation System for Land Vehicles

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In this paper, we present an algorithm of carrier phase and pseudorange based GPS/INS integrated navigation system, especially for land vehicles such as car, construction machines etc. The integration algorithm in this paper is developed as it efficiently combines the FOG (Fiber Optical Gyro) level IMU (Inertial Measurement Unit) and GPS information. There exist many research activities on integrated navigation systems that are referred to as “loosely coupling” and “tightly coupling” schemes. In recent researches, generally, the loosely coupling method uses the GPS position and velocity solutions to measure the INS errors. And the INS errors are estimated and corrected. On the other, in the tightly coupling method, the GPS raw data such as carrier phase and pseudorange measurements are utilized not only for estimating the INS errors but also for aiding the receiver e.g. carrier tracking loop. The advantages of use of raw GPS data rather than position and velocity solutions are: it can be operated even if there are not enough number of satellite to provide position solution, and it can efficiently utilize the accuracy and smoothness of carrier phase measurement. And with the tightly coupling method, the highest navigation performance can be achieved. On the contrary, the architecture of the system becomes considerably complex, and the special receiver hardware is required. In this paper, therefore, we try to develop the navigation system based on the concept of the loosely coupling method, but the GPS raw data are utilized to estimate the INS errors. The presented algorithm utilizes the advantages of the GPS raw data. Also we consider the case of land vehicle applications, so that the algorithm is derived as it is easy to apply the external data such as odometer, steering angle sensor etc. Some experimental results by using simulated data as well as real data collected in an running car will be also shown. The presented algorithm may achieve the positioning accuracy within decimeter level in various circumstances.

0092

Precise Point Positioning based on GR Models –Further Results in Single Frequency Applications

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In this paper, we present a new approach for carrier-phase-based precise point positioning (PPP) algorithm without linear combinations of the pseudorange or the carrier phase measurements and investigate its positioning accuracy through some experiments under various circumstances. In the traditional PPP processing methods, the following techniques are commonly applied in order to mitigate the errors and noises in measurements: ionosphere-free pseudorange and phase combinations, precise satellite orbit, clock and ionospheric correction provided from some organizations e.g. IGS(International GPS Service), troposphere models, and pseudorange smoothing techniques as pre-processing of the positioning. On the other hand, the concept of our PPP algorithm is based upon what we call GR (GNSS Regression) matrices as well as GR equations. With the concept of GR equations, the all possible error sources in the positioning are modeled or taken into account stochastically. And the unknown quantities are estimated by applying Kalman filtering method. Consequently, the algorithm can be implemented without external information as much as possible. Also the advantage of this method is it does not require the linear combinations of the multiple frequency measurements. In other words, it can be performed even if there exist only single frequency measurements. Therefore the algorithm has the ability to be widely utilized. We also show the positioning results of the derived PPP algorithm through experiments using real receiver data. It achieves the positioning accuracy in decimeter level, and will be possibly centimeter level in both of static and kinematic cases.

0093

Detection of Abnormal Pseudorange and Carrier Phase Measurements in GPS Precise Point Positioning

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This paper proposes an abnormal measurement detection algorithm for the GPS positioning. The algorithm is formed as it is better suited for operating in precise point positioning (PPP). Generally, the accuracy of PPP is achieved by using the carrier phase measurement, precise satellite orbit and some error mitigation techniques based on error models or linear combinations of the measurements for example ionosphere free combination. However, there are problems. The dominant error sources in GPS positioning are ionospheric and tropospheric effects, multipath and cycle slips. And there exist many research activities that investigate the errors individually. In practice, however, we need to deal every possible error to hold the accuracy high. Also there may exist remaining errors even if the error mitigation techniques are applied. Therefore, in this paper, we try to construct an abnormal measurement detection method which can work for various error sources. As far as we know, the existing error detection methods can fall into three types; namely positioning domain, measurement domain and both. The concept of our algorithm presented in this paper is based on the integration of these types of detection methods. The test statistics are formed by the positioning solution, measurement combination and innovation processes of Kalman filter which is utilized to estimate the unknown quantities such as position and ambiguities. The detection procedure is implemented at every measurement epoch. And if abnormal measurements are detected, they are eliminated or less weighted for positioning by the developed algorithm in this paper. Several experimental results for static and kinematic environment will be also shown.

0095

Relativistic GPS and quantum approaches to clock synchronization. How these could be combined?

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Time keeping is at the core of any Global Positioning System (GPS.) Effects that are related to clocks' rate and synchronization must be considered in the designing of such systems. Between them are relativistic effects on clock's rate and classical limits to clock synchronization. From the very beginning of the life of GPS, It becomes clear that we need to consider the predictions of Special and General Relativity for the system to work properly. For example, at today's accuracy of position determination, we have to deal with the relativistic Doppler shift and the gravitational shift. If we wish to improve the accuracy in the position then we have to take in account relativistic effects of higher order. A possible way to deal with this torrent of corrections is to build an intrinsically relativistic GPS. For the relativistic system we don't have to look for new unknown corrections each time we upgrade the clocks. In addition to keep the right track of the clocks rates, we need the clocks to be synchronized. Classical procedures to synchronize clocks are based on repeatedly sending electromagnetic pulses through space and measuring the time delay of arrival. The accuracy of such methods is limited by available bandwidth and power. Experiments show that it is possible to use quantum mechanic to overcome these limitations. Here, we present a discussion about the feasibility for a fully relativistic and quantum synchronized GPS.

0097

Geographic Information Mapping for Email Services

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Since GPS (Global Positioning System) became available for civilian use in 2003, GPS data applications have been widely used in navigation, surveying, and precise time reference. The beauty of GPS system is no time, weather, and location limitation. GPS receivers have been installed in cars, boats, planes, construction equipment, computers, PDAs, and even mobile phones and cameras. Google Earth is one example of GPS data applications that overlays satellite imagery, aerial photography and GIS (Geographic Information System) information over a 3D model of the Earth. Google Earth provides a platform allow people to allocate information geographically. On the other hand, Internet has become a collection of resources and infrastructure for modern offices. Although Internet provides many advantages, it still lacks of geographically localized information. For example, Email, as a part of Internet services, has become the most popular communication tool for business but organisers for meetings and conferences cannot establish locations of their presenters and attendee from their Email addresses unless they have knowledge of their companies' geographic locations.

In this paper, we will present a XML-based application to combine GPS and Internet technologies to mapping Email addresses visually on the Google Earth. It can decrease search times and increase visibility of local establishments and offer the ability for users to make decision based on geographic location. First Email addresses are extracted from in existing address books. Secondly their domain names associated with Email addresses are converted to IP addresses. Then these IP addresses are calculated and their corresponding geographic coordinates are determined. Finally Email addresses are mapping visually on Google Earth.

0098

Improved Multipath Model Validation in Semi-Urban, Aircraft, and Shipboard Environments

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A comprehensive GNSS multipath model has been developed and previously validated in several environments [1,2]. The model utilizes computer aided design (CAD) drawings in combination with satellite ephemerides, 3D ray-tracing algorithms, and detailed antenna and receiver models to predict code and carrier phase multipath. The complete model is comprised of five modules. 1) The satellite motion module uses ephemeris data to compute satellite locations with respect to the receiving antenna, known as the prediction point, at each epoch. 2) The environment module defines the reflector environment and is typically created using software such as AutoCAD®. Separate electrical properties may be specified for each individual surface or for groups of surfaces. 3) The ray-tracing module computes the paths and interactions of rays from the satellite to the prediction point. The user specifies how many reflections, diffractions, and transmissions are considered. The output of this module includes the following for both the direct and multipath signals: time of arrival, angle of arrival, power, and number and type(s) of interactions. 4) The ray-antenna module applies the receiving antenna pattern and determines the multipath signal delay, relative amplitude, and relative phase. This module utilizes right-hand and left-hand circularly polarized antenna gain and phase patterns. Both fixed radiation pattern antennas and controlled radiation pattern antennas may be simulated. 5) The tracking loop module simulates the receiver front-end and code/carrier tracking loops. Adjustable parameters include the front-end bandwidth, ranging code type (P, C/A, BOC, etc.), delay lock loop type, early-late spacing, and receiver noise model. The tracking loop module output is the code and carrier tracking error due to multipath.

This paper presents recently updated code multipath validation results for three static environments. These are the University of Colorado Engineering Center rooftop, a stationary F-18 jet, and the aircraft carrier USS Eisenhower. For each, at least 12 hours of experimental and simulated GPS multipath data at the L1 frequency are compared on the basis of code multipath time histories and overall error statistics summaries. The rooftop, F-18, and aircraft carrier environment models were developed based on detailed scale drawings and/or measurements and include 48, 752, and 748 surfaces, respectively. The ray tracing computations consider up to two reflections and one diffraction (or combination thereof). The receiver system is modeled to match the experimental system as closely as possible. Receiving antenna gain and phase models are derived from anechoic chamber measurements provided by the manufacturers. Receiver tracking is modeled such that all parameters are matched to the real receiver as closely as possible. The results of these studies are promising. Experimental and simulated multipath time histories often show good agreement in terms of magnitudes, frequencies, and times of activity. Overall comparisons of multipath error statistics show that the model accurately captures elevation-dependent elevation error magnitudes and trends. For example, the aircraft carrier statistics agree to within 15%.

These results are significant for several reasons. First, the simulations establish that the model is able to accurately capture the character of multipath errors in a variety of environments. The results also demonstrate that mismatches between the experimental and simulated data are to be expected due to the complexities involved in modeling the environment geometries, receiving antenna, and receiver tracking system. Nonetheless, these studies show that the model can be used to identify multipath sources and that it is possible to predict multipath errors in these types of environments. Finally, validated simulation scenarios make it possible to investigate the multipath performance of other receiver equipment or future ranging sources such as the L5 civil signal in controlled and realistic settings.

0100

SunPOZ : Enabling Centimetre Accuracy GNSS Applications in Queensland

Mr Garry Cislowski and Mr. Matt Higgins

Department of Natural Resources, Mines and Water

The Department of Natural Resources Mines & Water (NRM&W) has established a network of Continuously Operating Reference Stations (CORS) using the Trimble Virtual Reference Station (VRS) technology. Currently covering South-East Queensland, the service provides centimetre accuracy in real time for surveying, machine guidance and other high accuracy applications. Possibilities for expansion are currently being addressed. Testing to incorporate hardware and software from Leica Geosystems has also begun.

The paper will report on the advantages to users of the CORS approach being greater reliability, improved flexibility and increased productivity. SunPOZ has been used in applications as diverse as setting out rowing courses, photogrammetry and road construction. The service offers both real-time and post-processed products. The real-time service has seen field productivity increases of between 30% to 50% depending on the particular application. A number of case studies will look at the performance of the SunPOZ service as well as productivity. While the current applications for SunPOZ are in the surveying arena there are expanding applications in the areas of machine guidance for mining and construction as well as precision agriculture and asset management.

The robustness of GNSS has been given a boost by the resurgence of GLONASS as a viable satellite positioning system. This together with the pending Galileo system will have a significant impact on the usability of GNSS and services such as SunPOZ in difficult sites like open cut mines.

0102

Agricultural Opportunities of Precision (2cm) Navigation

J.N.Tullberg, D.F.Yule, T.Neale, W.Chapman

Control Traffic Farming Solutions

Controlled traffic was a major step in improving cropping systems by restricting all heavy field traffic to permanent lanes. It was the original stimulus for applying RTK GPS to tractor guidance, which is now an important facilitator of Controlled Traffic Farming (CTF)—an Australian development providing dramatic improvements in the sustainability and productivity of cropping.

Applying management inputs in precisely the right place and at the right brings obvious direct benefits to crop production. There are also a number of 'system' benefits of precision CTF which are less obvious but extremely important. This paper briefly describes both categories of benefit, and the importance of GPS guidance in achieving them.

High-precision (2cm RTK) GPS guidance is the key to straightforward operation of CTF Systems. It is the basis for economic 5cm contour topographic mapping required to design field layouts which prevent runoff concentration and minimise soil erosion while optimize drainage and efficiency. A range of other exciting possibilities are summarised here, indicating that this technology is the sleeping giant of 'precision' agriculture.

Agriculture is a very large potential market for manufacturers of precision guidance/navigation/surveying technology, but also presents the challenges of a widely dispersed and unsophisticated environment. This is probably the reason why current agricultural systems are all sold with their own base stations, which increase the cost of this technology by 20 – 30%.

Differences in base – rover communication systems currently prevent widespread sharing of base stations, and will slow the uptake of wide area high-precision CORS networks. This paper advocates a cooperative approach to provide major benefits for both farmers and manufacturers.

KEYWORDS: CTF, CORS, Precision Agriculture,

IGNSS 2006

Presenters List

Ordered by Speakers Name



First Name	Last Name	Organisation	Paper No.
Bilal	Amin	The University Of New South Wales	64
Joel	Barnes	The University Of New South Wales	12
Jan	Blachowski	Wroclaw University Of Technology	25
Troy	Bruggemann	Qld University Of Technology,	46
Stefan	Cacon	Agricultural University Of Wroclaw	24
Garry	Cislawski	Department of Natural Resources & Mines	100
Laura	Connolly	BAE Systems	21
Peter	Cooke	University Of Adelaide	42
Argenis	Da Silva	Louisiana State University	95
Andrew	Dempster	The University Of New South Wales	40
Andrew	Dempster	The University Of New South Wales	43
Andrew	Dempster	The University Of New South Wales	51
Jacqueline	Denham	Department of Sustainability and Environment, Spatial Information Infrastructure	41
Liam	Densley	RMIT University	84
Weidong	Ding	The University Of New South Wales	35
Murray	Dolling	Department Of Land Administration	48
Gary	Einicke	Mining Automation Research Group	68
Gary	Einicke	Mining Automation Research Group	70
Bernd	Eissfeller	University FAF Munich	58
Mark	Elsegood	Australian Communications And Media Authority	33
Werner	Enderle	Queensland University Of Technology	69
Werner	Enderle	Queensland University Of Technology	71
Werner	Enderle	Queensland University Of Technology	72
Yanming	Feng	Queensland University Of Technology	75
Yanming	Feng	Queensland University Of Technology	76
Camden	Fitzgerald	University Of Sydney	11
Roger	Fraser	Department of Natural Resources & Mines	47
Seigo	Fujita	Ritsumeikan University	92
Cristian	Gordini	Department Of Geomatics	9
Duncan	Greer	Queensland University Of Technology	52
P.M	Grgich	University Of Melbourne	32
Rajneesh	Gupta	Isro	44
Martin	Hale	Department Of Sustainability & Environment	7
Mark	Hardman	OmniSTAR Pty Ltd	29
Neil	Harper	Andrew Corporation	88
Usman	Iqbal	The University of New South Wales	31
Hiroshi	Isshiki	Institute Of Mathematical Analysis (IMA)	18
Toshiaki	Iwata	National Institute Of Advanced Industrial Science And Technology	8
Minghai	Jia	Geoscience Australia	45
Gary	Johnston	Geoscience Australia Earth Monitoring Group	65
Goetz	Kappen	Chair Of Electrical Engineering And Computer Systems	62
Yukihiko	Kubo	Ritsumeikan University	91
Yukihiko	Kubo	Ritsumeikan University	93
Yong	Li	The University Of New South Wales	28
Ge	Li	Institute For Automation	90
Jose	Lorga	TUDelft (Delft University Of Technology)	23
Rob	Lorimer	Position One Consulting	17
Ashley	Mallia	GPSat Systems Australia Pty Ltd	81
Keith	McPherson	Airservices Australia	19
Keith	McPherson	Airservices Australia	20
Peter	Mumford	The University Of New South Wales	5
Peter	Mumford	The University Of New South Wales	6
Peter	Mumford	The University Of New South Wales	59
Patrick	Oppenlander	GPSat Systems Australia Pty Ltd	82
Anuj	Pahwa	The University Of New South Wales	14

IGNSS 2006

Presenters List

Ordered by Speakers Name



First Name	Last Name	Organisation	Paper No.
Sang Hyun	Park	Korea Ocean R & D Institute	55
Zd	Qin	Nokia	73
Chris	Rizos	The University Of New South Wales	15
T	Sakai	Electronic Navigation Research Institute	60
Asghar	Tabatabaei Balaei	The University Of New South Wales	49
Fabrizio	Tappero	The University of New South Wales	39
Peter	Terrett	Rapid Map Australia	27
Jeff	Tullberg	Control Traffic Farming Solutions	102
Jinling	Wang	The University Of New South Wales	38
Jianguo Jack	Wang	The University Of New South Wales	54
Jan	Weiss	University Of Colorado	98
Jorge	Woods	Civil Aviation Safety Authority	66
Falin	Wu	RMIT University	36
Scott	Wyllie	RMIT University	79
Thomas	Yan	The University Of New South Wales	26
Susumu	Yoshitomi	Japan Aerospace Exploration Agency	56
Sharzil	Yousufi	RMIT University	13
Kefei	Zhang	RMIT University	80
Kefei	Zhang	RMIT University	85
Jing Yuan	Zhang	Victorian University	97
Yi	Zheng	Queensland University Of Technology - CRCSS	77