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Research Activities on the Locata Technology at the University of New South Wales

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BIOGRAPHY

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Joel Barnes is Senior Navigation Engineer for Locata Corporation, and is also a Senior Visiting Research Fellow at the University of New South Wales, Australia. He obtained a Doctor of Philosophy in satellite geodesy from the University of Newcastle upon Tyne, UK. Joel has assisted in the development of the *Locata* receiver and testing of the *Locata* technology since 2000, whilst working at UNSW as a research fellow. He formally joined Locata Corporation in 2007, and currently his research is focused on navigation algorithm development and error modeling.

Andrew Dempster is Director of Research in the School of Surveying and Spatial Information Systems at the University of New South Wales. He led the team that developed Australia's first GPS receiver in the late 80s and has been involved with satellite navigation ever since. His current research interests are GNSS receiver design, GNSS signal processing, and new location technologies.

Chris Rizos is a graduate of the School of Surveying, UNSW; obtaining a Bachelor of Surveying in 1975, and a Doctor of Philosophy in 1980. Chris is currently Professor and Head of School. Chris has been researching the technology and high precision applications of GPS since 1985, and has published over 200 journal and conference papers. He is a Fellow of the Australian Institute of Navigation and a Fellow of the International Association of Geodesy (IAG). He is currently the Vice President of the IAG and a member of the Governing Board of the International GNSS Service.

Nilofer Tambuwala is in her final year of double degree in Bachelor of Geomatics Engineering and Bachelor of Science. She is currently working part time at LogicaCMG in the spatial information. She aims to start postgraduate study next year.

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ABSTRACT

Early in 2007 the University of New South Wales established a permanent *LocataNet* installation at the University campus. The purpose of this network is to establish a research and test facility at UNSW devoted to *Locata* technology. This paper will discuss details of the *LocataNet* established at UNSW, and present results and analysis of some of the current research under investigation. These activities include the development of navigation processing software for processing data from the *Locata* receiver, signal propagation studies, and testing of the *Locata* technology in applications areas such as structural monitoring and positioning indoors. Several other future research topics are described and the motivation behind them is detailed.

INTRODUCTION

GNSS is undoubtedly the most popular and widely used 3D positioning technology today, providing 24/7 position, velocity and timing (PVT), with accuracies ranging from the 10 metre-level (using standard pseudorange single point positioning) to the centimetre-level (using differential carrier-phased based positioning). Despite this versatility, GNSS cannot provide the positioning requirements in many applications in surveying, machine control and everyday applications, such as open-pit mining, structural monitoring and indoor positioning. This is because the ranging signals from the satellites (at an altitude of approximately 20,000km) are severely attenuated when they reach ground-based receivers, and thus can be easily obstructed by buildings, walls, trees and terrain etc. Therefore the performance of GNSS is severely degraded under challenging operational environments such as monitoring dams in steep sided valleys, and positioning in deep open-cut mines, etc. Moreover, even if there are enough GNSS satellites available for positioning (at least 4 or more) in many applications the satellite geometry provided by the satellite constellation is insufficient for positioning accuracy requirements. This is especially true where satellite signals are masked at low-mid elevation angles, as in dams and open-cut mines. In the future with the increased number of satellite ranging signals (through GLONASS and Galileo) positioning availability will increase, but the accuracy will fail to meet requirements in many 'difficult' environments due to poor satellite geometry (dilution of precision DOP). Thus unless positioning signals from a lower elevation can be received (to improve geometry) the position solution will not be accurate enough for many applications.

Locata's positioning technology solution can be used an alternative to GNSS in 'difficult' GNSS environments, whereby a network of terrestrial based transceivers (*LocataLites*) transmit positioning signals. These transceivers form a positioning network (*LocataNet*) that can operate in combination with GNSS or entirely independent of GNSS. One special property of the *LocataNet* is that it is time-synchronous, allowing single point positioning with potentially cm-level accuracy. The *LocataLites* transmit their own proprietary signal structure in the 2.4GHz ISM band (license free) to ensure complete interoperability with GNSS. This allows enormous flexibility in the system design due to complete control over both the signal transmitter and the receiver. Further details of the current system design have been detailed previously in [1].

UNSW SETUP

In early January 2007, a small semi-permanent *Locata* network (*LocataNet*) was set up at the University of New South Wales (UNSW) in order to conduct different experiments using the system. The term *LocataNet* describes a network of *LocataLites* (at least four *Locata* transceivers) that transmit the positioning signals (in the 2.4GHz ISM band). Typically a *LocataNet* is deployed around the area where the *Locata* positioning signals are required. Once a *LocataNet* is established a *Locata* receiver (or rover) can determine its position independently of other positioning technologies (GNSS etc).

The *LocataNet* established at UNSW is illustrated in Figure 1. It consists of 10 *LocataLites* situated on top of three buildings. The *Locata* receiver antenna was situated on the roof of the Electrical Engineering building (Elec. Eng in Figure 1), and the distance from the *Locata* receiver antenna to *LocataLites* ranged from approximately 5 to 80 meters. Each *LocataLite* (LL) was assigned consecutive PRN codes (except LL8), starting from the "Master" in a clockwise direction. In operation, the "Slave" *LocataLites* 2-10 time-synchronize to the "Master" *LocataLite* 1. A *Locata* receiver using these positioning signals can compute a carrier-phase single point position with cm-level accuracy (without requiring a differential reference receiver and data links).

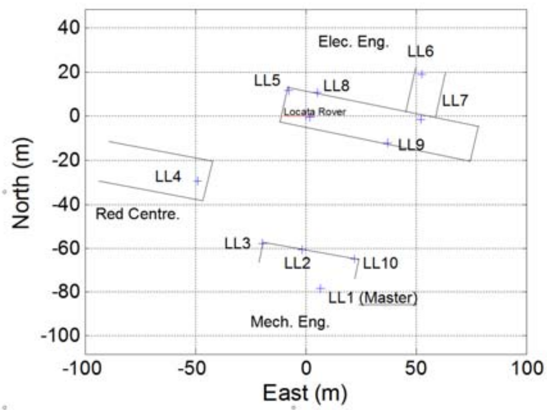

Figure 1: *LocataNet* of 10 *LocataLites* established on the roof-tops at UNSW

Each of the *LocataLite* sites consists of three main components: a pole with three antennas attached, a *LocataLite*, and a power source. For a fully operational *LocataLite* utilizing spatial diversity, two transmitting antennas and one receiving antenna are required. In the UNSW setup, directional patch antennas with beam width of 70 degrees were used for both transmission and reception. The transmitting antennas were positioned towards the rover antenna work area and attached to a vertical pole with a separation of approximately 75cm; the receiving antenna was directed towards the "Master" *LocataLite* and mounted just below the top of the transmitting antenna (see Figure 2).

The *LocataLites* were enclosed in customized weatherproof boxes, allowing for external connections to the antennas, data communication ports and power sources. The external interface is then wired to the *LocataLite* inside, as shown in Figure 2.

With the exception of the “Master” *LocataLite*, which operated on a mains power source, the *LocataLite* locations were powered by 12V/55AH batteries, which allowed a continuous run time of over 24 hours per battery. Y-splitters were connected to the power cables, which enabled the connection of a replacement battery in parallel to the exhausted one before disconnecting the latter, thus providing uninterrupted power to the *LocataLites*.

Figure 2: *LocataLite* (LL5) antenna setup (left) and weatherproof enclosure (right)

The coordinates of the transmitting antennas were surveyed using a combination of carrier-phase differential GPS (using Leica System 500 processed using Leica Geo-Office) and a reflectorless total station.

During early January to mid February the *LocataNet* was in continuous operation for several days at a time, without any network failure.

LOCATA RECEIVER ANALYZER

As Locata is a new technology, there are no tools readily available to perform analysis on the receiver outputs in a simple and convenient way. The UNSW *Locata* research team therefore developed the “Locata Receiver Analyzer” (LRA) – an easy to use utility that parses the receiver outputs and displays scatter plots, *LocataLites* position, SNR bar graphs and various statistics on a computer screen using a graphical interface.

In current stage, the *Locata* receiver outputs data on two serial ports simultaneously. The output messages for each of the serial ports can be configured to be one of few different types. In order to fully utilize LRA, the following two message types are used: the first is a standard NMEA GPS-like positioning message type that mainly describes the position solution along with information about the solution type, number of LocataLites being tracked, DOP values and timing information. The second is a *Locata* specific type that outputs raw data measurements such as pseudoranges and carrier-phase, as well as channel tracking information, signal-to-noise ratios and other internal debugging information.

A sample screen shot of LRA’s main screen is shown in Figure 3. The majority of the screen is dedicated to the 2D scatter plot. The position of the middle point of the plot and its scale are configured through the setup screen (shown in Figure 4). The plot also consists of three colored rings around the middle point (inner ring in blue, second ring in red and the outer ring in black). The rings ranges can be configured as well in order to assist visualizing the limits of the scatter plot. In the example given here, the three rings are configured to the ranges of 1cm, 2cm and 5cm respectively. The majority of the position solutions in this case are within 1cm of the middle point with only a few points between 1cm to 2cm and no points outside the 2cm range.

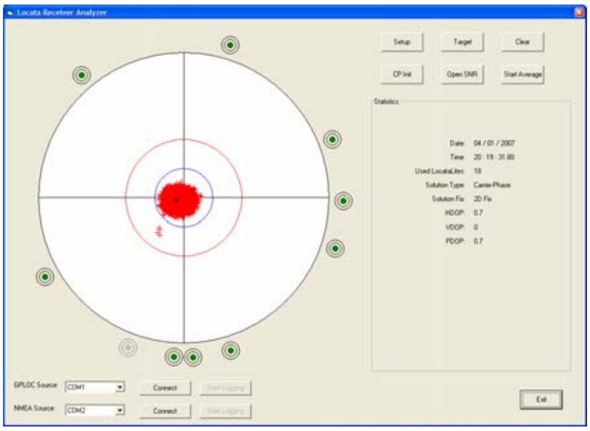

Figure 3: LRA sample screenshot

The *LocataLites* coordinates are read from a textual setup file upon the program startup. This information is used to visualize the geometry of the network in respect to the receiver position. The different *LocataLites* are drawn around the scatter plot to illustrate the incoming signals direction. Each *LocataLite* symbol can be in one of three states, represented by different colors: a green symbol indicates that the rover is tracking both PRN codes transmitted by its respective *LocataLite*; a red symbol indicates that only one of the two PRN codes is being tracked whilst a dimmed gray symbol specifies that the *LocataLite* is not being tracked by the receiver.

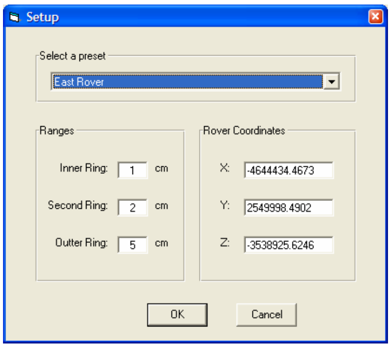

Figure 4: LRA setup screen

Various textual statistics is displayed on a panel to the right of the scatter plot. This information includes *Locata* time, number of tracked signals, position solution type (i.e. code or carrier-phase solution), HDOP, VDOP and PDOP values, average position, average error from the middle point and its standard deviation. LRA can work both in real-time when it is connected to the rover or as a post-process by reading log files captured in previous sessions. New features are added to the utility as required by different research experiments.

LONG TERM STATIC TEST

UNSW has conducted several experiments for deformation monitoring applications. In such applications, the monitored structures are generally relatively static and it is any deviation from this state that requires early detection. The long term stability of a positioning solution is therefore critical for deformation monitoring applications and thus, the *Locata* system was tested for such stability. For the purposes of this test, the network setup described earlier was used. The *Locata* receiver's omni-directional antenna was mounted on a tripod (shown in Figure 5), and the *Locata* receiver was located in an office below via a 30m low-loss coaxial antenna cable.

Figure 5: The Locata receiver antenna setup

The *Locata* receiver in the office was connected to a laptop computer via two serial ports. After powering up the receiver, the *LocataLite* signals are acquired and tracked within 10s of seconds. For a single point carrier-phase solution the receiver currently requires initializing at a known point to resolve the carrier-phase ambiguities. When *LocataLites* transmit on a second frequency in the 2.4GHz ISM band (expected in the next few months) the *Locata* receiver will be able to resolve ambiguities On-The-Fly. The coordinates of the *Locata* receiver were surveyed using differential GPS, at the same time as the *LocataNet* survey was conducted.

The receiver was initialized via a command through the laptop and then the receiver output single point carrier-phase solutions at a 1Hz rate in the NMEA format, which was logged and visually displayed. In addition to this the real-time position solution, raw data (containing pseudorange and carrier-phase) were logged. Data in this particular test were collected for approximately 13.5 hours. Due to the fact that the elevation angles to the *LocataLites* from the receiver location are all less than 8 degrees, the geometry in the vertical is very poor. The following results will therefore concentrate on the horizontal component.

Figures 6 and 7 show the horizontal scatter plot of the position error (with respect to the true position surveyed using GPS) and the individual East and North positioning error components. The mean position error in both East and North are less than 1mm and the standard deviation in East and North was 2.1 and 1.5mm respectively. The slightly larger standard deviation in the East component is due to the fact that the dilution of precision in the East-West (0.543) component is slightly worse than the geometry in the North-South direction (0.530).

Visually from Figures 6 and 7 it is clear that the overall precision and stability of the position solution is very good over the 13.5 hour period with no evident long term drifts. However, there are approximately 7 position solutions (out of ~48600) that could be considered as outliers, and the largest with a maximum error of 2 cm in the North component. *LocataLites* internally monitor their time synchronization integrity. If the time synchronization is not within specification the *LocataLite* takes steps to ensure the *Locata* receiver "sees" the signal as "unhealthy". However, in this particular *LocataNet* the distances from the *LocataLites* to the rover are very short (5-80 meters). At this distance it may have been possible for a rover to occasionally track "unhealthy" signals. On a *LocataNet* with distances of several hundred meters to the rover this is not likely to be an issue. In addition, these are "single events", so they could be easily removed using a filter or using data snooping techniques.

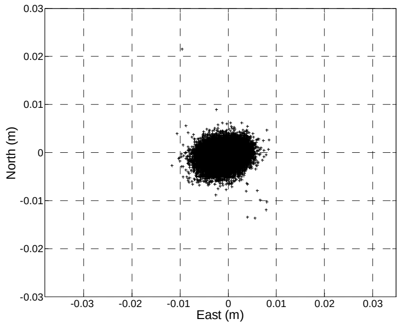

Figure 6: Horizontal error scatter plot for long term (13.5 hour) static positioning test

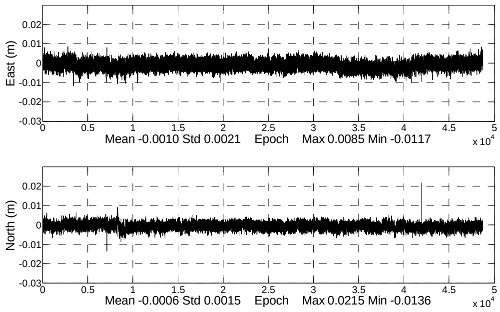

Figure 7: East and North error for long term (13.5 hour) static positioning test

SIMULATED DEFORMATION MOVEMENT TEST

In some structural deformation monitoring applications (such as for bridges) the positioning technology used must be able to detect centimeter to millimeter level movements. The purpose of this test was to establish if the accuracy of the *Locata* technology allowed one centimeter level movements of the *Locata* receiver's antenna to be detected.

For the purpose of this test, the rover antenna was required to move accurately over a small distance in a pre-defined pattern. The process needed to be automated and repetitive in order to test the system over a long-term period. To satisfy these requirements a HP XY plotter table was used. Both a *Locata* receiver antenna and a Leica GPS system 500 AT502 antenna were mounted to the printing-head of the plotter (as shown in Figure 8). The use of such a plotter enabled control of the device using a serial port connection to a laptop. The plotter supports the HPGL graphic language and thus, by creating appropriate computer scripts, it allowed the automation, repetition and accuracy of movement which was required.

The plotter, with the antennas attached, was placed on a leveled table on the roof of the Electrical Engineering building near the *Locata* rover antenna used in the static test. This location had a clear line-of-sight to all surrounding *LocataLites*. The coordinates of the *Locata* receiver antenna at the centre of the plotter table was surveyed using a reflectorless total station. In addition the plotter table was orientated so that the X and Y axes were as closely aligned with true North/South and East/West as possible.

It was decided to make this test more "challenging" by only using five of the *LocataLite* locations and thereby making the network geometry worse (and more "real world"). The five *LocataLites* used were LL1, LL4, LL5, LL7 and LL8. Conducting the test in a similar way to the static test, the *Locata* receiver was first initialized at the know point and the receiver then output positions at a 1Hz rate. After one minute, both antennas were moved 1 cm in the West direction. After one minute of static data collection, the antennas were moved a further 1 cm to the West. This procedure was repeated until the antenna was 12 cm to the West of the initial position. The antenna was then moved 1cm to the East repeatedly until the antenna was a full 12 cm East of the initial position. The antenna was then moved by 1cm steps in the West direction again until the antenna was back at the initial start location. The procedure described above was then repeated giving a total of 149 static points (each with 1 minute of data), with the entire test taking approximately 2.5 hours to run.

The GPS receiver data was post-processed using Leica Geo Office relative to an MC500 Leica GPS reference station with an AT504 choke ring antenna, located approximately 55 meters from the test area.

Figure 8: HP XY plotter table with Locata and Leica AT502 antennas

Figures 9 and 10 show the epoch-by-epoch position solutions from *Locata* and GPS for the horizontal trajectory and in East/North components. Visually from the figures the *Locata* solution is more stable and repeatable than the GPS solution. The *Locata* position solution has consistent positioning geometry with a HDOP of 0.64 with 5 *LocataLites*. In comparison the GPS HDOP varies from 1.5 to 4.1 with 5 to 9 available satellites. The section of poorer GPS geometry can easily be seen in the middle section of the data for the North component.

For the *Locata* North time series there is a repetitive pattern of movement in the North direction (as the antenna moves East-West), with a maximum deviation of about 2.5 mm. There are two possible explanations for the repetitive movement in the North-South direction. First, the error could be due to the actual movement of the plotter head. The second possible reason is multipath error. In an RF-based terrestrial positioning system the multipath error at a particular position in the network will have a similar multipath error if the same position is reoccupied. This is assuming the transmitter locations and local factors (buildings etc) do not change. The repetitive nature of the error signature in this particular test suggests that it may be possible to reduce the multipath error in a relatively static environment through calibration, although further investigations would be required to verify this.

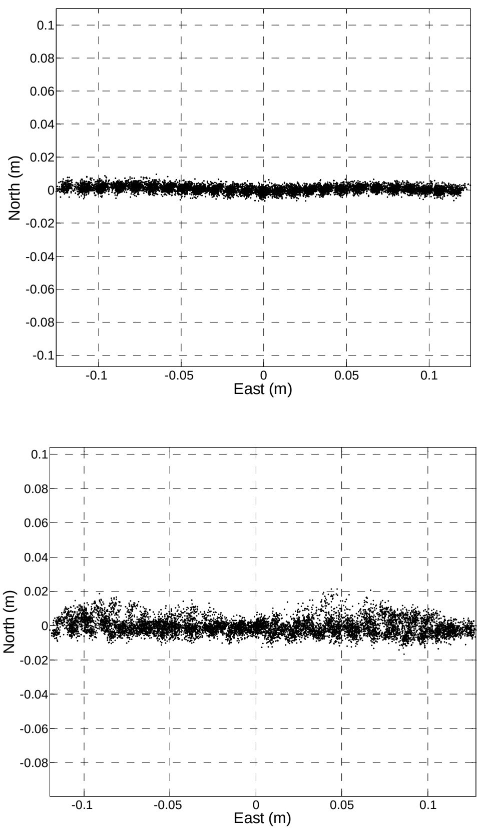

Figure 9: Horizontal trajectory: Locata (top), GPS (bottom)

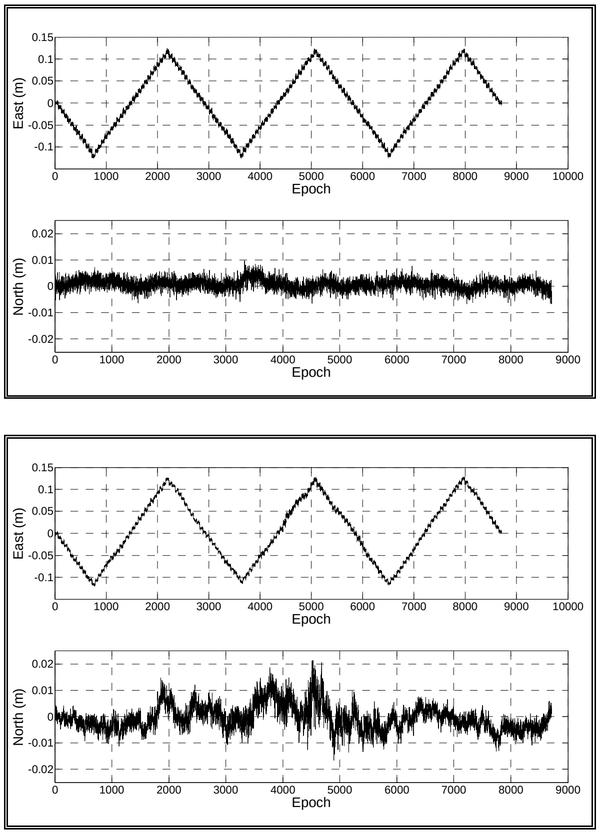

Figure 10: East and North time series: Locata (top), GPS (bottom)

The mean static position and standard deviation of each location was computed (from each 1 minute of static data) for the *Locata* and GPS solutions. The East and North standard deviation of each static point for *Locata* and GPS is shown in Figure 11. For *Locata* the largest standard deviation in the East and North coordinate components was 3.2 mm and 1.2 mm respectively, with the smaller North component being due to better geometry (lower DOP). For GPS the largest standard deviation in the East and North coordinate components was 4.0 mm and 5.3 mm respectively, which are correlated with the section of worse satellite geometry.

The distance 'traveled' with each 1 cm step was computed based on the mean position values, and the error computed, assuming a 'true' step value of 1cm. Figure 12 shows the error in the distance moved with a maximum error of 2.9 mm for *Locata* and 7.2 mm for GPS. This indicates that a 1 cm move can easily be detected using *Locata*, but for GPS cannot always easily be detected due to the varying satellite geometry. In addition the *Locata* solution can be improved by positioning the *LocataLites* in a more optimal network configuration. This was demonstrated in [2] with 10 *LocataLites* in the UNSW network, which gave a maximum horizontal error of 1.3 mm for a 1 cm antenna move.

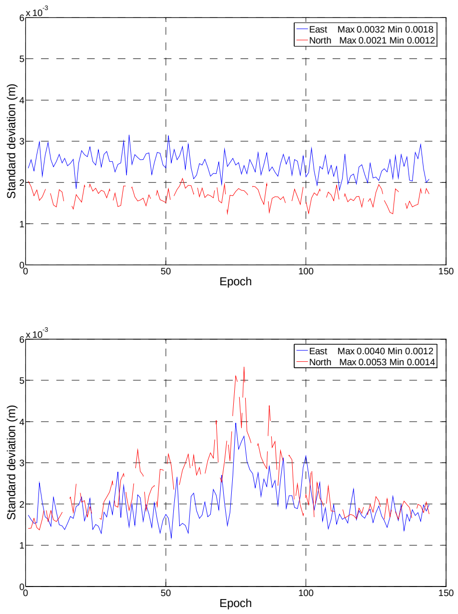

Figure 11: Standard deviation of static East and North: Locata (top), GPS (bottom)

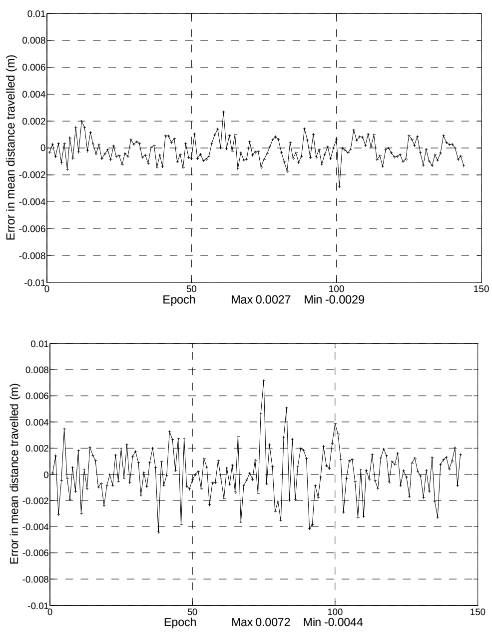

Figure 12: Error in distance traveled for each 1cm move (computed from mean position values): Locata (top), GPS (bottom)

INDOOR SIGNAL PROPAGATION TESTS

Indoor positioning is one of *Locata*'s potential applications as the *Locata* system answers number of issues arising when using other existing positioning systems indoors. As there is a full control over the *LocataNet* settings, its power levels can be adjusted to be able to penetrate through walls and buildings, hence allowing the receiver to track the transmitted signals.

In this test, the question of how the propagation through different construction materials affect the pseudorange of *Locata*'s transmitted signal was considered. The following construction materials were tested: timber, aluminum, iron, Plexiglas, cork, plasterboard and glass. Three different thickness of plasterboard and two different thicknesses of timber and glass were tested, as these are the most commonly used construction materials for walls and partitions within a building. The details of the materials tested are given in Table 1.

Table 1: Description of materials tested

Material	Comments
Plasterboard	Standard core encased in a heavy-duty paper line. By far the most popular interior lining product used in domestic and commercial construction today. 10mm, 20mm and 30mm tested. 10mm boards were stacked together to incrementally increase the width.
Wood	Particleboard used commonly for building panels and in furniture. 12mm and 24mm tested. Two 12mm boards were stacked together for the 24mm thickness.
Glass	Standard window panes. 3mm and 6mm tested. Two 3mm glass panes were stacked together for the 6mm thickness.
Aluminum	3mm tile tested. Aluminum is commonly used for window frames and other glazed structures.
Iron	Untreated iron tile. Multiple uses within the construction industry. 2mm tested.
Plexiglas	Used for casting and molding, and often used instead of glass. 7mm tested.
Cork	Low density fiberboard, commonly used to provide acoustic insulation. 17mm tested.

For this test, only one *LocataLite* was used (LL5 of the UNSW setup) that transmitted two PRN codes through its two transmit antennas. The power output level was set to 10mW. The receiver antenna was mounted on the same tripod used for the long term static test described earlier approximately 15 meters away from the *LocataLite* and within a direct line-of-sight. For each of the two tracked

PRN codes received from the *LocataLite*, the respective pseudorange was recorded.

Initial recordings were taken with the direct lines-of-sight completely blocked, to ensure the receiver was not tracking any multipathed signals. Once this was established, each construction material was placed in front of one of the transmitting antennas, at a distance of about 15cm, and the pseudoranges were recorded at 10Hz, for 3 minutes periods. Between the recordings for each material, a 2 minute recording with the transmitting antenna completely unobstructed was taken. Additionally, data was also logged for the transition period between no material and insertion of a material in front of the antenna, in order to confirm that the rover did not lose lock on the *LocataLite* during this process.

For each thickness of each material tested, the recorded signal was first analyzed to ensure that the rover had not lost lock on the *LocataLite* during the observation period. Any observations, where lock on the *LocataLite* had been lost, were removed from the output. The remaining raw pseudorange observations were averaged, with outliers (observations greater than 1.5 times the standard deviation) removed. For plasterboard, wood and glass, the pseudorange value obtained by averaging out the observations for each thickness, were further averaged, to obtain one value for an average of the tested thicknesses.

The pseudorange recorded when the antenna was unobstructed, was taken as the control measurement. Any deviation from this value, found in the remaining tests, was computed as an error in the pseudorange. This error can only be attributed to the presence of a material obstructing the transmitting antenna of the *LocataLite*, since all other variables were kept constant. The computed errors in the pseudorange for each tested material are shown in Table 2.

Table 2: Errors in pseudoranges for materials tested

Material	Error in pseudorange (m)	Thickness (mm)
No material	0.0000	0.0
Wood	-0.0793	18.0
Glass	-0.1709	4.5
Cork	-0.1795	17.0
Plexiglas	-0.4247	7.0
Plasterboard	-0.5502	20.0
Aluminum	-0.5652	3.0
Iron	N/A	2.0

The negative values indicate that the recorded pseudorange for each obstructing material was longer than the control pseudorange, implying that each of the construction materials worked to slow down the Locata signal. When iron was tested, the *LocataLite* signal had been completely blocked and the receiver could not track it, hence no pseudorange measurement was recorded.

The pseudorange errors that resulted from obstructing the direct line-of-sight of the *Locata* signal are significantly large, considering the rover was only located at a distance of 15 m from the *LocataLite* antennas. In order to standardize the data, and allow for appropriate corrections to be applied in future positioning with this technology, the above information was used to compute the pseudorange error that would result for 1mm thickness of each material that allows passage of the *Locata* signal. This is shown in Table 3.

Table 3: Error in pseudoranges for 1mm thickness of materials

Material	Error in pseudorange for 1mm thickness (m)
Wood	-0.0044
Cork	-0.0106
Plasterboard	-0.0275
Glass	-0.0380
Plexiglas	-0.0607
Aluminum	-0.1884

To further investigate the affect of the materials on the actual position solution, a full network consisting of 5 *LocataLites* (LL1 to LL5) was set up in an open field. The *LocataLites* were equally spread around a receiver antenna mounted on a tripod with a clear line-of-sight between the receiver antenna and each one of the *LocataLite* antennas. The coordinates of all of the *LocataLites* and receiver antennas were surveyed using a reflectorless total station and the network was configured with these coordinates.

The network was powered up and obtained time synchronization. The raw pseudoranges and position solutions were continuously recorded from the receiver output ports. During the experiment, sheets of material were inserted in front of transmitting antenna 2 and/or 5 (Figure 13), and the data was logged at 10Hz, for a period of 5 minutes each time. The different test scenarios are described in Table 4.

Figure 13: Plasterboard sheet blocking LL2

Initial examination of the results obtained from this test indicates noticeable errors in the position solutions when different materials were introduced in the network. However, a complete analysis of this test has yet to be finalized and the full results description and analysis will be published in a future paper.

Table 4: Network tests carried out. Numbers in the table indicate the antenna obstructed

Test	Plaster-board (10mm)	Wood (12mm)	Aluminum (3mm)	Iron (2mm)	Plexi-glas (17mm)
1					
2				2	
3	2				
4	2 and 5				
5	2				5
6			5		2
7		2	5		
8	5	2			
9		2			5

FUTURE RESEARCH

In the upcoming future, UNSW will conduct several other research activities on the *Locata* system. Some of these activities are described below.

Locata antenna analysis – an experiment that will attempt to locate the exact position of the phase centers of the different antennas used in a *Locata* network. The phase center location is important in accurate positioning systems based on electromagnetic ranging signals as the ranges calculated in such a system correspond to the distances between the phase centers of the respective transmitter and receiver antennas. When sub-centimeter accuracy is desirable an accurate knowledge of the antenna phase centers is required.

Locata interference analysis – an experiment that will attempt to quantify the interference of different RF devices with a *Locata* network, and suggest ways to mitigate it. *LocataLites* transmit ranging signals in the 2.4GHz license-free ISM band. However, several other widely-used devices also transmit on the same frequency band, with WiFi being the most popular. In some conditions, the external devices will introduce errors into the position solution or jam the system altogether. The experiment will aim to describe the interfering conditions and their affect on the system.

Tropospheric analysis – *Locata* is a terrestrial based system and as such, is not affected by the ionosphere in a similar way to other GNSS systems. However, the tropospheric effects on the signal propagation need to be considered and some of the errors introduced by it need to be corrected. An experiment will attempt to investigate the effects of the troposphere in different weather conditions on the *Locata* signals and a mathematical model will be suggested in order to correct positioning errors caused by it.

CONCLUDING REMARKS

In this paper, current and future research activities on *Locata* have been discussed. A network consisting of 10 *LocataLites* had been set up on top of three buildings at the university campus to allow the conduction of different experiments using the network. A simple, yet effective software utility has been developed to visualize positioning results from the receiver in real-time as well as to display other relevant information regarding the operation of the network. The deformation monitoring application was addressed and the stability and accuracy of the *Locata* network has been tested. The results from the deformation monitoring experiments concluded that *Locata* would be suitable for such applications. Indoor applications were also considered by investigating the effects of different construction materials on the signal propagation and the measured pseudoranges. The full results of the propagation study have yet to be determined and will be published as they become available. Other research projects will commence at UNSW in the coming future which include antenna phase-center analysis, network-interference analysis and tropospheric effects analysis.

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