New Concepts In Long Range Positioning

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Civil GPS Service Interface Committee
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Introduction

- Background to developments
- Requirements & Objectives
- Technical challenges
- Description of techniques and methods
- Solutions and results
- Summary and conclusions
Background

- GPS hardware and software developments
- Increase in positioning accuracy requirements
  - MBES, construction and deep water projects
- Cost and availability of positioning services
- Dual frequency data
- WAAS, EGNOS and Competition.
DGPS Hardware Developments
GPS Systems Performance

- Standalone GPS (with SA): 100m
- Standalone GPS (no SA): 10m
- Code-based DGPS: 1-5m
- Carrier-based DGPS: 1-5cm

- 5m
- 1m
- 5cm
GPS Observables

- Two independent range observables
  - Code (pseudo-range)
  - Carrier phase
- GPS receiver only measures fractional part of observables
-Both measurements ambiguous by an integer number of wavelengths
GPS Measurement Wavelengths

Carrier frequencies
L1: 1575.42 MHz (wavelength ≈ 19cm)
L2: 1227.60 MHz (wavelength ≈ 24cm)

Code
L1: C/A code - civilian
   (code wavelength ≈ 293m)
P (Y) code - military
L2: P (Y) code - military

CYCLE SLIPS
↓
New Integer Ambiguity (N)
GPS Error Sources

Satellite Clocks
Selective Availability
Ephemeris
Atmospheric Delays
Multipath
Receiver Clocks, etc
Carrier-Phase DGPS

Advantages
- Lower levels of multipath error
- Lower levels of measurement noise

Disadvantages
- Unknown number of wavelengths
- Positioning affected by similar biases to Pseudo-Ranges:
  - Ionosphere and troposphere
  - Satellite & receiver clocks
Genesis - The RACAL LRTK System

OVERVIEW

- Accurate to better than 20 cm
- Satellite-based LRTK system
- Operational over long baselines (>500km)
- Provides a robust LRTK System
  (User Equipment, Quality Parameters, smooth positioning mode, Network Solution)
RACAL LRTK Challenges

- **Technique**
  - Error Modeling (Atmosphere, Multipath)
  - QC Statistics (reliable QC statistics)
  - Robust Transition between solution types

- **Data Transmission**
  - Data Compression
  - Transmission mode vs Baseline lengths (i.e. performance at long ranges required to support Satellite-based Transmission mode)
RACAL Genesis System Components

GPS Receiver

Almanac\Time\ Ephemeris

Phase\Code Observables

Multipath Map

Compress

Data TX

Data RX

Repair and Filter Observations

\cdot Combine
\cdot Synchronise
\cdot Transform

Weights

Position Estimates and Quality Control

Base Station

Mobile Station
RACAL Genesis Results - 50km Baseline

50km baseline
Typical Static real time performance over 2 hours including initialization:

- Mean: Delta East -0.002m, SD(2σ): 0.17m
- Mean: Delta North: 0.070m, SD(2σ): 0.11m
- Mean: Delta Height -0.026m, SD(2σ): 0.21m
RACAL Genesis Results - 200km Baseline
RACAL Genesis Results - 200km

Baseline

Typical Static real time performance over 2 hours including initialization:

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD(2σ)</th>
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<tbody>
<tr>
<td>Delta East</td>
<td>0.110m</td>
<td>0.14m</td>
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<tr>
<td>Delta North</td>
<td>-0.004m</td>
<td>0.12m</td>
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<tr>
<td>Delta Height</td>
<td>-0.013m</td>
<td>0.20m</td>
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RACAL Genesis Results - 900km Baseline

900km baseline
Typical Static real time performance over 2 hours including initialization:

Mean    SD(2\sigma)
Delta East  0.490m  0.09m
Delta North -0.185m  0.35m
Delta Height 0.316m  0.38m
4 Station Network LRTK Solution v Single User
SV Tracking (24 Hours)

2 periods in particular would not have enough DD’s for Single Baseline
RACAL Genesis Results - Network

Typical Static real time performance over 2 hours including initialization:

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<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD(2σ)</th>
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<tr>
<td>Delta East</td>
<td>0.100m</td>
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<tr>
<td>Delta North</td>
<td>0.002m</td>
<td>0.09m</td>
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<tr>
<td>Delta Height</td>
<td>0.062m</td>
<td>0.10m</td>
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</tbody>
</table>
Delta Position – Wrong Integer Determination

Time (Hours)

Delta Position

Delta North

Delta East

Delta height
Statistical QC Control of LRTK Position Calculation

![Graph showing statistical values over time with a threshold line.](image-url)
Delta Position – Right Integer Determination

Delta North
Delta East
Delta Height

Time (Hours)
Statistical QC Control of LRTK Position Calculation

![Chart showing statistical thresholds and time intervals.](chart.png)
Summary & Conclusions

- Sophisticated GPS Processing using a network of stations demonstrates LRTK potential.

- Genesis available in North and Norwegian Seas in 2001.
Genesis North West Europe Coverage

GENESIS - N.W. Europe
December 2000

RACAL
GENESIS - Gulf Of Mexico
Applications for High Accuracy Positioning
Positioning & Vertical Control
High Accuracy Navigation
High Accuracy 3D Control