INSTITUTE OF
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Online GNSS Data Processing - Status and Future Developments

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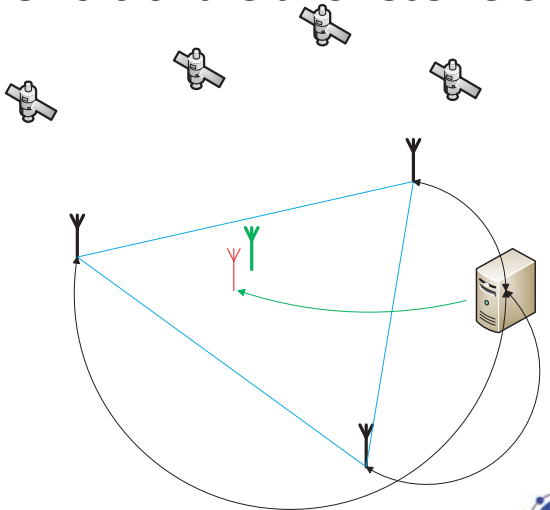
Introduction

- Many navigation applications need a precise position with absolute accuracy on the decimeter or even centimeter level
- Only GNSS can deliver this accuracy globally in dynamic scenarios in real-time when aiding data is provided in form of reference data or corrections
- Several services are existing and/or upcoming.

  But: This approach is based on infrastructure not available everywhere
- Services differ in their accuracies, convergence time, coverage, availability and user fees

A fundamental look: DGPS 1

- GNSS Measurements are biased due to atmospheric effects and satellite errors
- For small distances differential errors are highly correlated
- Single- or Double Differences with a second receiver on known position eliminate common bias errors of the two receivers:
  - satellite clock error
  - differential receiver clock error
  - Correlated atmospheric delays
- Reference Networks solve their ambiguities and compute corrections in form of virtual measurements



A fundamental look: DGPS 2

- GNSS receivers provide mainly two measurements:
  - Pseudorange: No ambiguity but noisy (decimeter to several meters)
  - Carrier Phase: Integer ambiguity but very accurate (only few mm)
- Differencing measurements allows to determine the relative number of carrier cycles (ambiguity)
- This makes positioning very precise to the level of the carrier phase precision
- Usually two frequencies are used (e.g. GPS L1, L2) for a better estimation of the ionospheric delays and therefore a more reliable ambiguity resolution
- Time for Ambiguity Fix depending on distance to reference or network size and on latency time interval

Network-based Services 1

→ **Network based – RTK** (e.g. SAPOS, SWIPOSS)

- Network of reference stations with max. distance of 50-70 km
- Typically provided by Geodetic Surveys
- Methods for correction derivation:
  - Area-Correction-Parameters (FKP)
  - Virtual reference station (VRS)
  - Master auxiliary concept (MAC)
- User receives corrections over mobile com. network e.g. GSM (latency: few sec)

http://www.sapos-bw.de/images/AlleStationen.gif

→ Accuracies: < 5 - 10 cm

→ Availability: ≈ 98% in coverage area

→ <u>But</u>: access to mobile communication network mandatory

Network-based Services 2

→ **Global correction services** (e.g. Trimble RTX)

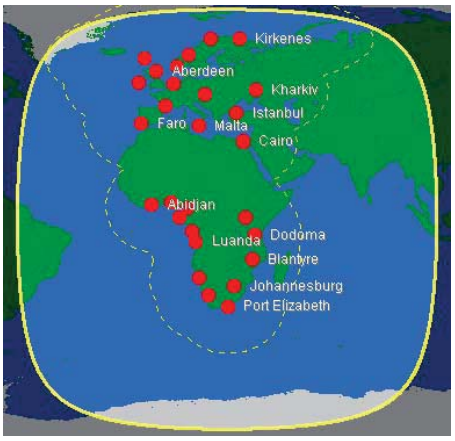
- Precise satellite orbits and clocks derived from a global reference station (RS) network (similar to IGS)
- Based on PPP method (precise point positioning)
- Corrections provided via geostationary OmniSTAR satellite link on L1 frequency (orbits, clocks, atmospheric corrections)
- Standalone: **absolute GNSS measurements on cm-level**
- Convergence time from 30 min (global mode) to
- Convergence time < 1 min (with regional augmentation (RA))
  - RA consists of a RS network with inter-station distances of more than 100 km to provide atmospheric corrections (ambiguity resolution)

EGNOS

- Delivers fast and long term corrections for satellite orbits and clocks, ionospheric corrections from 3 GEO satellites over Europe
- Certified for safety-of-life applications since March 2011
- Standardized and available also in US, Japan and planned in India, China and Russia
- Based on range and integrity monitoring stations
- Provides meter level accuracy
- Widely used in consumer receivers
- Integrity information useful also for precise applications to ensure robust reliable positioning

OmniSTAR: Overview

- Global real-time differential GPS broadcast system providing corrections based on reference station network
- Data is uplinked to geostationary satellites, which distribute them over their respective footprint
- In April 2011 Trimble acquired certain OmniSTAR assets from Fuegro N.V.
- OmniSTAR services broadcasted by 8 geostationary satellites
- One way communication from satellite to user
- Correction data is down-linked near below GPS L1 center frequency



OmniSTAR coverage map for EUSAT/AFSAT, http://www.omnistar.nl

OmniSTAR: Services I

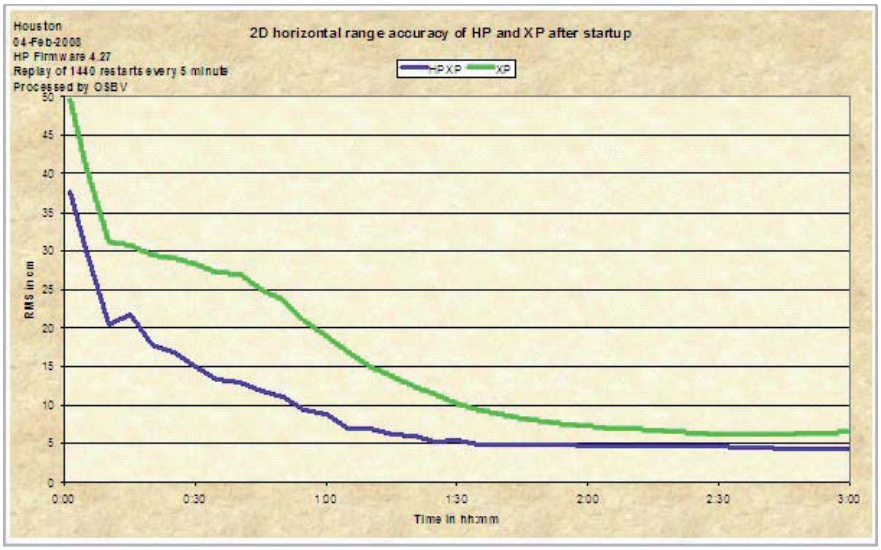
- OmniSTAR VBS (Virtual Base Station)
  - Based on GPS L1 Code measurements of reference stations
  - Calculation of optimized GPS corrections for the user location
  - Corrections used by GPS receiver to create an optimized DGPS solution
  - Accuracy better than 1m (2DRMS) horizontal at mid-latitudes inside the reference network
- OmniSTAR HP (High Performance)
  - Dual frequency DGPS service
  - Broadcast consist of phase and code measurements from the reference station network
  - Broadcast data are applied to the raw GPS measurements gathered by the user GPS receiver
  - Accuracy in the decimeter level domain

OmniSTAR: Services II

- OmniSTAR XP (Extended Performance)
  - Positioning based on precise orbit and clock data for GPS satellites
  - Precise satellite orbit information broadcasted every minute and precise clock information every ten seconds
  - Technique is also referred to as “Precise Point Positioning” (PPP)
  - Accuracy up to the decimeter level without the need for a user to work close to one of the OmniSTAR reference stations.
- OmniSTAR further services
  - OmniSTAR G2 as combination of GPS and Glonass
  - OmniSTAR HP+ based on combination of OmniSTAR HP & XP
  - Combination of OmniSTAR HP, XP and G2

OmniSTAR: Performance and Fees

- Convergence time needed to obtain good position solution accuracy
- Convergence time is enlarged in case of high dynamics (e.g. airplane)
- Static initialization shortens convergence time



Standard deviation of horizontal accuracy after start-up for HP+ (HPXP) and XP only, Visser H.: *OmniSTAR Satellite Service*

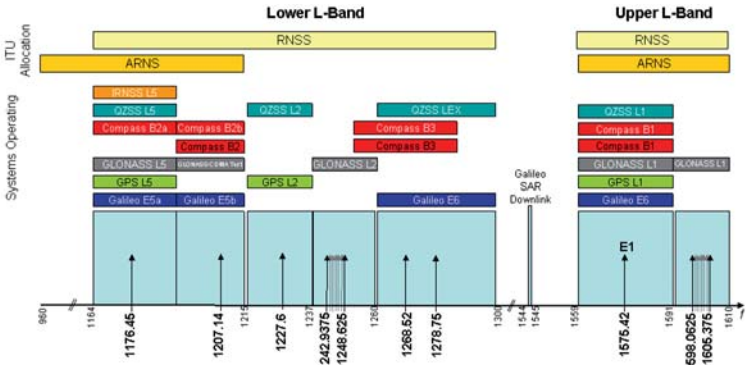
- Fess depending on application and geographical region, standard North American subscription pricing for GIS/Mapping applications (Aug. 2011):
  - OmniSTAR VBS - $800 per year per receiver
  - OmniSTAR XP - $1,500 per year per receiver
  - OmniSTAR HP - $2,500 per year per receiver

Other Systems

- IALA standard conform DGPS corrections
  - For maritime users broadcasted via MF (IALA beacons)
  - Reference/broadcast station mostly located at the coast line
- FAA Ground Based Augmentation System (GBAS)
  - Reference receivers located around a central location e.g. airport
  - Derived corrections sent via VHF data broadcast to user receiver
  - Main drawback is the very local character of the corrections
- StarFire (John Deere)
  - Commercial satellite based augmentation system comparable to the OmniSTAR system
  - Real-time accuracy is on the decimeter level on a worldwide basis
  - Corrections are broadcast at L-Band frequencies via geostationary satellites

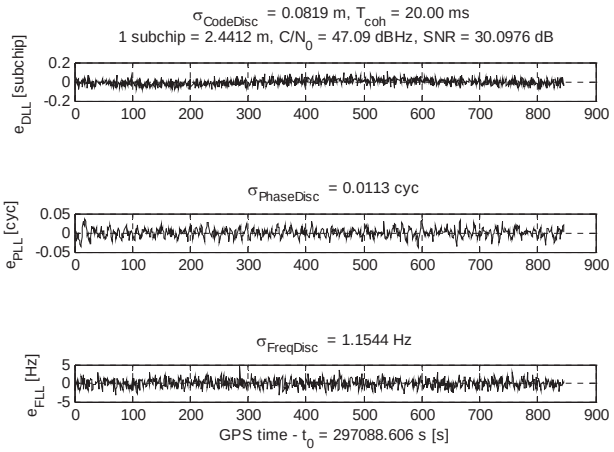
Future Developments: GNSS Systems

- Future receivers will support a GNSS System of Systems
- Legacy systems will be upgraded: US, Russia
- New systems are developed: Europe, China, India
- Upcoming additional Systems and frequencies can lead to:
  - Higher visibility, robustness
  - Less effort of infrastructure (e.g. reference networks)
  - Higher coverage of services
  - Higher accuracy
  - Higher availability of precise position



Future Developments: Signals

- Galileo E5 AltBOC signal features cm level code range accuracy and highest multipath rejection due to its wideband offset carrier modulation
- Enabling single frequency applications of highest accuracy
- Possible elimination of inonosphere with code-plus-carrier techniques
- Preliminary results from the GATE Test-Bed in Berchtesgaden with the institutes software receiver ipexSR confirm the performance of the signal



Summary

- Overview of today's real-time GNSS correction services

Service/Type	Accuracy	Areal availability	Fee	Additional equipment	Initialization time
RTK	few centimeter	local	no	reference station	few minutes
Network RTK	few centimeter	regional	yes	communication link (e.g. GSM)	few seconds
EGNOS	few meter	Europe	no	none	few minutes
OmniSTAR	one meter to few centimeter	nearly worldwide	yes	suited L-band antenna	depending on mode and operation
StarFire	few meter to few centimeter	nearly worldwide	yes	suited L-band antenna	depending on operation
GBAS	few meter	local	no	VHF link	few minutes
IALA DGPS	few meter	regional coastal area	no	medium wave link	few minutes

- Upcoming new signals like the Galileo AltBOC might lead to scenarios where high real-time GNSS positioning performance can be reached without the need for auxiliary correction data

Thanks for your attention

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