FIG REPORT

FIG PUBLICATION NO 49

Cost Effective GNSS Positioning Techniques

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INTRODUCTION

- Report focuses on Cost-effective Use of GNSS
- Global Navigation Satellite Systems (GNSS)
  - Initially developed in early 1970's
  - Improve global positioning and navigation from space
- First Commercial Receivers
  - On the market in 1982
  - Large , bulky, expensive (250,000 €)
  - Manually select satellites on first receivers
- Receivers Today
  - Sophisticated, multi-frequency, multi-constellation
  - Geodetic quality receivers – 5,000 € to 12,000 € (surveying, engineering)
  - Still expensive for developing countries

GLOBAL NAVIGATION SATELLITE SYSTEMS

- Primarily used for Positioning, Navigation and Timing Applications
- Positioning
  - Stationary objects
  - Moving platforms
- Overview of Satellite Positioning
  - Satellite positions as a function of time (ephemerides)
  - Range between visible satellites and antenna (from receiver)
  - Range between visible satellites and origin of a coordinate system (ECEF)
  - Remaining unknown is the position vector of the antenna

GLOBAL NAVIGATION SATELLITE SYSTEMS

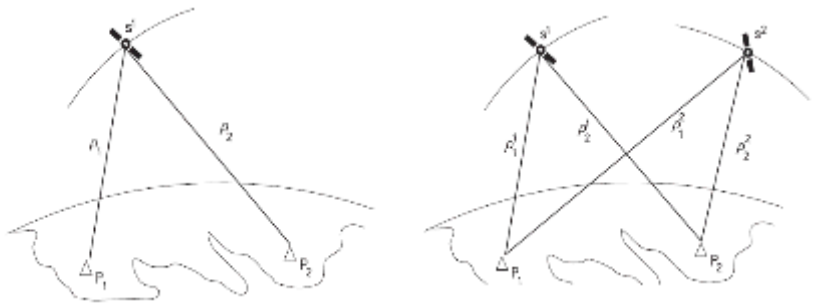
- Global Constellations
  - Global Positioning System (GPS)
    - 24 operational satellites plus a number of spares
    - Six orbital planes inclined at 55°
    - Fundamental frequencies : f1 = 1575.42 MHz, f2 = 1227.60 MHz
  - GLONASS
    - 20-22 operational satellites
    - Three orbital planes inclined at 64.8°
    - L1 band uses frequency division multiple access (FDMA). Frequencies centered around 1602.0 MHZ
    - 15 L2 frequencies centered around 1246 MHZ

GLOBAL NAVIGATION SATELLITE SYSTEMS

- Global Constellations (cont.)
  - GALILEO
    - GIOVE-A and GIOVE-B **G**alileo **I**n-**O**rbit **V**alidation **E**lement. Designed for 27 + 3 medium earth orbit (MEO) satellites
    - Three orbital planes inclined at 56°
    - Code division multiple access (CDMA) to transmit up to 10 signals (1164 – 1592 MHZ)
  - COMPASS / BEIDOU-2
    - Up to 35 satellites
    - Medium earth orbits
    - Frequencies from the E1, E2, E5B AND E6 bands
    - ICD – very soon

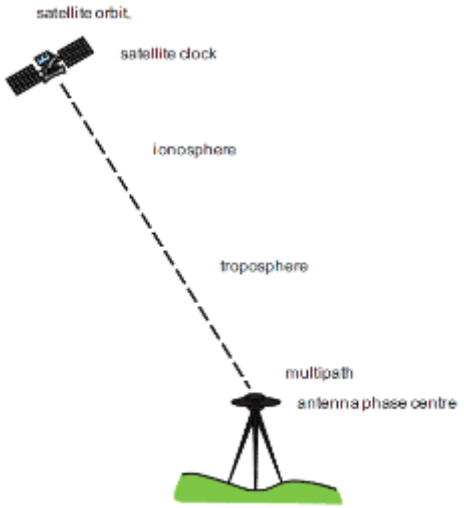
GNSS POSITIONING TECHNIQUES FOR SURVEYING

- Absolute Positioning
- Relative or Differential Positioning



GNSS POSITIONING TECHNIQUES FOR SURVEYING

- Error Sources



GNSS POSITIONING TECHNIQUES FOR SURVEYING

- Precise Point Positioning
  - Elimination of errors by differencing replaced by precisely modeling many error sources
  - Satellite positions from accurate orbits
  - Accurate satellite clocks

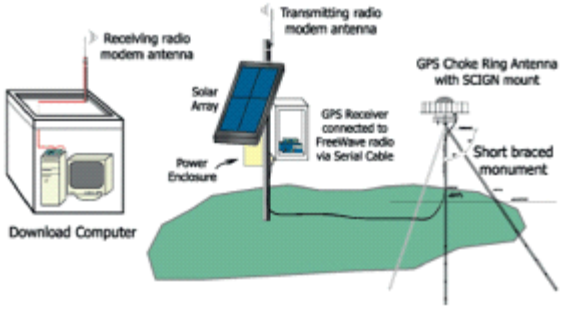
		Accuracy	Latency	Sample Interval
Broadcast	Orbits	~100 cm	Real time	Daily
	Sat. clocks	~2.5 ns SDev		
Ultra-Rapid (predicted half)	Orbits	~5 cm	Real Time	15 min
	Sat. clocks	1.5 ns SDev		
Rapid	Orbits	2.5 cm	17–41 hours	15 min
	Sat. clocks	25 ps SDev		5 min
Final	Orbits	2.5 cm	12–18 days	15 min
	Sat. clocks	~20 ps SDev		30 s

COST-EFFECTIVE GNSS

- Economize Financial and Physical Resources
- Work as Accurately as Necessary
- Two Possibilities to Economize Resources

1) Low-Cost GNSS Receivers
2) Continuously Operating Reference Stations

Continuously Operating Reference Stations (CORS) and resp. Networks



Courtesy UNAVCO, CO

- Expense of reference station spared
- Multiple reference station

COST-EFFECTIVE GNSS

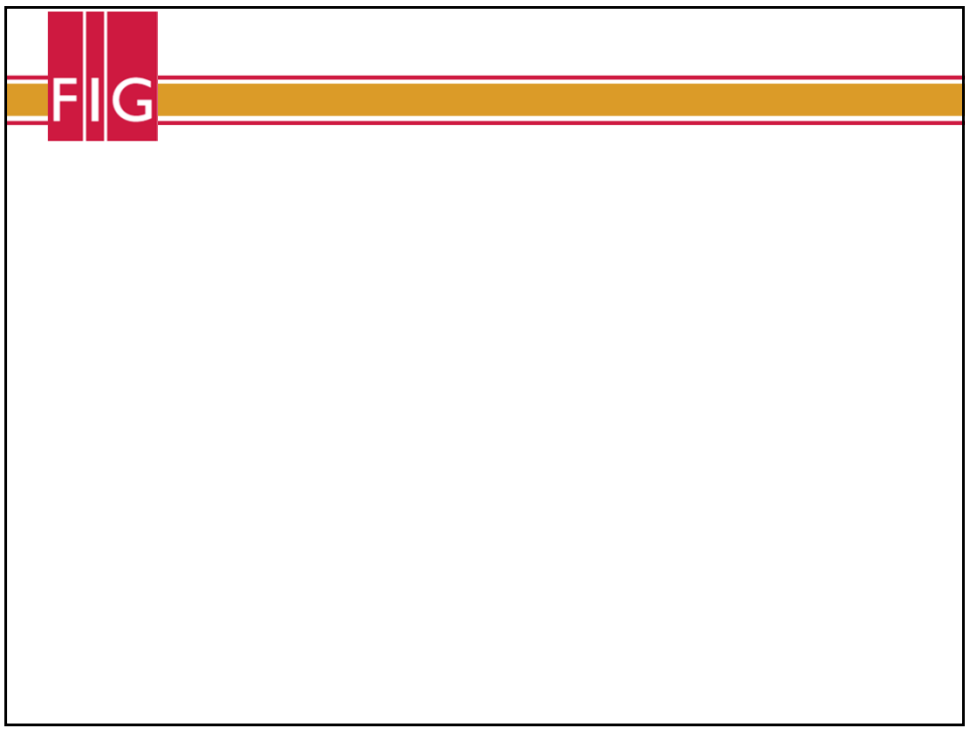
Use Less Expensive Low-Cost GNSS Receivers and Antennas (150 € and up)

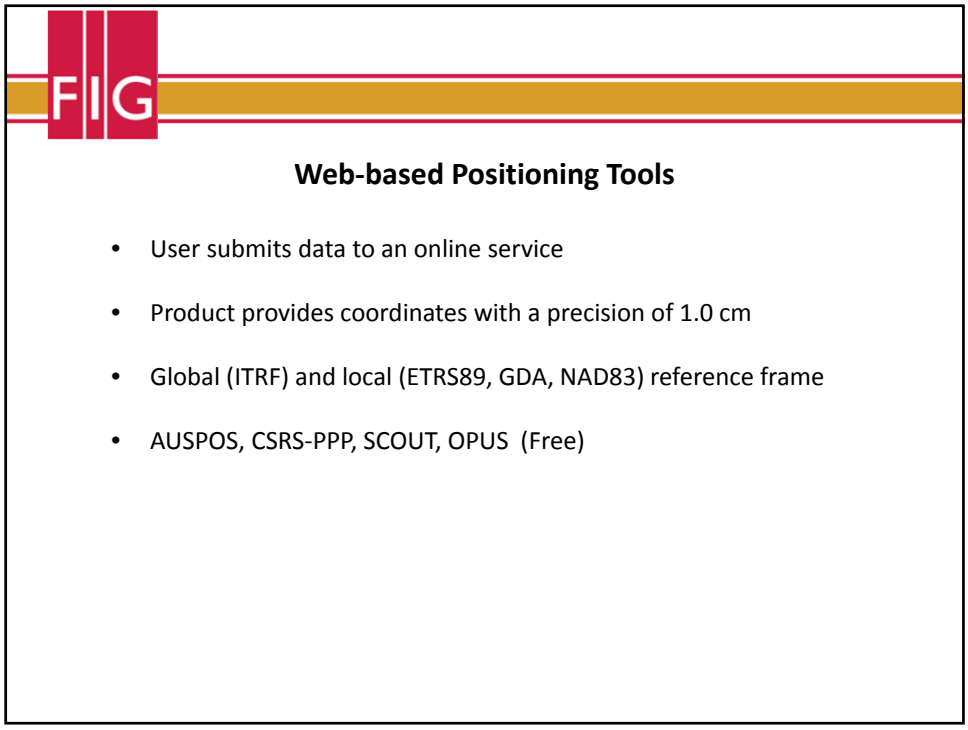
Receiver class	Used signal	Applications	Accuracy	Costs
navigation	code or phase-smoothed code, 1 frequency	car navigation, location based services, sailing, mass market	1 to 10 m	5–100 €
geodetic	code and phase, in general 2 frequencies	surveying, geodesy, geodynamics	0.001 to 0.1 m	10,000–30,000 €

COST-EFFECTIVENESS

- Calculation base:
  - labor costs between 1 € and 70 € / hour
  - geodetic receiver: 20.000 €
  - low-cost receiver + equipment: 2.000 €
  - calculated for three years using

- Variant 1: GNSS CORS network
- Variant 2: Low-Cost GNSS receiver
- Combination of variant 1 and 2




Web-based Positioning Tools
• User submits data to an online service
• Product provides coordinates with a precision of 1.0 cm
• Global (ITRF) and local (ETRS89, GDA, NAD83) reference frame
• AUSPOS, CSRS-PPP, SCOUT, OPUS (Free)

GLOBAL AND REGIONAL REFERENCE STATION NETWORKS
- Examples -

- ***Global***

IGS Tracking Network
http://igscb.jpl.nasa.gov/network/netindex.html

- ***North America***

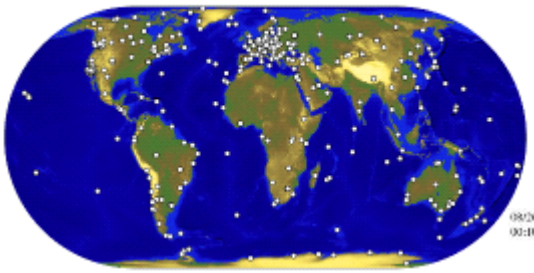
The National CORS Network – United States
http://www.ngs.noaa.gov/CORS/
Plate Boundary Observatory – Western United States
http://pboweb.unavco.org
The Southern California Integrated GPS Network
http://www.scign.org/

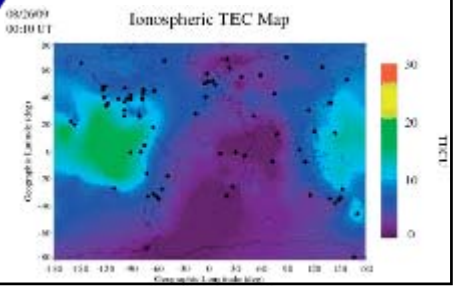
THE INTERNATIONAL GNSS SERVICE

- Voluntary Scientific Organization (200 Groups from 80 Countries)
- Many Products Offered
  - Reference Station Data from Global Network (RINEX)
  - GPS and GLONASS Satellite Orbit and Clock Products
  - Earth Rotation Parameters
- Ongoing Projects
  - Clocks
  - Real Time Pilot Project
  - Reference Frames
  - Ionospheric and Tropospheric Working Groups

THE INTERNATIONAL GNSS SERVICE

IGS Tracking Network





Courtesy IGS

For more information on Cost-Effective GNSS:

Cost Effective GNSS Positioning Techniques

http://www.fig.net/pub/figpub/pub49/figpub49.pdf