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Global Navigation Satellite Systems (GNSS): GPS, GLONASS, GALILEO

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National Culture High School, 13 November 2012, Gorna Bania, Bulgaria

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Global Navigation Satellite Systems (GNSS)

параметри	GPS	TASHACC	GALILEO	COMPASS
години	1971/1993	1976/1995	1994/2020	2000/2020
спътници	24	24	27	35
орбити	6, елипт.	З, кръгови	З, кръгови	>10
височина	20200 км	19100 км	23 222 км	21 155 км
инклинация	55°	64,8°	56°	55,5°
основни	1,58 GHz	1,61 GHz	1,57 GHz	1,56 GHz
сигнали	1,23 GHz	1,25 GHz	1,28 GHz	1,20 GHz

source: Tzvetan Simeonov's BSc thesis: "GNSS meteorology in Bulgaria" July 2011

USA: Global Positioning System (GPS)

- · Why Global Positioning System (GPS) was created
 - · Need of high-accuracy, real-time position, velocity and time on variety of platforms
 - Worldwide, all weather operation military and civilian users
- What is GPS

GNSS

overview G.Guerova

- NAVSTAR GPS satellites 24 active satellites 6 orbital planes
 - altitude 20 200 km
 - inclination 55° (with respect to the Equator)
 - orbit periods 11h 58 min
- · Ground based reference receivers
 - Europe 1700
 - Japan 1000
 - Bulgaria 120
- Control segment
 - · worldwide monitor and control stations
 - · maintain the satellites orbits
 - · maintains health and status of the satellite constellation

NAVSTAR GPS satellites



Satellite constellation

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GPS

Block IIA satellite type

source: GPS.gov http://www.gps.gov/systems/gps/space/

The GPS signal

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• Microwave bi-phase signal

- Fundamental frequency fo = 10.23 MHz
- L1 carrying frequency with wavelength 19cm
- L2 carrying frequency with wavelength 22.4cm
- Pseudo Random Code structure
 - Navigation message low frequency signal added to L1 code 1500 bits
 - · Information about: satellite clock and satellite orbit

All satellites use the same frequencies but have different codes



source: Global Positioning System: Theory and Applications, Volume I & II, 1996, ISBN-13: 978-1-56347-249-7

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RUSSIA: GLObal NAvigation Satellite System (GLONASS)

• GLONASS satellites - 24 active satellites - 3 orbital planes

- altitude 19 100 km
- inclination 64.8° (with respect to the Equator)
- orbit periods 11h 15 min

• Ground based reference receivers: mostly GLONASS compatible

- Europe 1700
- Japan 1000
- Bulgaria 120

source: http://www.glonassgsm.ru/information.html

GLONASS constellation



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GLONASS/GPS constellation

GLONASS satellites



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1	MAL			CO TSNIMASH
_	1982	2009	2010	2013
,	Glonass	Glonass-M	Glonass-K1	Glonass-K2
	3 year design life Clock stability - 5*10 ¹³ Signals : L1SF, L2SF, L1OF, (FDMA) Totally launched 81 satellites Real operational life time 4.5 years	 7 year design life Clock stability 1*10-13; Signals : L10F, L20F, L10F, L20F (FDMA) Totally launched 28 satellites and going to launch about 11 satellite until to end 2012 	 10 year design life; Clock stability 5*10-14; Signals L1SF, L2SF, L1OF, L2OF (FDMA) L3OC (CDMA) - test: 	 10 year design life; Clock stability 1*10-14; Signals L1SF, L2SF, L1OF, L2OF (FDMA) L1OC, L3OC, L1SC, L2SC (CDMA):

GLONASS signal

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• Each satellite has its own frequencies

- · All satellites have the same code
 - Fundamental frequency $f_o = 5 \text{ MHz}$
 - L1 band range: 1602.5625 MHz to 1615.5 MHz
 - L2 band range: 1240 MHz to 1260 MHz

	L1	L2	L3	L1, L2	Future	Status
«Gionass»	L1OF, L1SF	L2OF, L2SF	÷.,	-		Done
«Glonass-M»	L1OF, L1SF	L2OF, L2SF	12	·*		Done
«Gionass-K1»	L1OF, L1SF	L2OF, L2SF	L3OC test			From firs test sat (2010 c)
«Gionass-K2»	L10F, L1SF	L2OF, L2SF	L3OC	L10C, L1SC, L2SC		From #3 sat Gionass-I
«Gionass-KM»	L10F, L1SF	L2OF, L2SF	L3OC	L10C, L1SC, L2SC	L3SC, L10CM, L20C,	Under developm After 2015

EUROPE: GALILEO

Why GALILEO was created

- · Need of high-accuracy, real-time position, velocity and time on variety of platforms
- · Worldwide, all weather operation civilian only
- · Galileo will provide a global Search and Rescue (SAR) function

What is GALILEO

- satellites 30 active satellites 3 orbital planes
 - altitude 23 222 km
 - inclination 56° (with respect to the Equator)
 - orbit periods 14h 07 min repeat every 10 days
- · Ground based reference receivers: GALILEO compatible
 - Europe 1700
 - Japan 1000
 - Bulgaria 120

source: GALILEO at ESA

http://multimedia.esa.int/Videos/2012/10/Galileo-In-Orbit-Validation-Phase

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GALILEO constellation

GALILEO satellites



GALILEO satellite

GALILEO signal

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Microwave signal

- Fundamental frequency fo = 10.23 MHz
- E1 carrying frequency: 1575.42 MHz
- E5 carrying frequency: 1191.795 MHz
- E6 carrying frequency: 1278.75 MHz





Figure 1. Galileo, GLONASS and GPS Frequency Bands

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EUREF permanent GNSS station Sofia (SOFI)





GNSS antenna GNSS receiver source: EUREF http://www.epncb.oma.be/_trackingnetwork/pictures/_large/sofi013.jpg

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Measuring distances - how it works

Three measurements puts us

- · Measuring distances satellite as a reference point
 - three satellites on view



- signal travel time \sim 0.06s
- speed of light S = V t

source: Trible tutorial http://www.trimble.com/gps/howgps.shtml

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Science Applications: atmosphere

- Propagation errors in GNSS
 - ionosphere: delay in the range of 30 m
 - troposphere: 2 m delay at zenith, up to 20 m at low elevation



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Science Applications: GNSS meteorology



source: Tzvetan Simeonov's BSc thesis: "GNSS meteorology in Bulgaria" July 2011

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Science Applications: earthquake I

Solid Earth Studies

- crustal deformation (with support of M. Schmidt, GS Canada)
- uplifting phenomena Sweden



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Science Applications: Japan 11 March 2011



source: Prof. Richard Langley's group at the University of New Brunswick, Canada available from: http://gge.unb.ca/News/2011/2011.html#JapanGPS

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Science Applications: volcano monitoring

Solid Earth Studies

· monitoring volcanic activities



Day to day applications

Scientist, sportsmen, farmers, soldiers, pilots, surveyors, hikers, sailors, dispatchers, lumberjacks, fire-fighters ...

- Location and mapping (Where I am?)
 - measuring height of Mount Everest (8 850 \pm 2m) Khumbu glecier moves towards Everest's Base camp
- Navigation and tracking (Where I am going?)
 - · high tech fishing (orange fish underwater sea mounts)
 - landing plane in the middle of a mountain (Juneau Airport Alaska)
 - taking the top of the world
 - vessels and vehicle tracking police, emergency services (Chicago 911)





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GNSS

GLONA: GALILE GNSS station

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Conclusions

- all weather operation
- cost effective
- global coverage
- extremely accurate (~cm) for public users
- very compact

Prospective:

- Further integration in businesses cellular phones, computer networks, agriculture, car industry
- Public safety services (decreasing costs, improving service efficiency)
- Replacement of conventional measuring techniques
- Improving weather prediction, helping to monitor earthquake activities, climate change and hazardous phenomena

Soon everything will be tracked and mapped from elephants to ...

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Future constellation



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Future constellation



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