

# 12.540 Principles of the Global Positioning System

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<http://geoweb.mit.edu/~tah/12.540>

# Overview of class

- Aim: To introduce the principles of the operation of the GPS system and its applications
- There is flexibility in the exact content of the course depending on student interests
- Generic topics include millimeter accuracy positioning and kinematic GPS
- Emphasis is on fundamental principles and limitations

# Class expectations

- This is a graduate level class. There is no final exam
- Grading in the class is based on homework (75%) and on a final written report (25%)
- The report will be revised during semester and should be 2000-3000 words (8-10 double spaced pages)
- Topic for the paper will be due around Spring break

# Class Behavior

- It will be acceptable in this course to work together on homework with the aim of better understanding the material and to refer to other books and published material provided that these additional materials are cited appropriately in the homework. Each student should complete the homework separately. It is not acceptable to simply copy the homework of another student.

# Basic course outline

## Classes

- 1: Coordinate and Time systems **2**
- 2: Satellite orbital motions **2**
- 3: Estimation procedures **4**
- 4: GPS Observables **4**
- 5: Propagation medium **3**
- 6: Mathematical model of GPS observables **4**
- 7: Methods of processing GPS data **4**
- 8: Applications and examples of GPS. **2**

# Topics to be covered

- Coordinate and time systems:
  - When working at the millimeter level globally, how do you define a coordinate system
  - What does latitude, longitude, and height really mean at this accuracy
  - Light propagates 30 cm in 1 nano-second, how is time defined

# Topics

- Satellite motions
  - How are satellite orbits described and how do the satellites move
  - What forces effect the motions of satellites
  - What do GPS satellite motions look like and what are the main perturbations to the orbits
  - Where do you obtain GPS satellite orbits

# Topics

- GPS observables
  - GPS signal structure and its uniqueness
  - Pseudo-range measurements
  - Carrier phase measurements
  - Initial phase ambiguities
  - Effects of GPS security: Selective availability (SA) and antispoofing (AS)
  - Data formats (RINEX)

# Topics

- Estimation procedures
  - Simple weighted-least-squares estimation
  - Stochastic descriptions of random variables and parameters
  - Kalman filtering
  - Statistics in estimation procedures
  - Propagation of variance-covariance information

# Topics

- Propagation medium
  - Neutral atmosphere delay
  - Hydrostatic and water vapor contributions
  - Ionospheric delay (dispersive)
  - Multipath

# Topics

- Mathematic models in GPS
  - Basic theory of contributions that need be to included for millimeter level global positioning
  - Use of differenced data
  - Combinations of observables for different purposes

# Topics

- Methods of processing GPS data
  - Available software
  - Available data (International GPS service, IGS; University consortium (Unavco))
  - Cycle slip detection and repair
  - Relationship between satellite based and conventional geodetic systems (revisit since this is an important topic)

# Topics

- Applications and examples from GPS
  - Tectonic motions and continuous time series
  - Earth rotation variations; measurement and origin
  - Kinematic GPS; aircraft and moving vehicles
  - Atmospheric delay studies

# Text books

- No specific text books are required for this course.
- The books below cover the geodetic and engineering aspects of GPS
  - B. Hofmann-Wellenhof, H. Lichtenegger, and J. Collins, *GPS Theory and Practice*, Springer-Verlag, Wein, New York, pp. 326, 1992.
  - Parkinson, B. W., J. Spilker, P. Axelrad and P. Enge, *Global Positioning System: Theory and Applications*, 793 pp., Am. Inst. Aeronaut. Astronaut., Washington D. C., 1996.

# Other reference material

- Most of the reference material for the course will be posted as links on the web page
- Some web sites to explore:
  - <http://www.navcen.uscg.gov>
  - <http://www.unavco.org>
  - <http://reason.scign.org/> -- Link to the data products part of the GPS network in Southern California.

# Homeworks

- The theme of the homeworks will for you to write a program for GPS data analysis. The program will read GPS data and satellite information in RINEX format
- Programming will be required: Most students use Matlab and some use fortran or C

# Coordinate systems

- Suggested reading (links on web page):
  - Herring, T. A., Geodetic Applications of GPS, *Proceedings of the IEEE*, 87, 1, 92–110, 1999.
  - Herring, T.A., Z. Altamini, H-P Plag, P. Poli, The future geodetic reference system, GGOS, 2009
- Questions to ponder
  - Why do we need a coordinate system
  - What properties should it have
  - How were coordinates defined before space based geodetic systems were available

# Coordinate systems

- More questions:
  - Does the Earth's gravity field play a role in coordinate systems?
  - How does this type of system relate to space based systems?
  - What is needed to define a coordinate system and how are they “realized” (i.e. implemented)

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