

ASEN 6091 / ECEN 5014
Global Navigation Satellite System (GNSS) Receiver Architectures

Fall Semester 2022 – AERO N250
Lecture Times: TTH 01:00 PM - 02:15 PM

(Lectures recorded/available via Canvas for online section of course offering)

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Office Hours: anytime via zoom/inperson by apt (please email)

Course Overview

GNSS is a generic term describing the expanding field of satellite-based navigation/timing systems. The most prevalent of these systems currently is GPS which is owned and operated by the US. However, Russia maintains a system known as GLONASS. Both the European Union and China have/are developing their own GNSS system designated Galileo and Beidou (Compass), respectively. Lastly, there are a number of regional GNSS augmentation systems including but not limited to: WAAS (US), QZSS (Japan), EGNOS (EU), India (GAGAN) each of which provides GNSS corrections and, in some cases, ranging information.

There are a multitude of GPS receivers on the market today. Often times these receivers are embedded for monitoring and control and often, unfortunately, treated as a "black box". This course goes into the inner workings of a GPS L1 C/A code receiver and also discusses features common to all GNSS receivers. The course will cover the analog radio frequency conditioning from the antenna to the analog-to-digital converter, then focus on the various signal processing algorithms used in GNSS receiver (acquisition, code tracking, carrier tracking, and navigation data decoding), as well as present the position/time solution. Such treatment of the operation of the receiver will provide insight into the trade-offs that go into GNSS receiver design.

The GNSS receiver is a specialized Code Division Multiple Access (CDMA) spread spectrum receiver. Thus those interested in CDMA technology will benefit from a "hands on" perspective and gain insight into the specifics of CDMA receivers designed for navigation and timing functionality.

Students interested in the course will be required to have a solid background in using Matlab. Some knowledge in signal processing, particular time/frequency domain transforms, and control theory would be helpful. Lastly, background on GPS or GNSS in general (such as ASEN 5090) is expected, but not required, and will aid in the overall understanding of the technology.

Course Format

The course will follow a blend of traditional lectures with external independent lab/computing assignments. The traditional lectures will provide the basics of low-level GPS signal processing building on the internal operation of a GNSS receiver. Comprehensive assignments on the implementation of this receiver processing in Matlab will be given to the students. There will be a midterm which will be a take-home 24-hour exam. And then a final course project which will result in a presentation and report on the day of the final exam.

Textbook (not required)

A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach; K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. H. Jensen; 2007; ISBN-10: 978-0-8176-4390-4

Reference Material

- 1) Course Notes
- 2) Understanding GPS/GNSS: Principles and Applications; E.D. Kaplan (Editor); 3rd ed; 2017; ISBN13: 978-1630810580
- 3) Global Positioning System: Signals, Measurements and Performance, P. Enge, P. Misra, 2nd ed; 2010, ISBN-13: 978-0970954428
- 4) ICDs for GPS - <http://www.gps.gov/technical/icwg/> (Also will refer to ICDs for other GNSS)
- 5) Akos' Lab Web Page: <https://www.colorado.edu/lab/rf-satnav/>
- 6) GNSS Software Receivers; Kai Borre, Ignacio Fernández-Hernández, José A. López-Salcedo, M. Zahidul H. Bhuiyan; Cambridge University Press; 2022; ISBN: 9781108934176
- 7) Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications, Volume 1 & 2; Y. Jade Morton, Frank van Diggelen, James J. Spilker Jr., Bradford W. Parkinson, Sherman Lo, Grace Gao; Wiley-IEEE Press; 1st edition (9 Feb. 2021); ISBN-13 : 978-1119458418
- 8) Spread Spectrum Systems with Commercial Applications, R. C. Dixon, 3rd ed; 1994, ISBN13: 978-0471593423
- 9) Phase-Locked Loops : Design, Simulation, and Applications; R. Best; 6th ed; 2007; ISBN13: 978-0071493758

Course Schedule

Week(s)	1	Course Introduction & GPS Software Receiver Overview (Assignment 1)
Week(s)	2	Front End Design/Data Collection
Week(s)	3 & 4	GNSS Signal Acquisition (Assignment 2 & 3)
Week(s)	5 & 6	GNSS Signal Tracking (Assignment 4 & 5)
Week(s)	7	Navigation Data Decoding (Assignment 6)
Week(s)	8	Position Solution (Assignment 7)
Week(s)	9	Differential Position/Carrier Phase Solution (Assignment 8)
Week(s)	10	Midterm & Project Proposal
Week(s)	11-15	Project Work

Final Exam/Presentation Sunday Dec. 17 4:30–7PM (based on CU's final exam schedule)

Course /Grades/Evaluation

40% - Assignments
30% - Midterm (typically take-home 24 hour exam)
30% - Final (Course Project Presentation/Report)

Notes

- 1) Comprehensive assignments will be assigned approximately once per week at the beginning of the term, expected to be worked individually
- 2) Each assignment will be based on a 100 point scale
- 3) A midterm should be expected during the tenth week of the semester, typically format is an individual "take-home" 24 hour exam
- 4) A final project, based on the material from two thirds (approximate) of the course will replace a final exam. The project will require both a presentation and written report/code submission. It will be possible to work in groups of two, if preferred given sufficient scope for the project.

Material is preliminary and subject to change

SYLLABUS STATEMENTS

CLASSROOM BEHAVIOR

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy.

For more information, see the [classroom behavior policy](#), the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).

REQUIREMENTS FOR INFECTIOUS DISEASES

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the [further guidance of the Public Health Office](#). For those who have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

[Disability Services](#) determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance.

If you have a temporary medical condition or required medical isolation for which you require accommodation, you need to notify the instructor for the class, ideally in advance if possible. Also see [Temporary Medical Conditions](#) on the Disability Services website.

PREFERRED STUDENT NAMES AND PRONOUNS

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

HONOR CODE

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the [Honor Code](#). Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology

[such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: honor@colorado.edu, 303-492-5550. Students found responsible for violating the [Honor Code](#) will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit [Honor Code](#) for more information on the academic integrity policy.

SEXUAL MISCONDUCT, DISCRIMINATION, HARASSMENT AND/OR RELATED RETALIATION

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits [protected-class](#) discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, [reporting options](#), and support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive an outreach from OIEC about their options for addressing a concern and the support resources available. To learn more about reporting and support resources for a variety of issues, visit [Don't Ignore It](#).

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, any religious holidays which should be accommodated during the fall semester should be flagged via an email to the instructor in the first week of the semester.

See the [campus policy regarding religious observances](#) for full details.

MENTAL HEALTH AND WELLNESS

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact [Counseling and Psychiatric Services \(CAPS\)](#) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through [Academic Live Care](#). The [Academic Live Care](#) site also provides information about additional wellness services on campus that are available to students.