Winter Quarter

1.3 Carrier phase positioning, augmentations and integrity

Module: 1.3
Period: Winter Quarter

Responsible: Adjunct professor

Credits: 4
Total hours: ~40

Course Objectives

Lessons aim to provide knowledge about the structure and performance of the carrier phase synchronizer inside the digital receiver and about the use of phase information to improve the accuracy of the positioning.

Course Syllabus

Part 1. Phase synchronization, carrier tracking systems and carrier phase measurements (3 credits)

- Synchronization in digital receivers
  - Role of the clock/carrier synchronizer in digital receivers
- Closed-loop synchronizers: the null seeker architecture
  - Digital model of a tracking loop
  - Components of a null-seeker
  - Linearized model of the null-seeker
- Closed-loop synchronizers: Loop filter design and transient analysis
  - Loop filter design criteria
  - Analysis of the dynamic stress tolerance
  - Noise-free analysis of the transient response
  - Noise jitter analysis
    - Loop noise equivalent bandwidth
    - Jitter variance
  - Setting the loop filter coefficients
- Phase Lock Loops Architectures
  - Examples of carrier phase synchronization architectures
  - Typical PLL architectures for GNSS receivers
  - Carrier tracking loops performance:
- Carrier phase measurements for positioning
  - Introduction to the use carrier phase measurements for positioning, signal model

- The concept of integer ambiguity
- Combining code and carrier phase measurements: “carrier smoothing”

- Carrier phase positioning: phase-only ranging
  - Limitations of code-phase positioning
  - Pseudorange by using carrier-phase
    - Errors in carrier phase measurements
  - Introduction to precise relative positioning
    - The baseline concept
    - Differencing GPS observations
    - The problem of the ambiguity resolution

Part 2. Precise positioning with carrier phase (1 credit)

- Precise Point Positioning: PPP
  - Precise Orbits and Clocks
  - Code and carrier measurements and modelling errors
  - Linear observation model for PPP
  - Parameter estimation: Floating Ambiguities
  - Carrier Ambiguity fixing concept: DD and undifferenced
  - Fast-PPP
- Carrier based differential positioning. Ambiguity resolution techniques
  - Linear model for DGNSS: Double Differences
    - Differential Code and carrier based positioning
    - Precise relative Positioning
  - Ambiguity resolution Techniques
    - Resolving ambiguities one at a time

Resolving ambiguities as a set: Search techniques

1.5 Time scale and timing in GPS and Galileo

Module: 1.5
Period: Winter Quarter

Responsible: Adjunct professor

Credits: 3
Total hours: ~30

Course Objectives

The course aims to provide basic elements about the role of timing in GPS and Galileo. The addressed topics focus on time scales and their role in satellite navigation systems.

Course Syllabus

- **Basics on time scales and timing**
  - What is a time scale, astronomical and atomic time
  - Current time scales for civil, legal, and scientific use
  - Terminology and general concepts
  - Clock model: frequency and time deviations,
  - polynomial and stochastic models, Allan variance, clock prediction

- **Role of timing in GNSS**
  - Reference time
  - Time synchronisation
  - Clock offset predictions

- **The timing in GPS**
  - Which clocks
  - Control networks on ground
  - Synchronisation
  - Formation of the GPS time scale
  - Connection to Universal Coordinated Time

- **The timing in Galileo**
  - Clocks
  - Synchronisation system
  - Reference time
  - Connection to UTC
  - Precise Timing Facility and Time Service Provider

- Experimentation activity in the Galileo system

2.1 GPS and Galileo receivers

Module: 2.1
Period: Winter Quarter

Responsible: Adjunct professor

Credits: 5
Total hours: ~50

Course Objectives

The main objective of the course is to describe in details the architecture and the functionality of a GNSS receiver. The basic functions of a GNSS receiver are: to capture and separate the signals in space (SIS) transmitted by the satellites in view; to measure the Time of Arrival (ToA) and Doppler shift of each received signal; to demodulate the navigation message; to estimate the PVT (Position, Velocity and Time).
The main functional blocks necessary to perform the above mentioned tasks are:

- The receiver antenna
- The Radio Frequency front-end
- The Analog-to-Digital Converter (ADC)
- The acquisition block
- The Carrier tracking system
- The Code tracking system
- The navigation message demodulator
- The block for PVT computation

All these topics will be covered in this course. However, special attention will be given to some of them, not already covered in the other courses of this Master.

Course Syllabus

- **The acquisition blocks (architecture and functionality)**
  - Analysis of different types of ACF (Autocorrelation Function) and CCF(Cross Correlation Function) that may be embedded into a generic digital system, with particular attention to the following methods:
    - Linear correlation
    - Circular correlation
  - Basic concepts about detection and estimation of particular interest in acquisition schemes.
  - Non-coherent acquisition scheme at IF:
    - Integration time

- Search space
- Bin size
- Carrier wipe-off
- Serial correlator
- Parallel correlator

- **The Code tracking system: coherent and non-coherent DLLs**
  - Detailed analysis of the DLL scheme:
    - Code wipe-off
    - Frequency wipe-off
    - S-curve
    - Early-Late
    - Incommensurability

- **Pseudo-range evaluation**
  - Analysis of the receiver block that demodulates the navigation message and evaluates the pseudo-range.

- **The effect of ADC in the SIS, in the code correlation, and in the noise**
  - Quantization effects introduced by the ADC on correlation blocks that constitute the core elements of both the acquisition system and the DLL (Delay Lock Loop). In particular, the following cases will be examined:
    - Sampler at IF with infinite precision quantization
    - Sampler at IF with 1-bit quantization

2.7 Augmentation systems and their Applications

Module: 2.7
Period: Winter Quarter

Responsible: Letizia Lo Presti (Politecnico di Torino - DET)

Credits: 3
Total hours: ~30

Course Objectives

The module focuses on the concepts of augmentation and differential GPS. Wide Area Augmentation systems, such as WAAS, EGNOS, GAGAN, MSAS in Japan are described together with some of their applications.

Course Syllabus

Part 1. Augmentation Systems

- Fundamentals on Augmentation systems and Differential GPS
- WAAS system description
- EGNOS system description
  - Elements of the system
  - OD&TS corrections and ionospheric error computation.
  - EGNOS signal and data
  - User Performance
  - EGNOS and other SBAS
  - EGNOS modernization
  - EDAS
- GAGAN
- Russian augmentation system
- MSAS

Part 2. Basics on Integrity

- Integrity concepts and definitions
  - Availability
  - Continuity
  - Accuracy
  - Reliability
- Issues to be addressed in Safety-of-Life receivers development
  - Key requirements

- Performance
- Safety, Integrity, Reliability, Continuity
- Design process
- Qualification process

- Integrity algorithms at User Receiver level
- Introduction to ARAIM