GEO1003 - Shared Notes

Master Geomatics Students

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Contents

Introduction

This is the introduction to the notes.

Example

Introduction

The goal of this chapter is just to demonstrate how things should be organized. It will be removed from the notes in the end.

Markdown Basics

Resources and Helpers

A nice cheat sheet about Markdown can be found at this link: https://www.markdownguide.org/cheat-sheet/.

On VS Code, there are some nice extensions that can help you write Markdown files:

- Markdown All in One to provide useful shortcuts and commands
- markdownlint to properly format your Markdown files

Feel free to ask me if you have questions about Markdown.

Comments

```
This <!--This is a comment.--> is
<!--
Comments are not rendered.
They can take multiple lines
-->
a
sentence.
```

This is a sentence.

Headers

```
<!-- Comment the fist headers to avoid messing up the outline of this file -->
<!--
# Level 1

## Level 2

### Level 3
-->

#### Level 4

##### Level 5

###### Level 6
```

Level 4

Level 5

Level 6

Bold and Italic

```
- Normal text
- **Bold text**
- _Italic text_
- **_Bold and italic text_**
```

- Normal text
- **Bold text**
- *Italic text*
- ***Bold and italic text***

Lists

```
*Unordered list:*

- Unordered list item 1
- Unordered list item 2
  - Nested unordered list item

Ordered list:

1. Ordered list item 1
2. Ordered list item 2
   1. Nested ordered list item
```

Unordered list:

- Unordered list item 1
- Unordered list item 2
    - Nested unordered list item

Ordered list:

1. Ordered list item 1
2. Ordered list item 2
    1. Nested ordered list item

Links

```
[Example link](https://www.example.com)
```

Example link

Images

```
![Example image](../../../images/example.jpg){ width="250" }
```

Figure 1: Example image

Blockquotes

```markdown
> This is a blockquote.
```

> This is a blockquote.

Code

````markdown
Inline code: `print("Hello, World!")`

Code block:

```python
def hello_world():
    print("Hello, World!")
```
````

Inline code: `print("Hello, World!")`

Code block:

```python
def hello_world():
    print("Hello, World!")
```

Tables

```markdown
Table: A simple table

| Header 1 | Header 2 |
| -------- | -------- |
| Cell 1   | Cell 2   |
| Cell 3   | Cell 4   |
```

Table 1: A simple table

Header 1	Header 2
Cell 1	Cell 2
Cell 3	Cell 4

Math

```markdown
Inline math: $x^2$ is the square of $x$.

Block math:

$$
\int_0^\infty e^{-x^2} dx = \frac{\sqrt{\pi}}{2}
$$
```

Inline math: x^2 is the square of x.

Block math:

$$\int_0^\infty e^{-x^2} dx = \frac{\sqrt{\pi}}{2}$$

Empty Section

An other section that is empty.

How does GNSS work?

Introduction

GPS (Global Positioning System), also known as NAVSTAR (NAVigation Satellite Time And Ranging) had its first satellite launched in 1978.

GPS segments

The GPS system consists of *three segments*:

1. **Space segment** (satellites with atomic clocks)
2. **Control segment** (ground stations for clock offsets)
3. **User segment** (receivers)

Radio Signal

The GPS radio signal contains:

- the **L-band carrier frequency** between 1 and 2 GHz
- the **Pseudo Random Noise** (PRN, also called the **spreading code**), unique to each satellite, publicly available
- the **navigation message** containing the satellite orbit and clock information

Initialisation

When starting, GPS receivers try to find a particular GPS satellite on *each of their channels* (tens to hundreds). This is done by **overlaying the received signal** with a replica of the **spreading code** and then shifting it until correlation shows a maximum (best fit, or match).

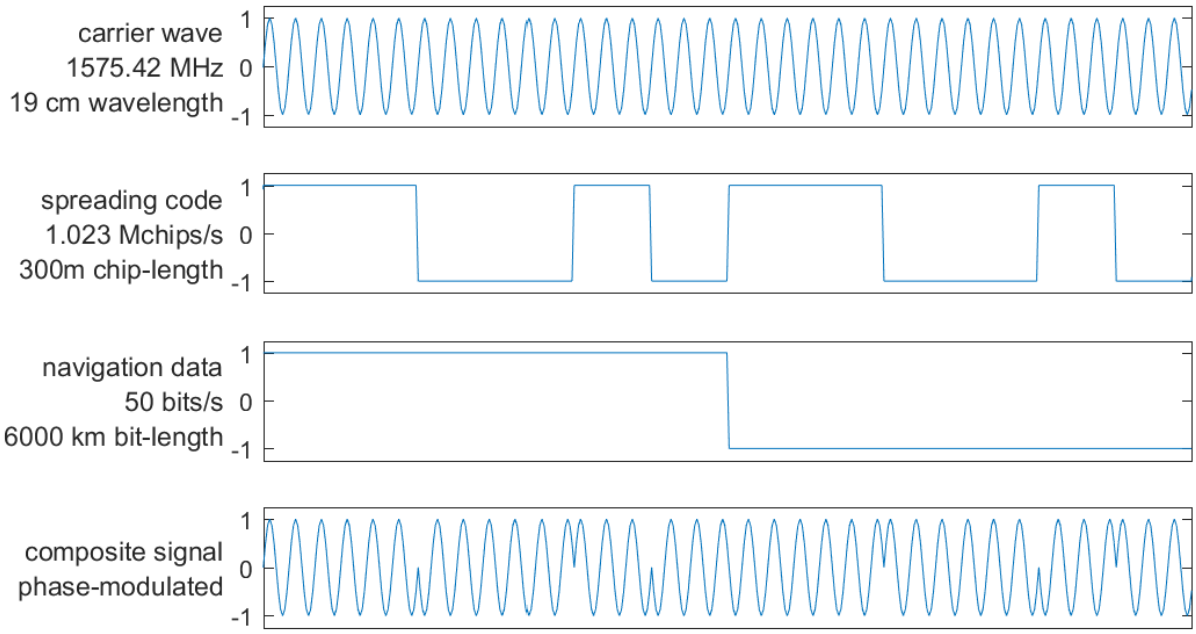

Figure 2: GPS L1 CA-signal (scale is not accurate)

Pseudorange Measurement

The **pseudorange** $p_{r,s}$ is calculated by multiplying the travel time $\tau_{r,s}$ by the speed of light c:

$$p_{r,s} = c \cdot \tau_{r,s} \text{ where } \tau_{r,s} = t_r - t_s$$

Carrier Phase Measurement

Carrier Phase Measurement:

- Measures **fractional phase difference** between the received *carrier wave* from the satellite and a locally generated *replica*.
- Provides a **very precise distance** measure (satellite to receiver)
- Needs to be **initialized** by finding the initial number of carrier wave cycles.
- Is much more precise than pseudorange code measurement. thanks to the **carrier period** being **much smaller** than code chip duration (in L1 CA-code signal, *1540 carrier periods* fit in one PRN spreading code chip).

Jamming and Spoofing

GPS Jamming

GPS Spoofing

GNSS performance

Introduction

Error Sources

Pseudorange Calculation

Multiple issues affect the calculation of the pseudorange:

- **satellite clock offset** (known).
- **receiver clock offset** (unknown).
- **ionosphere delay** (unknown).
- other errors, such as *multipath* (unknown).

The calculation is very sensible since $c \approx 3 \times 10^8$ m/s, and a **1 µs** error will cause a **300 m** error in the calculated distance.

Ionosphere Delay

Ionospheric delay:

- Is due to **free electrons** in the ionosphere.
- Is highly variable (depends on **time** and **space**).
- Ranges from *a few meters to hundreds of meters*.
- Is maximum near geomagnetic equator, around local noon and during solar maxima.
- Is proportional to 1/frequency^2.
- Can be estimated using two frequencies. This is why satellites emit at **L1** (1575.42 MHz) and **L2** (1227.60 MHz).

Accuracy and Precision

The quality of the measurement can be assessed through the carrier-to-noise-density ratio C/N_0 (signal strength).

The precision of the measurement depends on the method used:

Table 2: Precision of GNSS measurements

	Pseudorange	Carrier Phase
Precision	Few meters to few decimeters	Few centimeters to millimeter

Dilution of Precision

Availability, Continuity and Integrity

Availability

Continuity

Integrity

PPP-RTK

PPP

RTK

DGNSS

GNSS in the built environment (outdoor, indoor and in between)

Introduction

Multipath

Urban Canyon

Shadow Matching

CRS

Introduction

Coordinate Systems

Ellipsoids

Geocentric Coordinate Systems

Topocentric Coordinate Systems

Coordinate Reference Systems (CRS)

Terrestrial Reference Systems and Frames

Terrestrial Reference Systems

ITRS

ETRS

Terrestrial Reference Frames

ITRF

ETRF

Datum and Transformations

Datums

Transformations

Conversions

Map Projection

RDNAP

Rijksdriehoeksmeting (RD)

Normaal Amsterdams Peil (NAP)

Wi-Fi-monitoring / Fingerprinting

Introduction

Wi-Fi-Based Approaches

Wi-Fi Monitoring

Wi-Fi Fingerprinting

Radio Signal Based Techniques

Received Signal Strength (RSS)

Time of Arrival (ToA)

Time Difference of Arrival (TDoA)

Angle of Arrival (AOA)

Path-Loss

Fine Timing Measurement (FTM)

Radio Frequency Identification (RFID)

Hybrid and Other Techniques

Trilateration

Inertial Navigation Systems (INS)

Visual Based Indoor Localisation

Isovists