# GEO1003 - Shared Notes

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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

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

> This is a blockquote.

#### Code

```
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

```
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

```
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

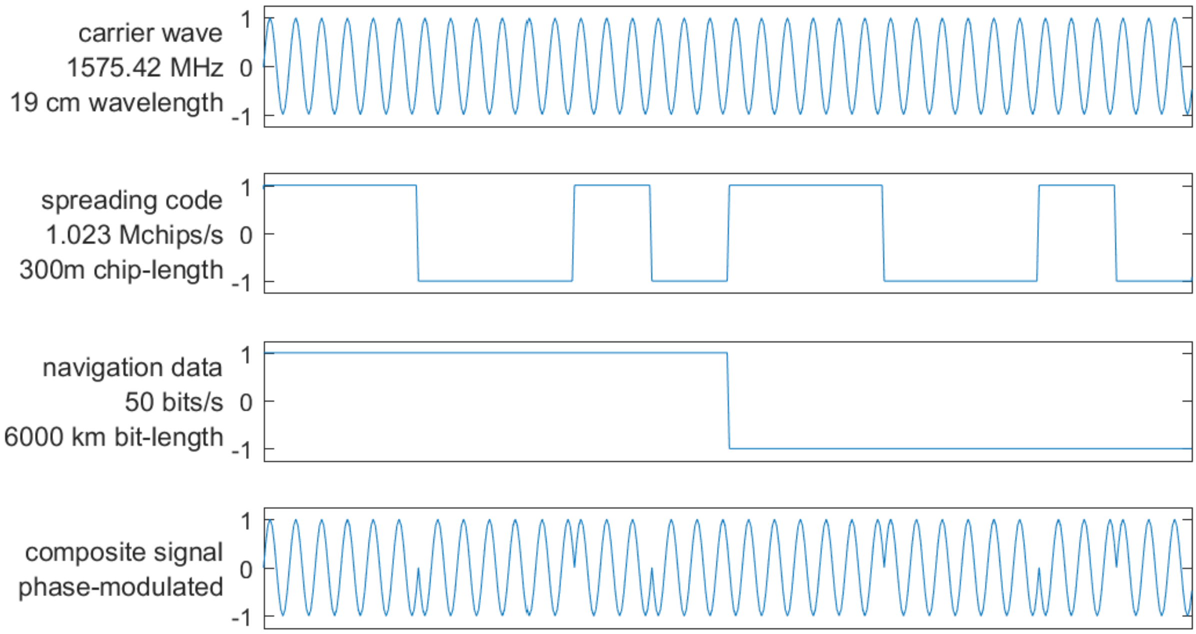


Figure 2: GPS L1 CA-signal (scale is not accurate)

### 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).

### 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 $1/\text{frequency}^2$.
- 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

### Terrestrial Reference Systems and Frames

### Datum and Transformations

#### Datums

#### Transformations

#### Conversions

### Map Projections

### RDNAP

#### Rijksdriehoeksmeting (RD)

#### Normaal Amsterdams Peil (NAP)

## Wi-Fi-monitoring / Fingerprinting

### Introduction