

# GEO1003 - Shared Notes

Master Geomatics Students

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## 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

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## Links

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

Example link

## Images

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

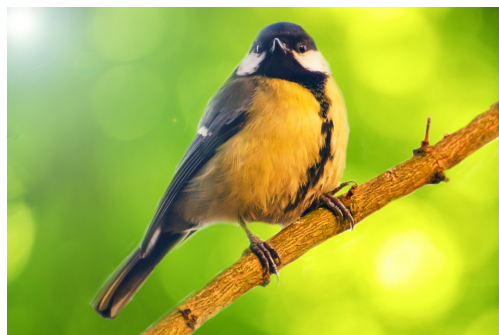


Figure 1: Example image

## 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:

```
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

## 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).

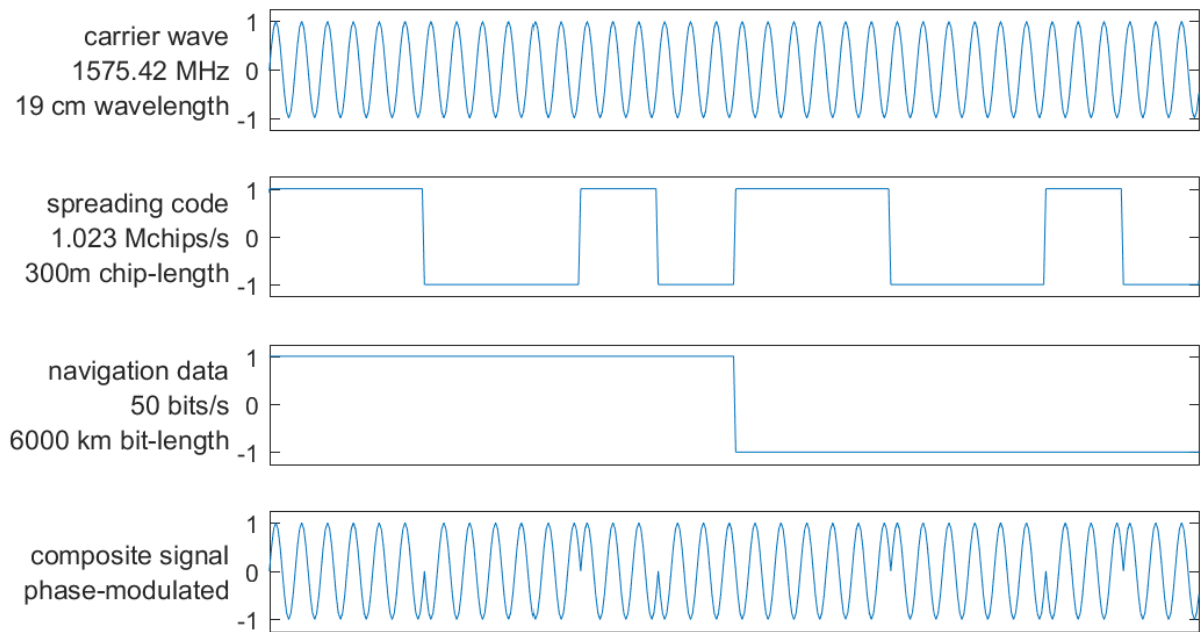


Figure 2: GPS L1 CA-signal (scale is not accurate)

## 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  $\mu$ s** 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**

**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)**

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**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**