

Free parking spaces detector

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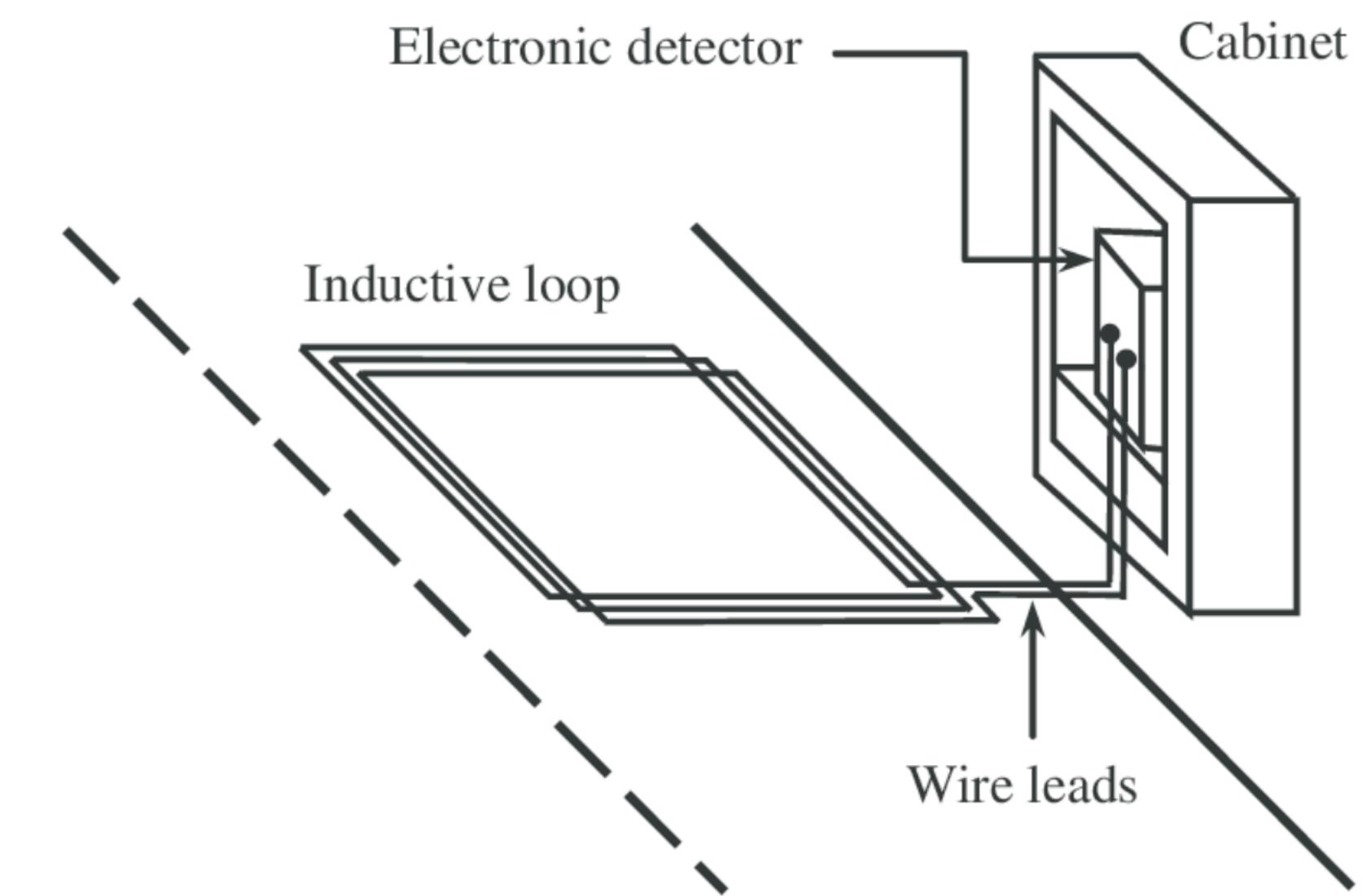
Requirements

- The system shows the availability of free parking spaces, consists of a main unit and a sensor device.
- The main unit provides operation to up to **200** sensor devices.
- Sensor device:
 - detects whether the parking space is free and sends information to the main device using the **wireless protocol**
 - is **insensitive** to dirt, swamp, snow, etc
 - has a **long battery life** (at least 1 year) or the ability to charge wirelessly.

Car detection

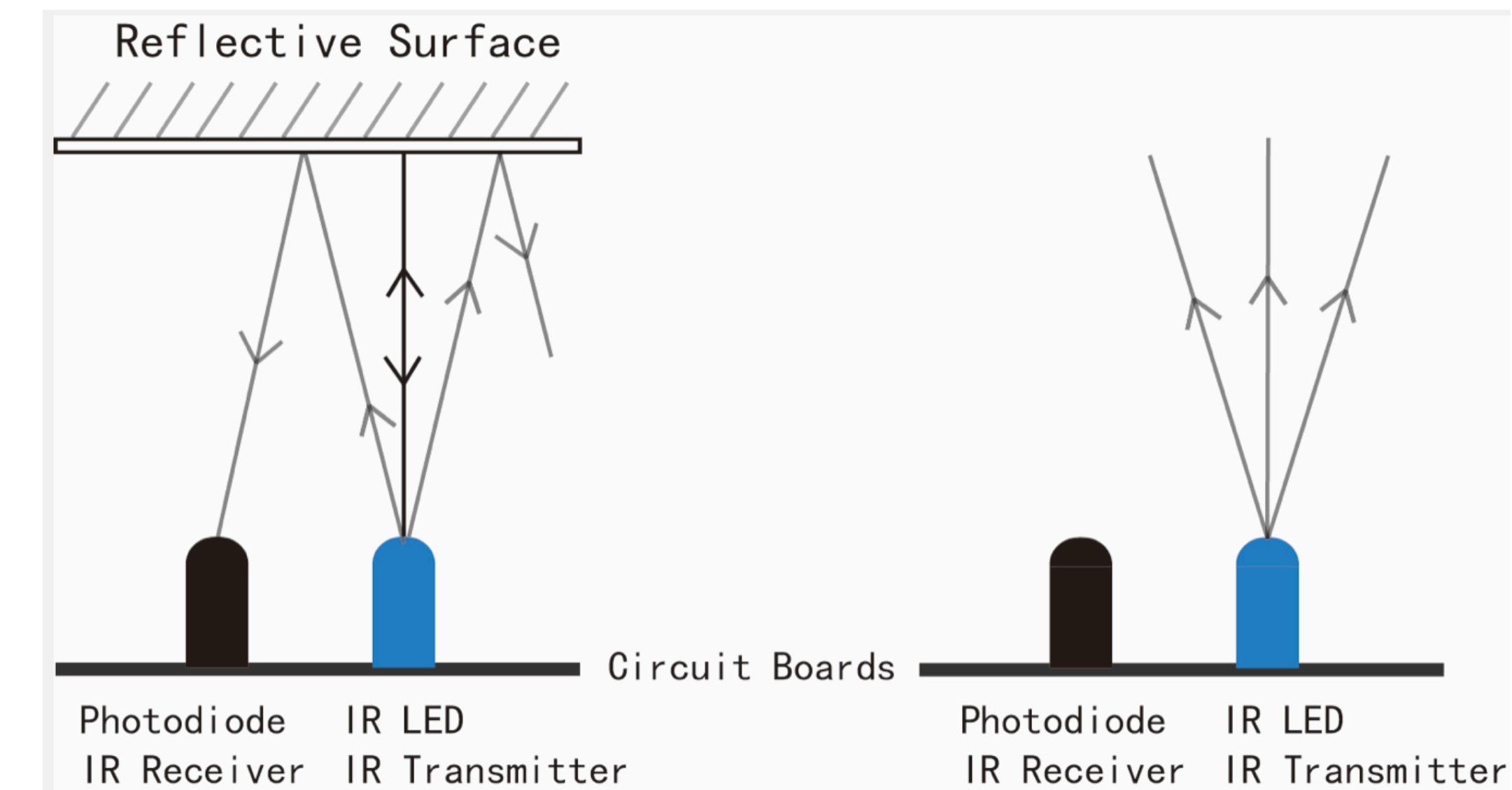
Inductive loops

- note disturbance in the magnetic field, generated by the loop (electromagnetic induction).
- Hard to install: either requires underground electrical wire or cab be really hard to achieve needed sensitivity (inductive loop becomes too small).



Infrared detectors

- Infrared sensors or the IR sensors are low frequency light emitting diodes.
- Sensitivity of the sensor is reduced in heavy rain, snow, leaves or dense fog.
- It may be hard to come up with the solution for the covered parking.

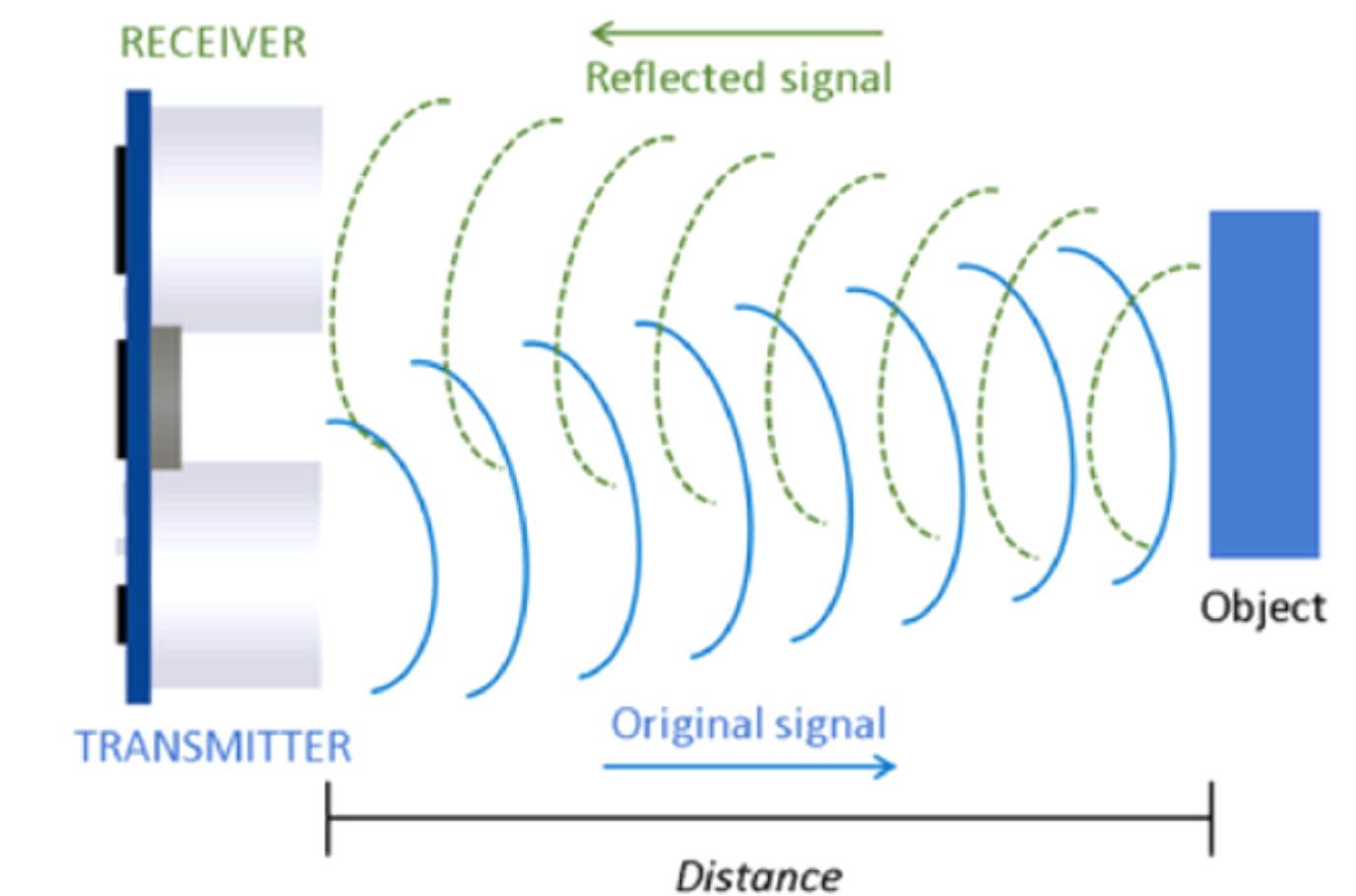
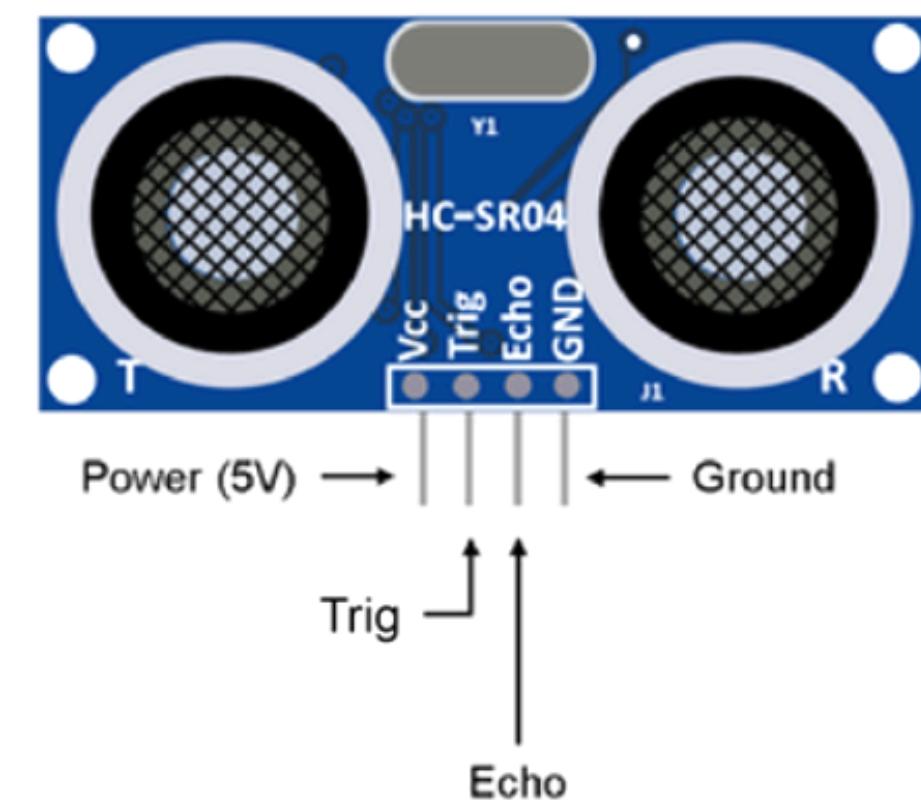


Ultrasonic Range meters.

- Use a sonar-like sound pulse (detectors are calibrated with the known distance from detector to pavement and can then note a difference in echo time to determine the presence of a vehicle)

• performance can be impacted by extreme wind and temperature

- Will be affected by the weather conditions (snow, rain, temperature and extreme wind).



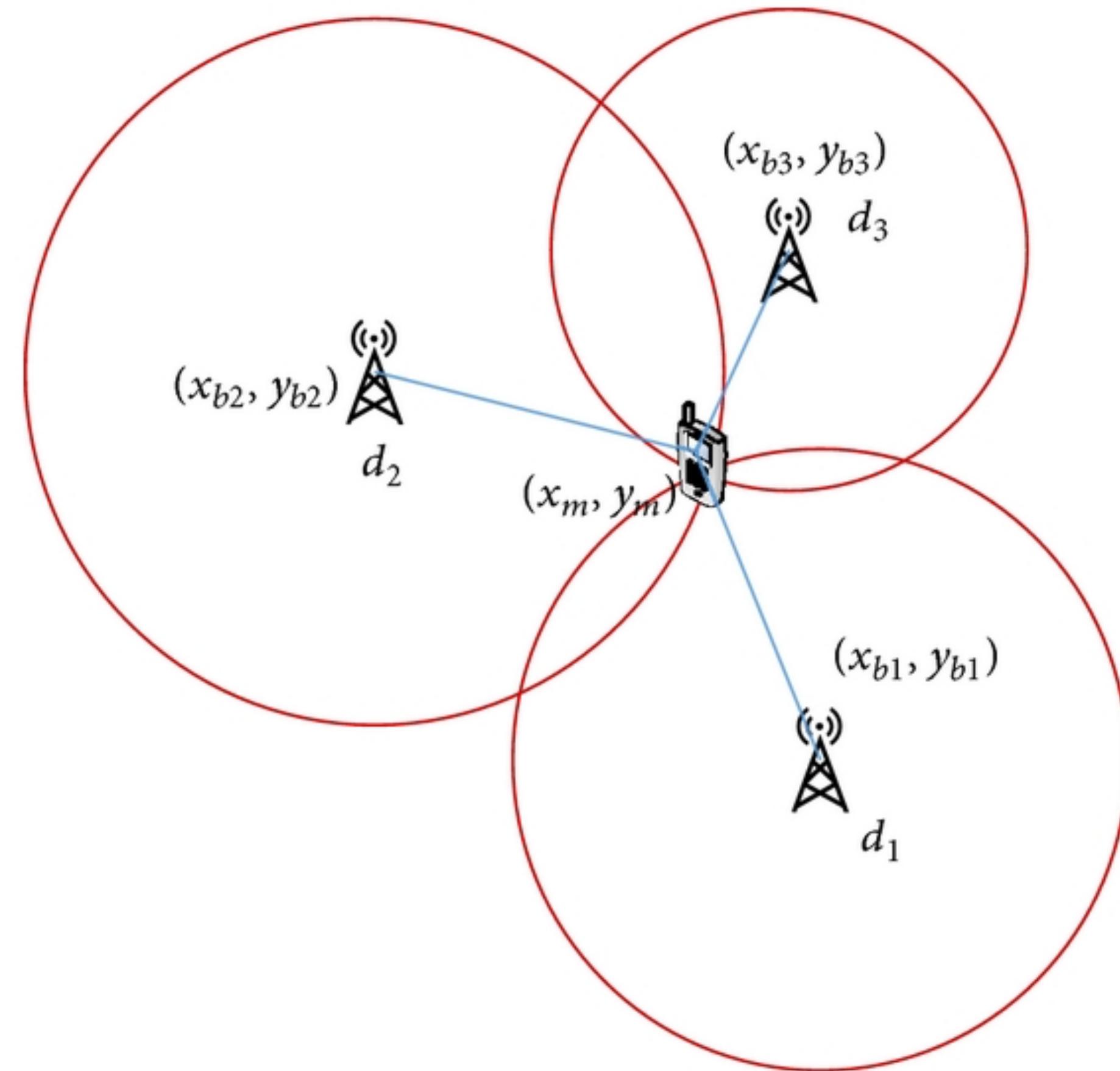
Video-detection

- Expensive
- May be affected by the level of light etc.
- There is a risk of drivers' privacy violation
- Cameras should be installed above the level of parking - problem with covered parkings.



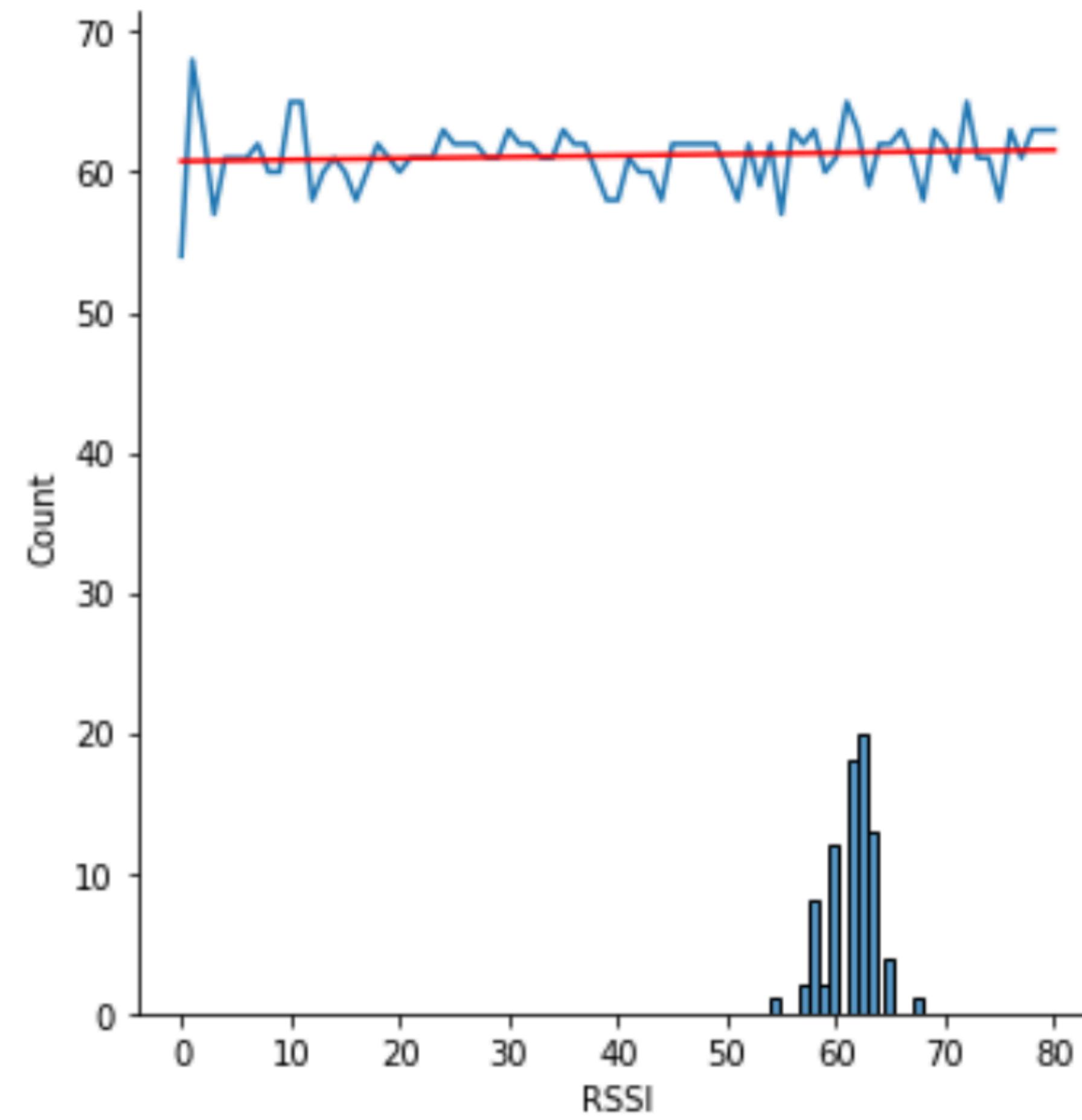
BLE RSSI for user detection

- indoor localisation approach
- Initial plan to experiment with triangulation based on BLE RSSI
- RSSI - indicates the energy loss in the process of signal transmission
- User-system direct interaction to minimise the delays and improve reliability



$$PL = P_{Tx_{dBm}} - P_{Rx_{dBm}} = PL_0 + 10\gamma \log_{10} \frac{d}{d_0} + X_g$$

- Absorption, reflection and defraction
- Computational cost
- We rely on user, not on machinery
- Timing problems
- Scientific works mainly investigate this issue without obstacles and in two-dimensional space



RSSI measurements at distance of one meter with one sample in two seconds

What to do?

Magnetometer

- Measures the projection of the magnetic field induction* on the axis of sensitivity (unit of measurement - tesla).
- It is exposed to hard-iron (eg: permanent magnet action) and soft-iron distortions.

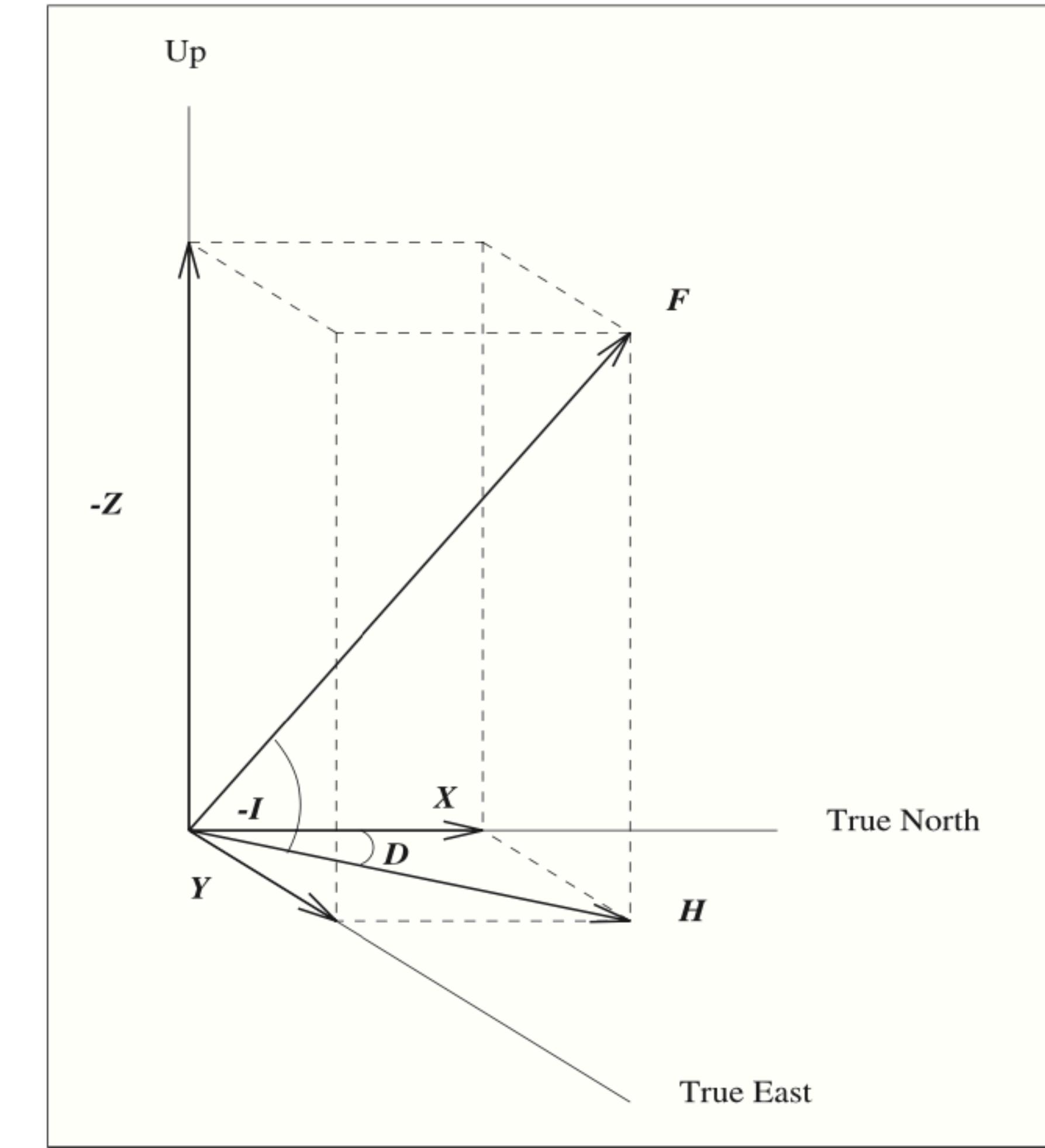


Fig. 1. Components of Earth's magnetic field (total field F , horizontal component H , vertical component Z , north component X , east component Y , declination D , inclination I). The orientation of the vertical component, which results in both Z and I having negative values, describes the southern-hemisphere magnetic field direction.

* (Magnetic induction - vector physical quantity, the main characteristic of the magnitude and direction of the magnetic field)

Why?

- They allow to detect the presence of ferromagnetic objects (iron, cobalt and nickel). Massive components like engine, gearbox, driveshaft, axles and wheel suspensions contain a lot of steel, therefore will greatly influence magnetometer.
- Not requires no energy to be emitted, thus minimising both energy consumption and risk of electromagnetic interference

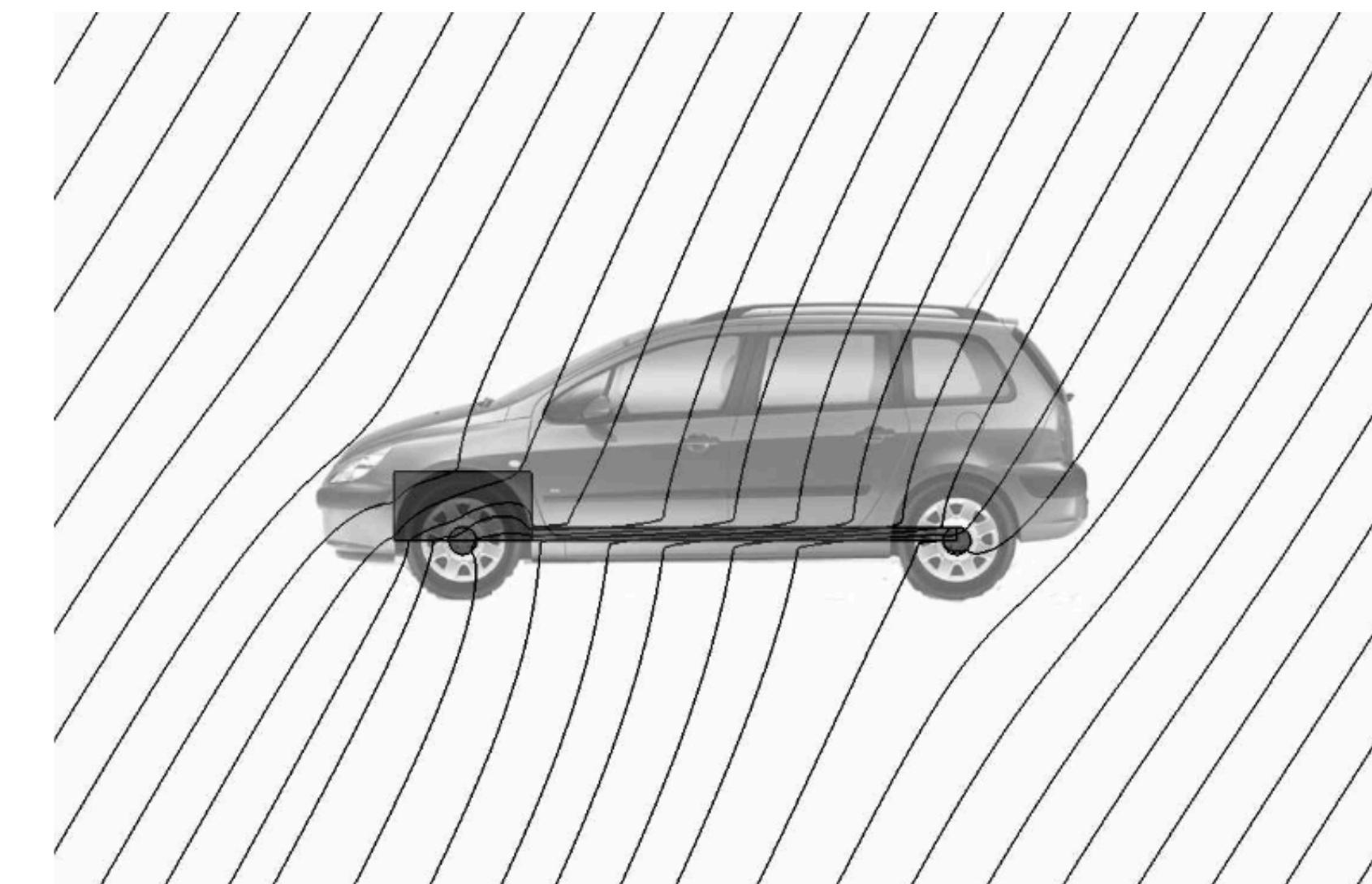
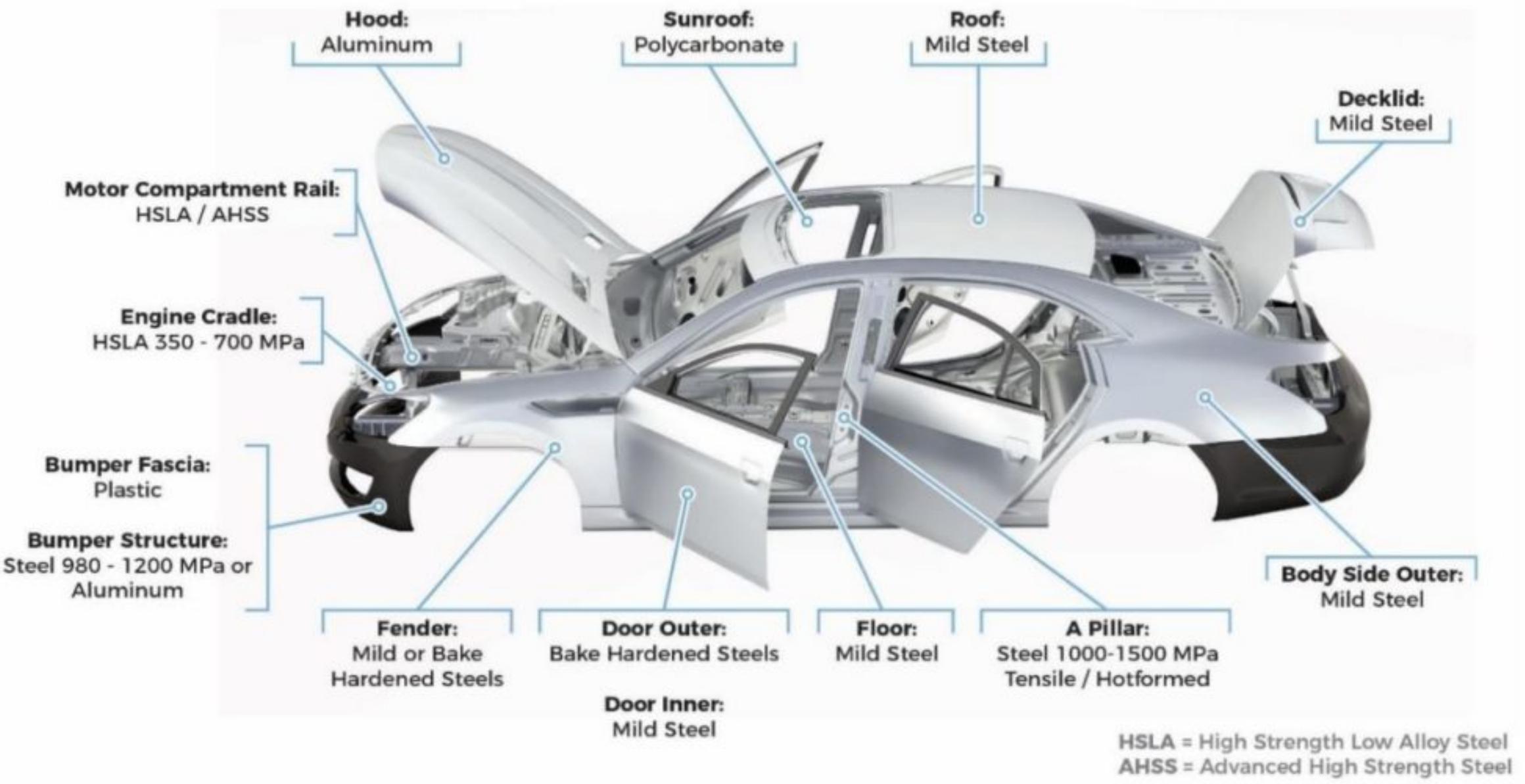
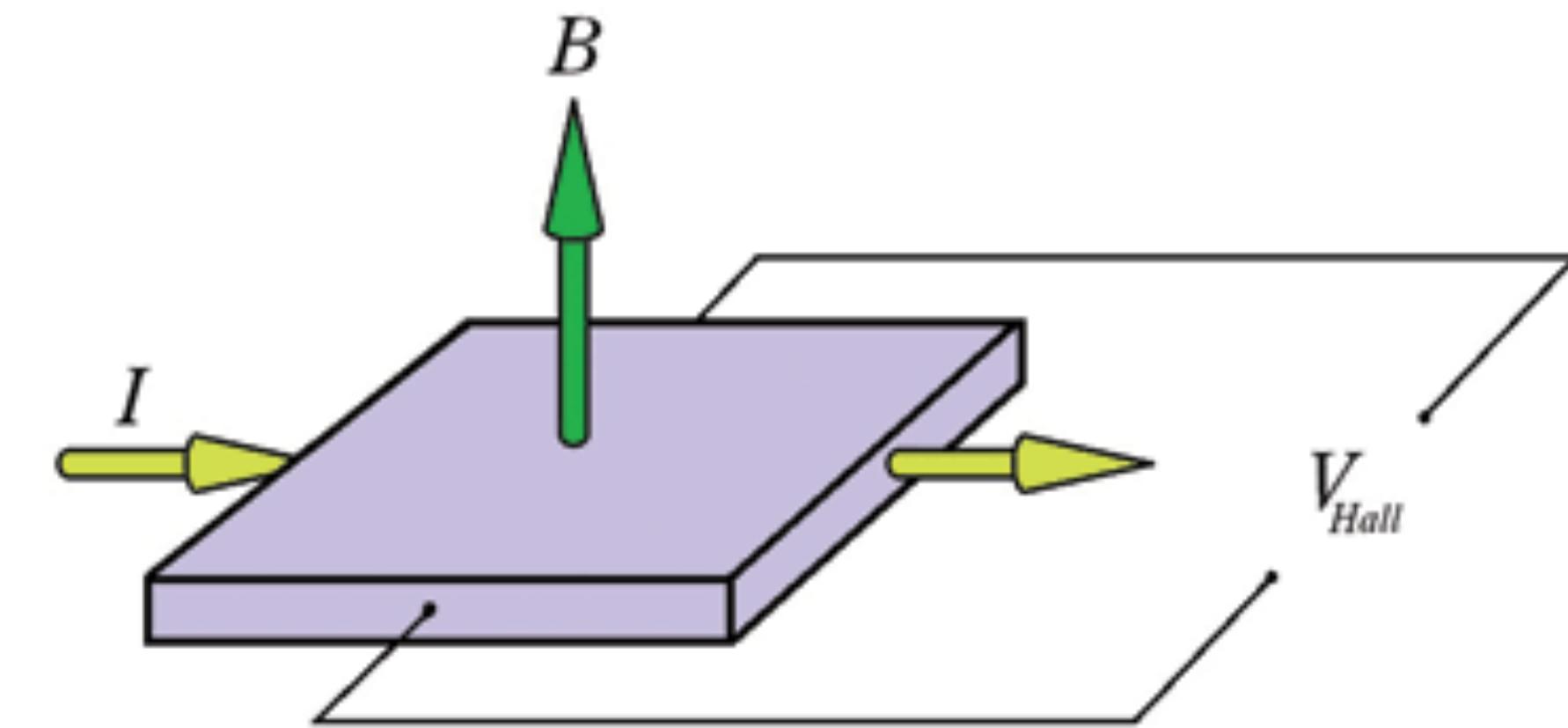


Fig. 1. Simulation of the deformation of the Earth's magnetic field by a car

Hall Effect

- Principle: voltage (Hall voltage) can be detected across a thin metallic element, when the element is placed in a strong magnetic field perpendicular to the element's plane
- Comparatively low sensitivity and temperature stability.

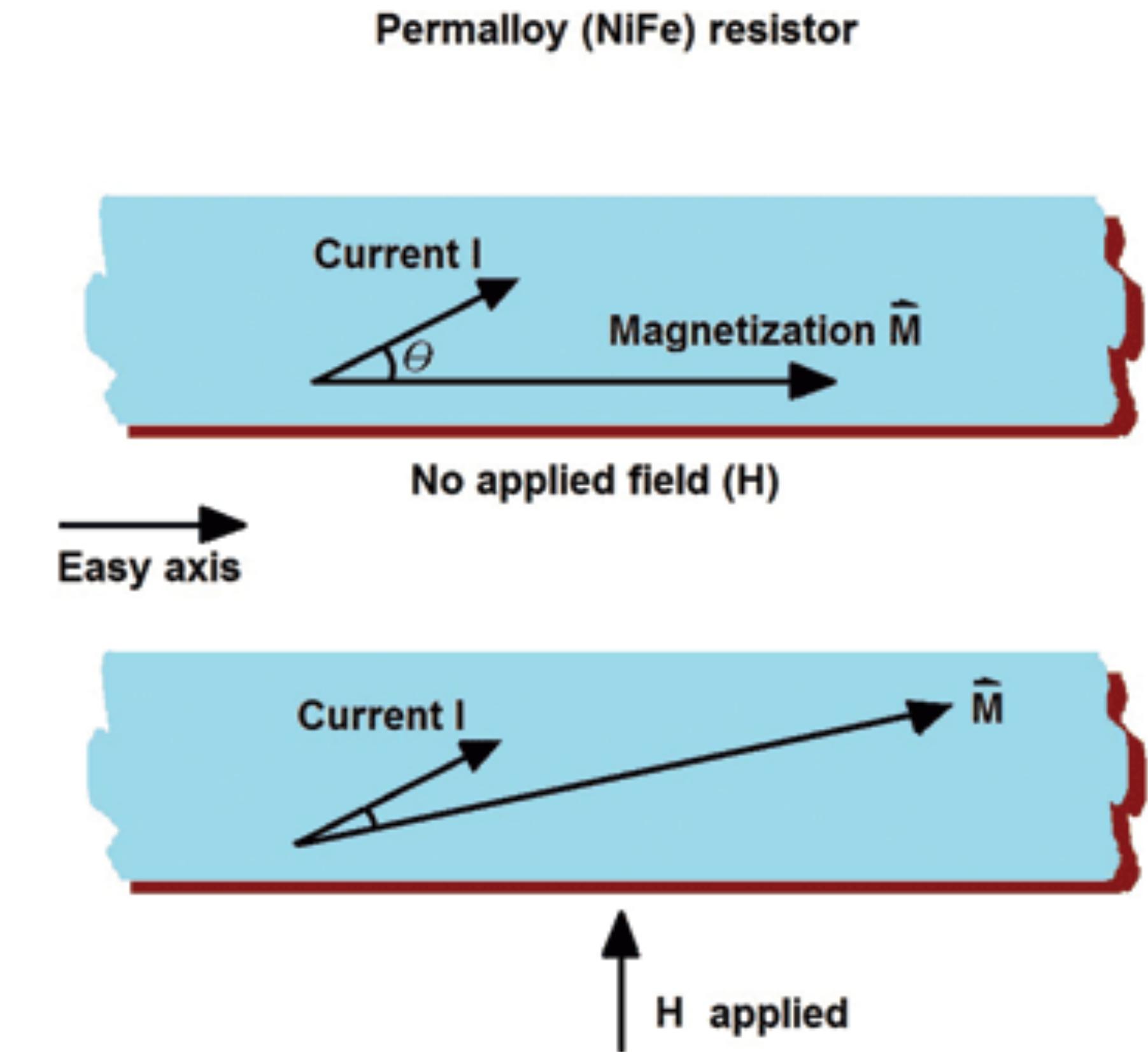


$$V_{Hall} = k |I \times B|$$

AMR

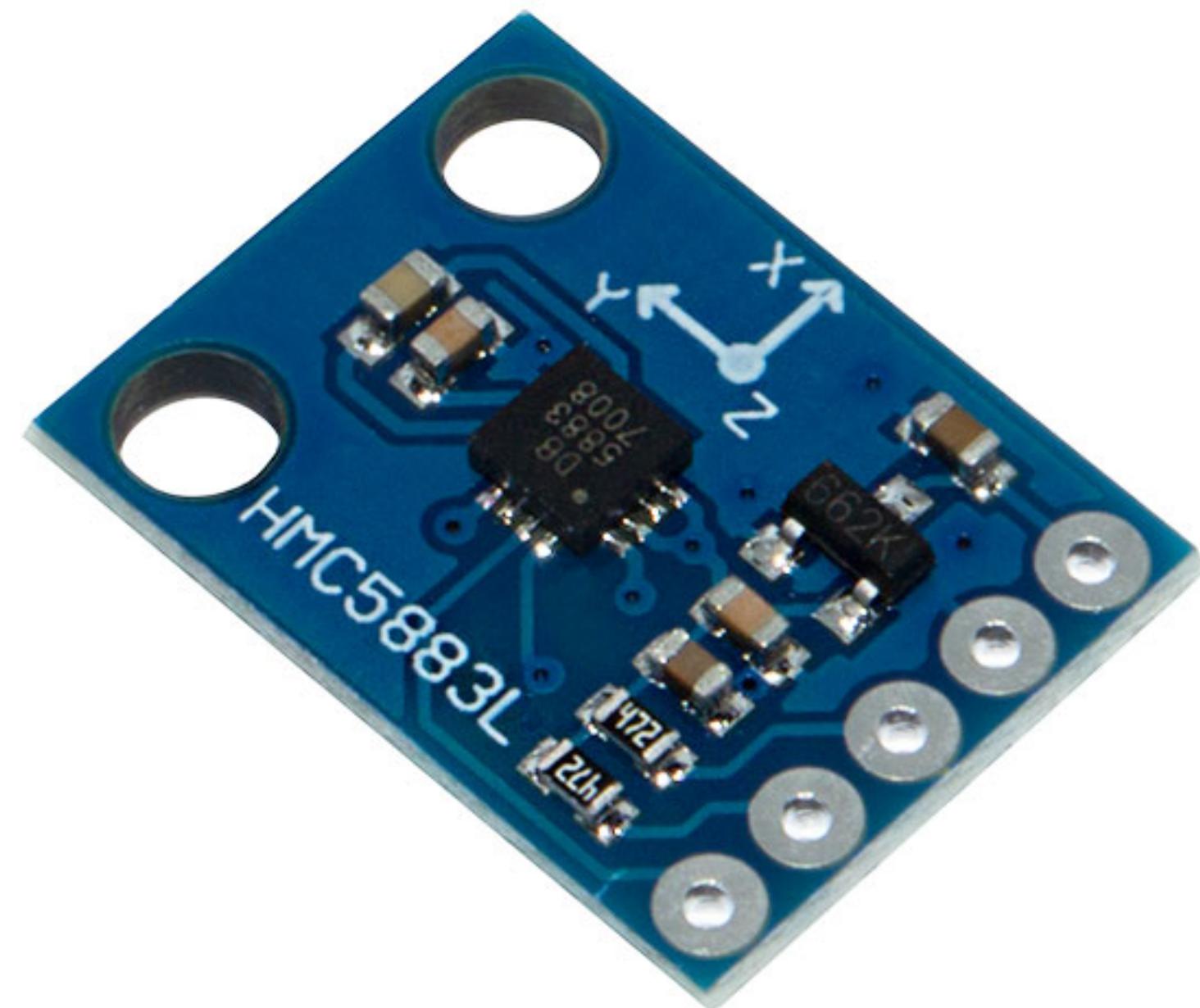
Anisotropic magnetoresistance

- Utilises object's capacity to change electrical resistance upon exposure to an external magnetic field.
- Concept makes use of permalloy (80% nickel and 20% iron). Its resistance depends on the angle between the magnetisation and the direction of current flow



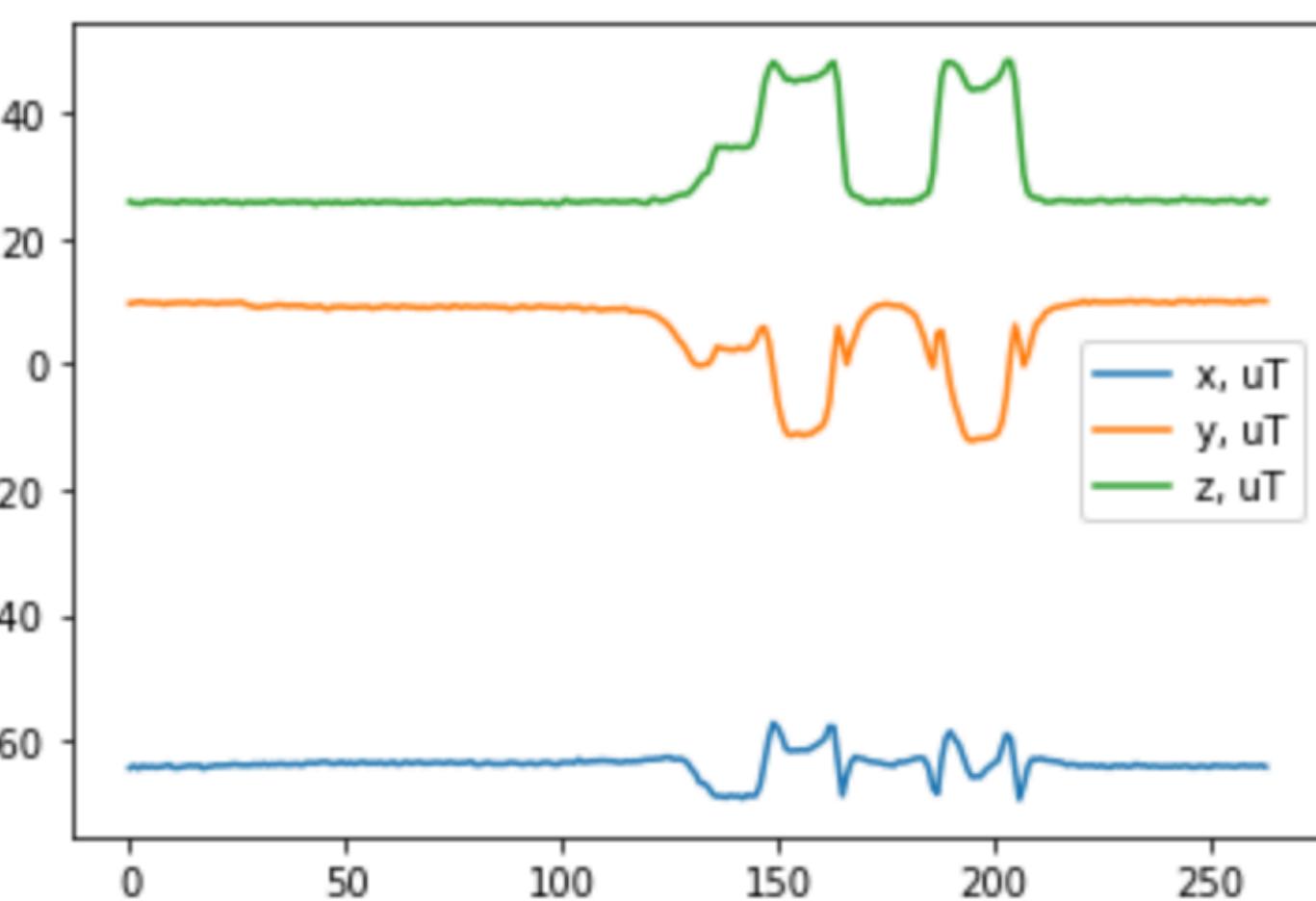
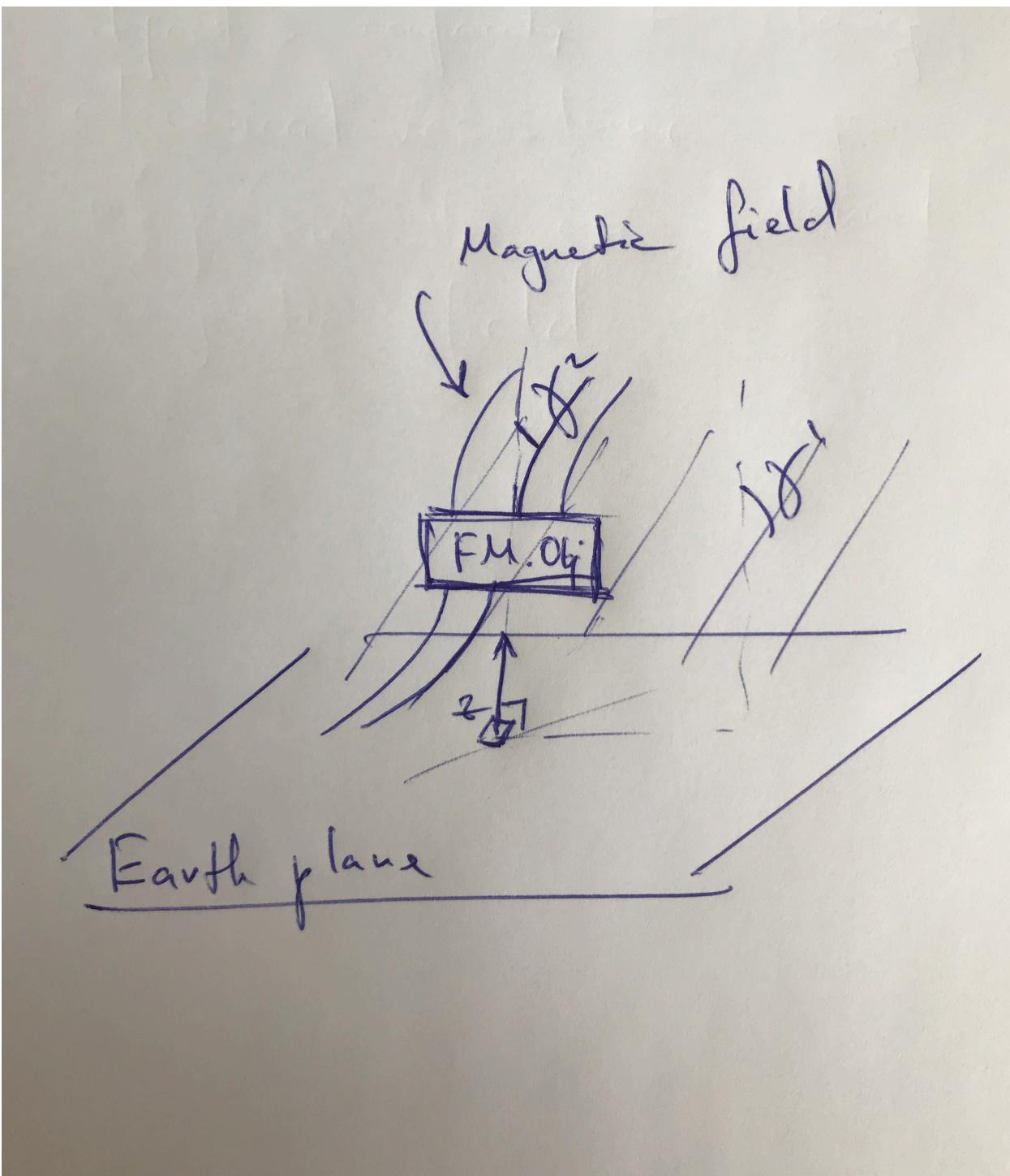
HMC5883L

- HMC5883L magnetoresistive sensor circuit is a trio of sensors and application specific support circuits to measure magnetic fields.
- Supply voltage: 2.16 - 3.6 V
- Field range: -8 to +8 gauss (average field strength of the Earth's magnetic field is between 30uT (0.3 Gauss))
- Digital resolution: 2 milli-gauss
- Supports I2C communication protocol



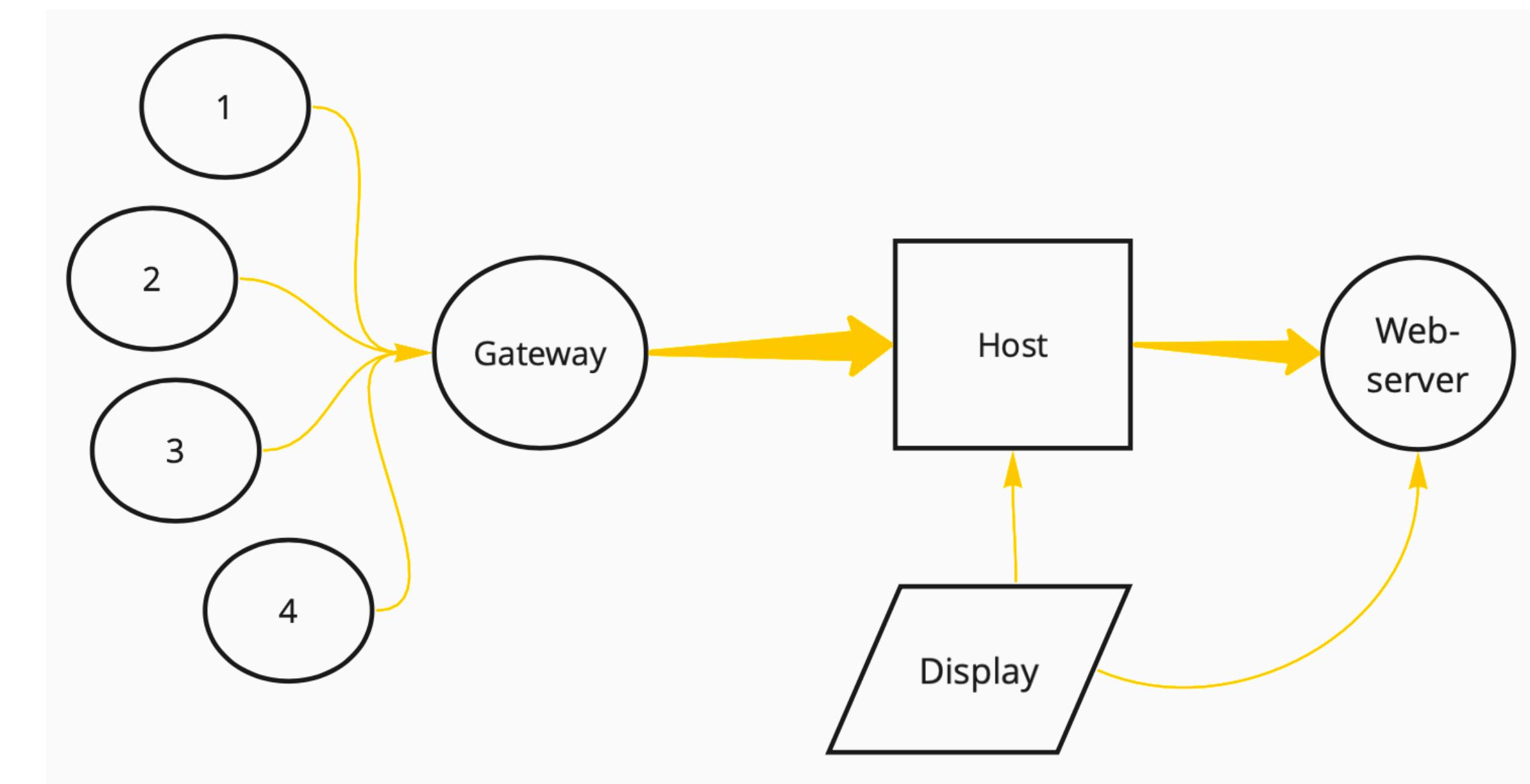
Proof of concept

- The Z-axis of the AMR sensor is perpendicular to the plane of Earth.
- As with the appearance of ferromagnetic object the angle between the Z-axis and the local magnetic field becomes smaller, we wait for the sensors' readings to increase as the resistance becomes smaller.



System specification

- Each parking space is equipped with a **sensor** (magnetometer and periphery for its support).
- Data from several sensors is transmitted to a **gate-way** that then passes it further to host-machine.
- **Host**-machine is responsible for management of free parking spaces.
- **Display** fetches data from host-machine directly or via remote web-server.



Data transmission

nRF24L01+

- Very low current consumption: 9mA for transmission
- Power down mode support
- Support of star-topology
- Possibility to receive acknowledging basing on node's unique id
- Up to 100m range
- Up to 32 bytes in one transmission



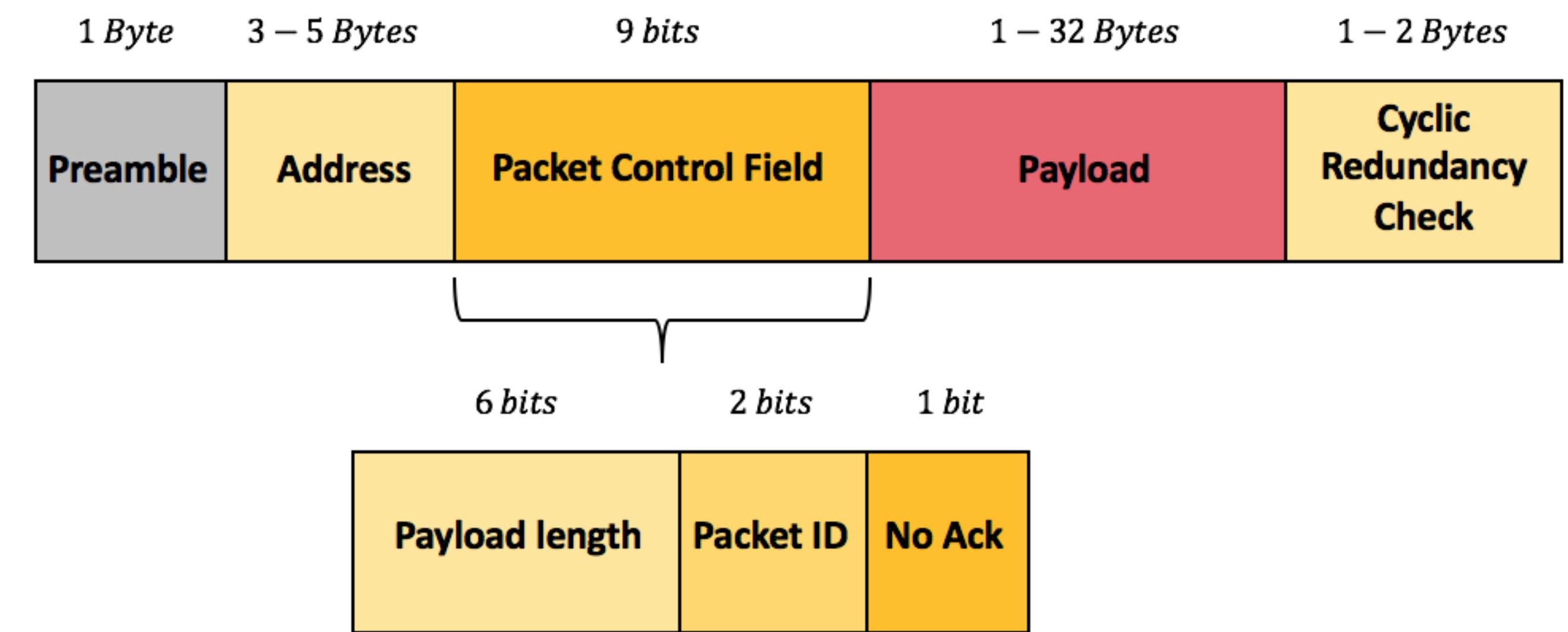


- 39 mA
 - Much greater range: up to 15km
 - Much greater sensitivity
 - Much greater cost
 - Brings complexity to the system as LoRaWAN is needed to manage star topology



Enhanced ShockBurst Protocol

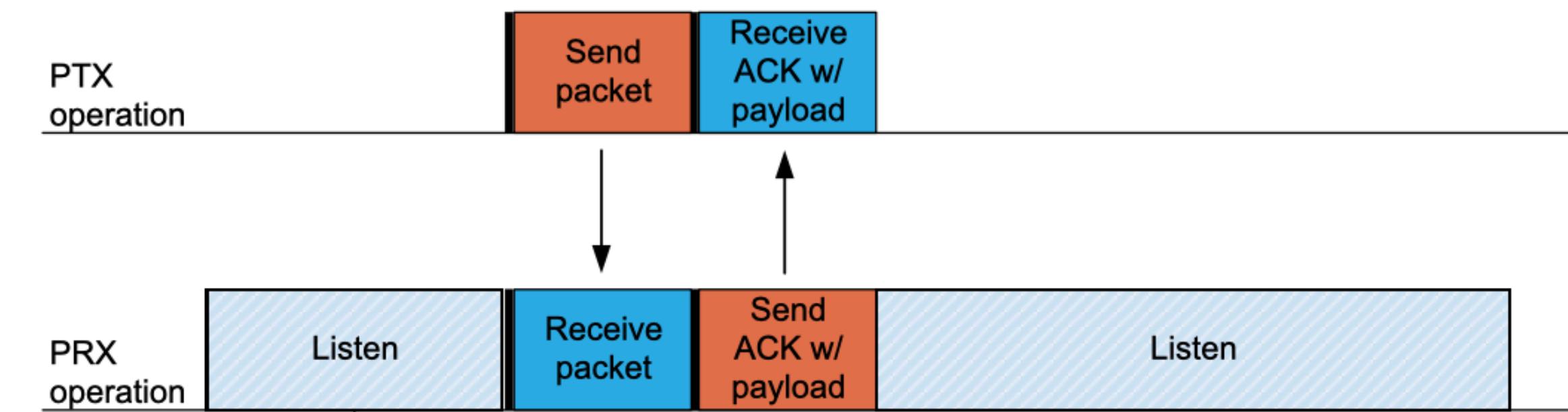
- Up to 32 bytes payloads that support dynamic change.
- Each sent packet with a packet ID, which allows the receiving device to determine whether a message is new or whether it has been retransmitted.
- Each message can request an acknowledgement to be sent when it is received by another device



How the automatic packet handling works?

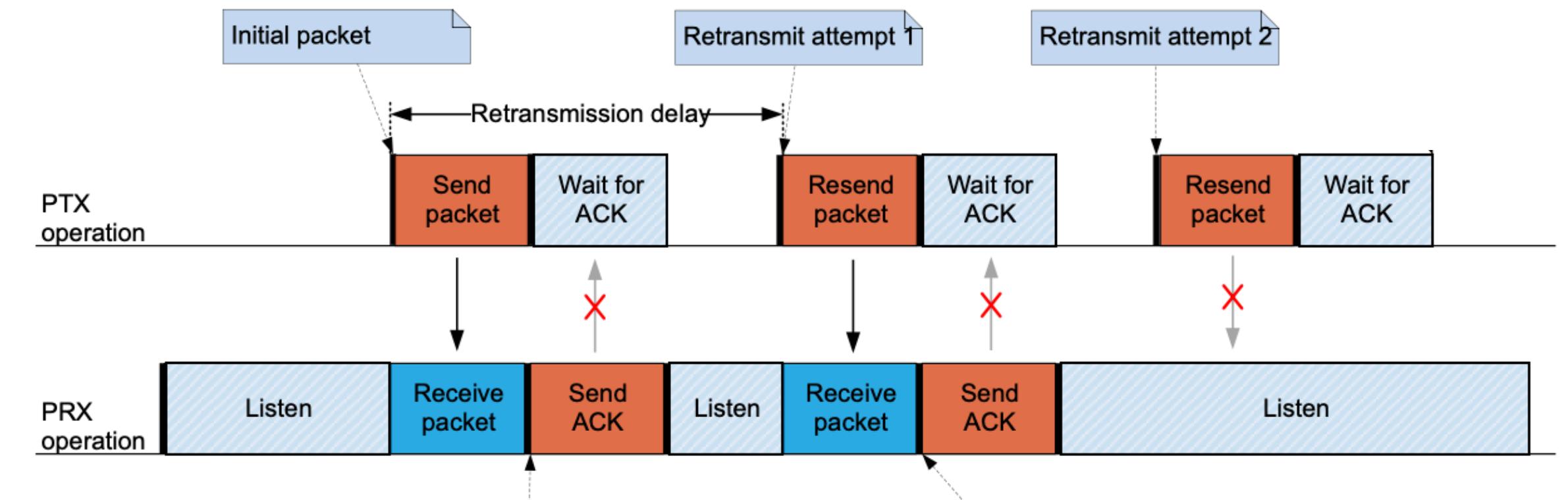
Transaction with acknowledgement and interrupt.

- TX sends a data packet to the receiver.
- Once the packet is transmitted, it waits ($130 \mu\text{s}$) for the ACK packet.
- When the receiver receives the packet, it sends ACK packet to the transmitter.
- On receiving the ACK packet the transmitter asserts interrupt (IRQ) signal to indicate the new data is available.



Transaction with data packet lost

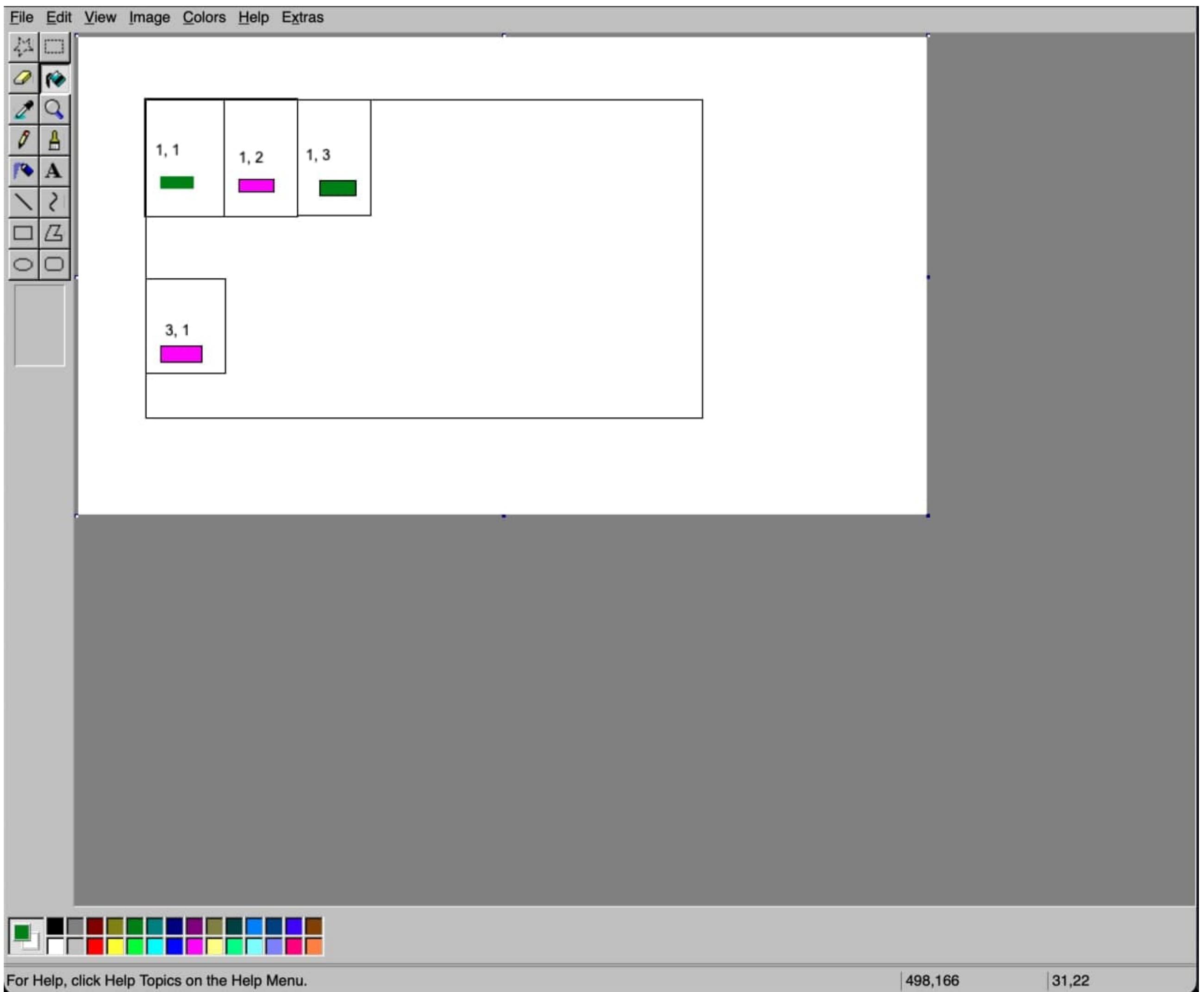
- After the packet is transmitted, the transmitter waits for the ACK packet to receive.
- If the transmitter doesn't get it within Auto-Retransmit-Delay (ARD) time, the packet is retransmitted.
- When the retransmitted packet is received by the receiver, the ACK packet is transmitted which in turn generates interrupt at the transmitter.



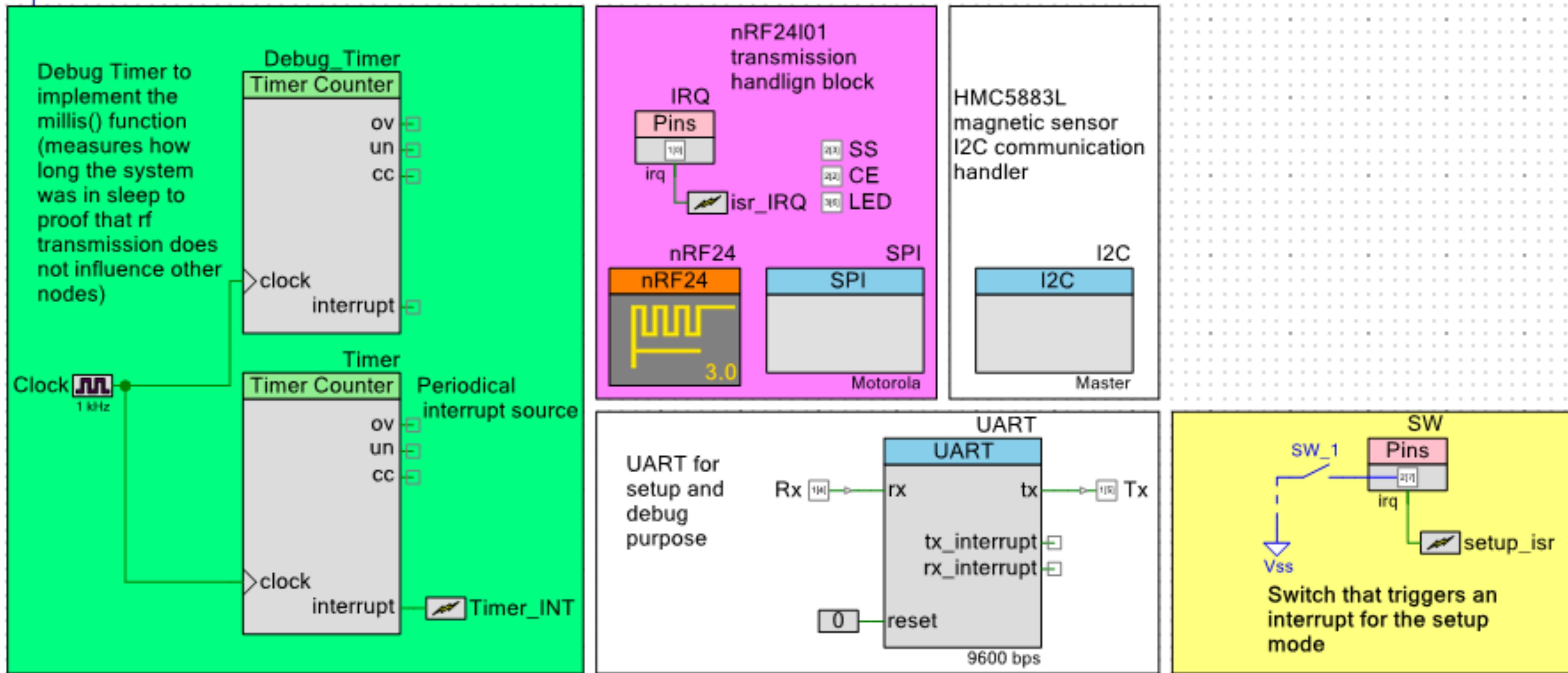
Transaction with acknowledgement lost

- When receiver receives the packet containing same packet ID as previous, it discards it and sends ACK packet again.

Displaying

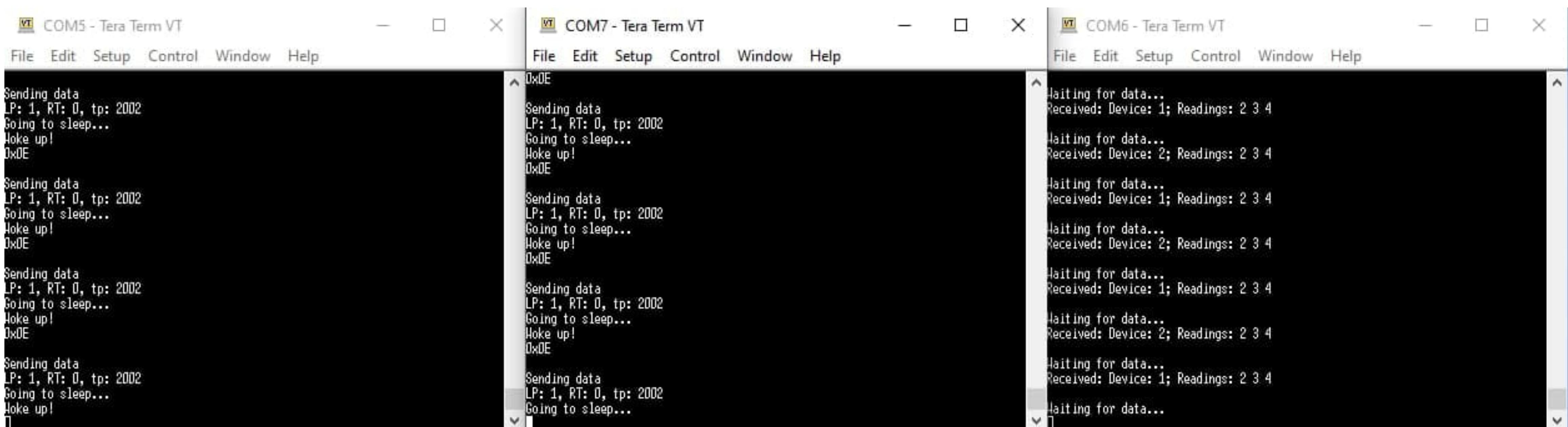


Scheme



Example of execution

does-not-affect-neighbours proof



Power consumption

What to improve?

- Port host functionality to PSoC 6 with WiFi support, so to make the remote web-server possible.

Q&A