Simultaneous measurement of ruminal parameters and physical activity of dairy cows

Roman Čečil
University of West Bohemia, Pilsen, Czech Republic

2.2.2023, Pasohlávky

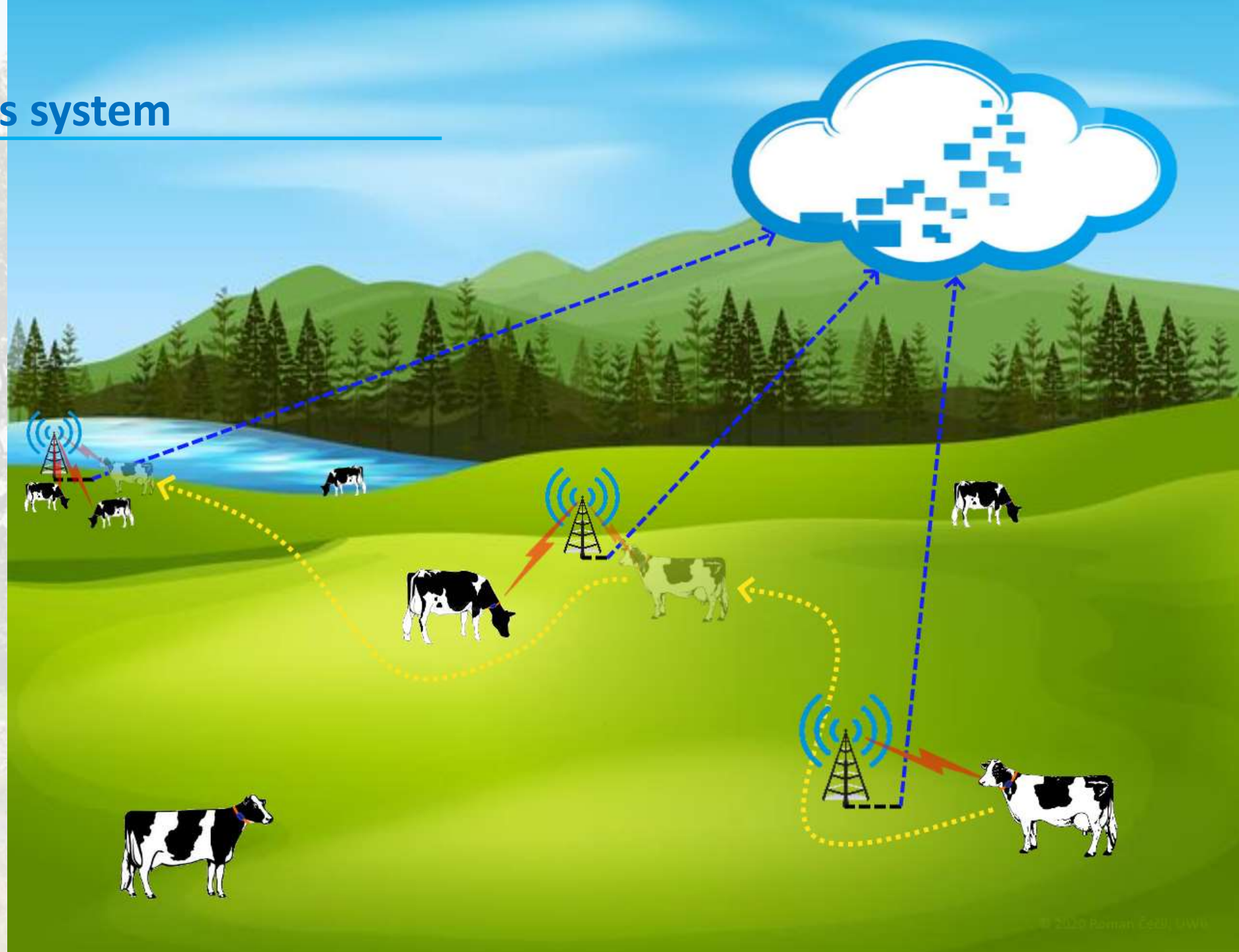
This project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 783221. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Austria, Belgium, Czech Republic, Finland, Germany, Greece, Italy, Latvia, Norway, Poland, Portugal, Spain, Sweden.

Ruminal probes system

SARA detection (subacute ruminal acidosis)

General health-state

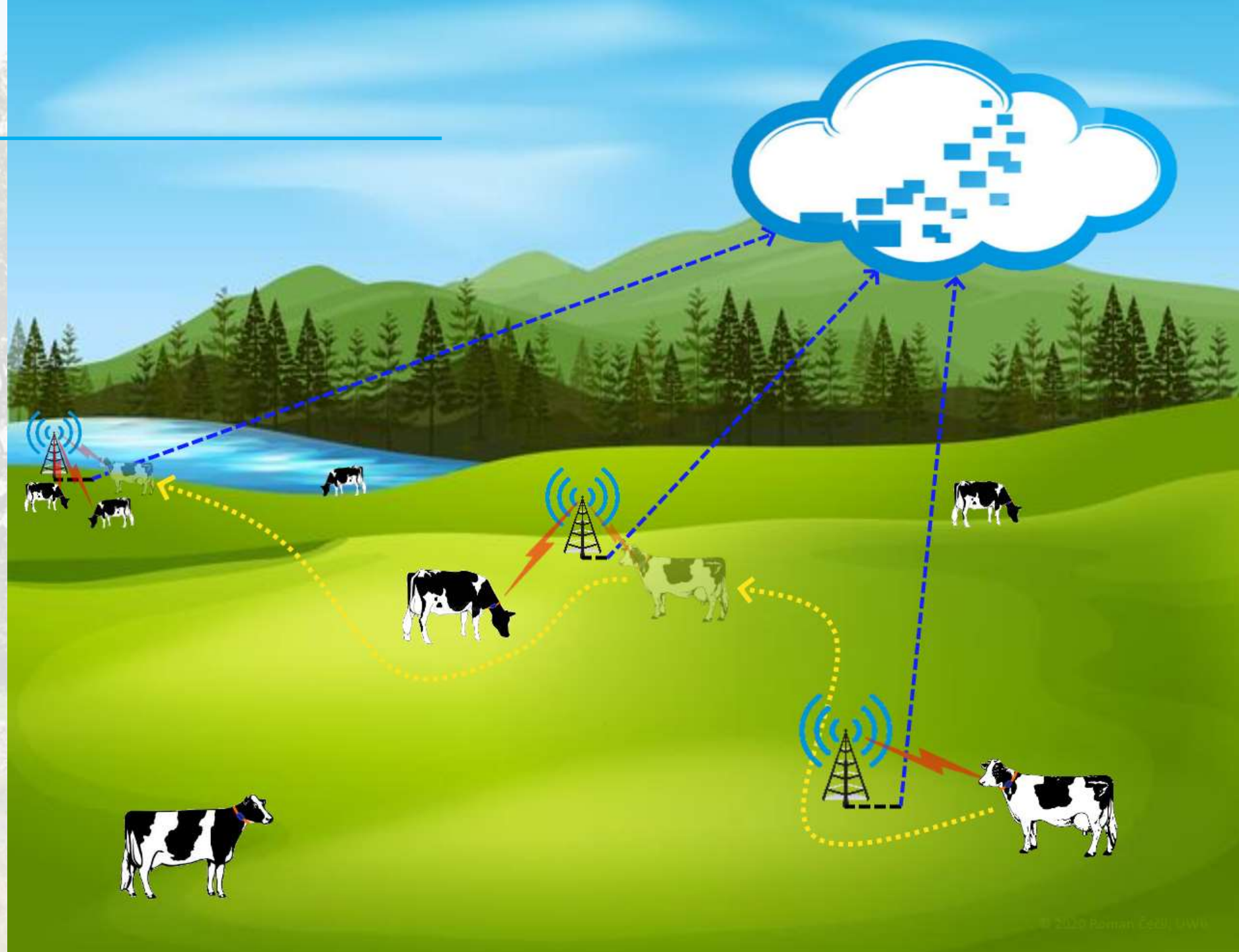
Animal well-being



Challenges

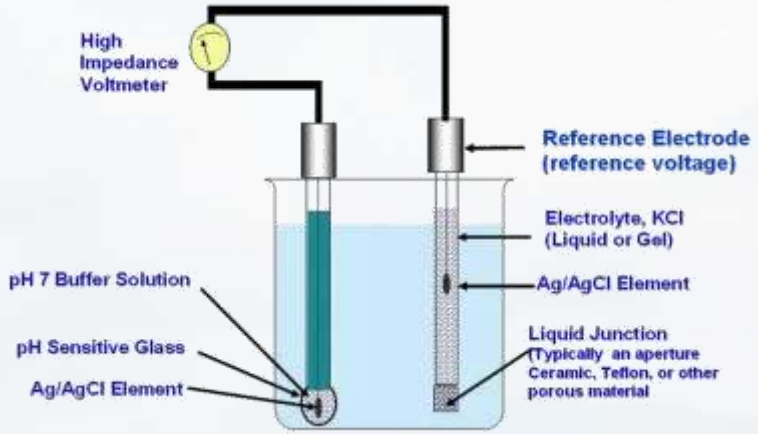
pH sensing

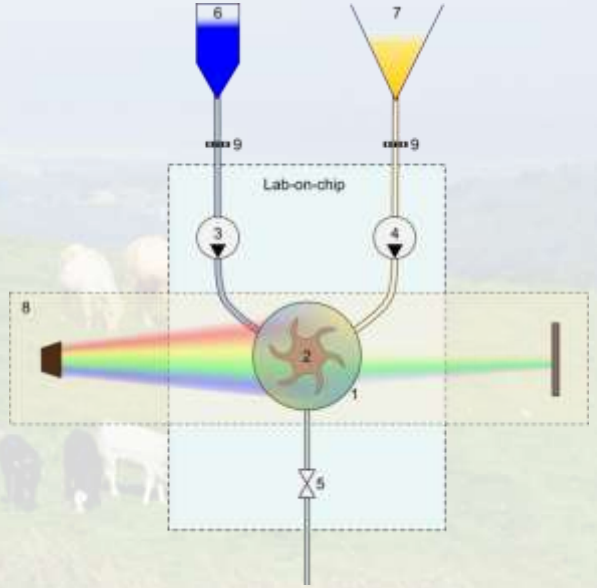
Wireless data transmission



pH sensing

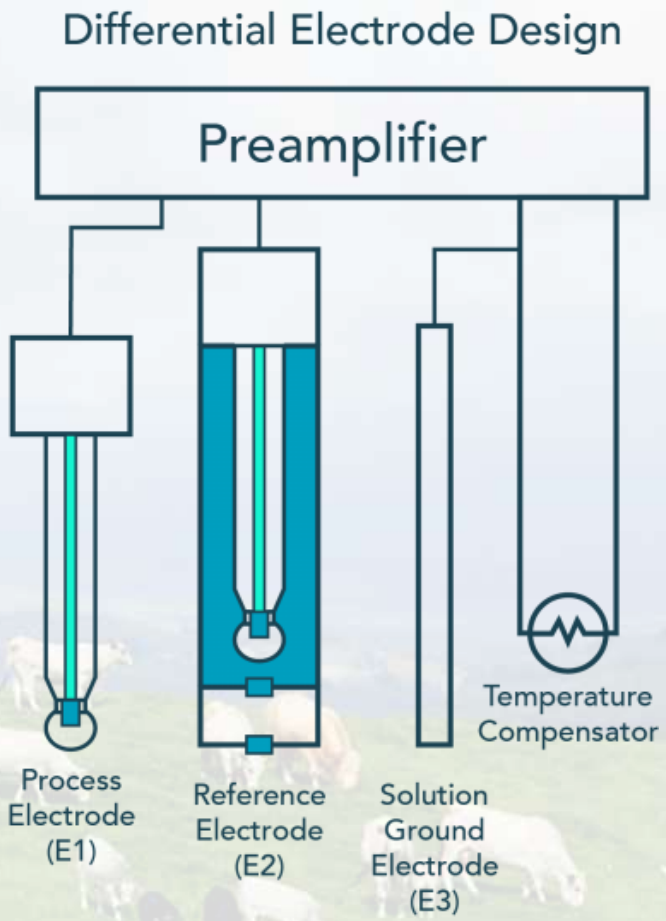
- Electrochemical sensors
- MER (Magneto-elastic resonance sensor)
- titration spectroscopic sensor
- pH nanosensors





Differential pH sensing

- Measures potential of reference electrode and pH sensing electrode with regards to solution ground
- Removes ground loops and thus current flowing through the electrodes, which results in strong suppression of reference electrode drift caused by poisoning of the reference electrode
- Commercial solutions exist, but are too big and expensive



Ruminal probe – value sensing

pH

- Off-the-shelf pH sensor from Hanna Instruments is used
- Integrated reference and pH electrodes
- Titanium body

Temperature

- Digital temperature sensor from Silicon Labs is used
- 0.1 °C absolute accuracy

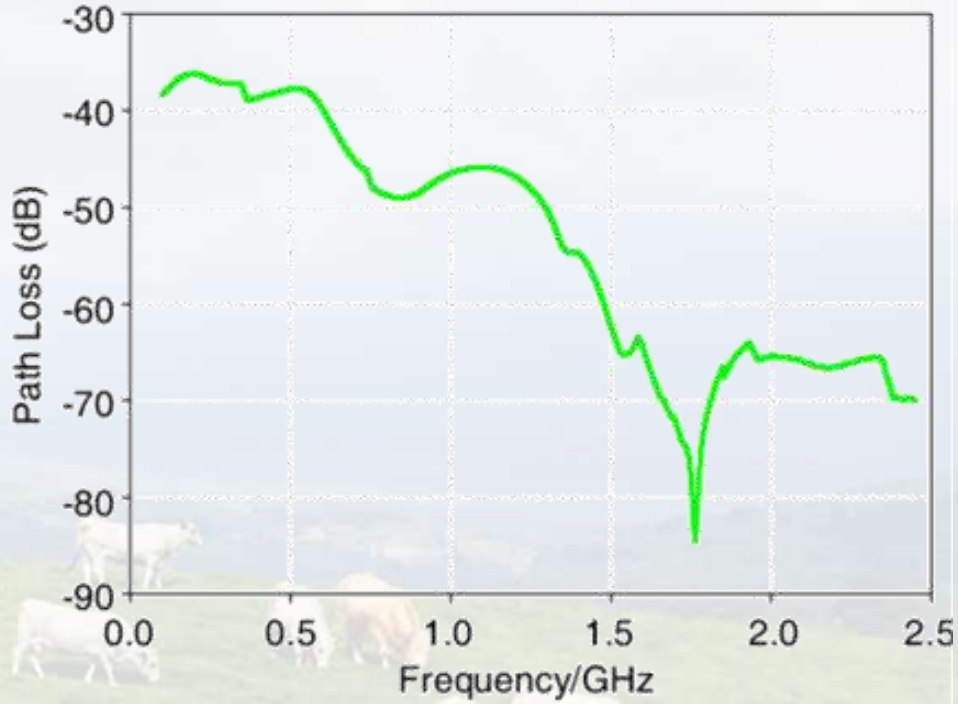
ORP

(oxido-reduction potential)

- Platinum-coated ceramic rod (expensive)
- Platinum wire

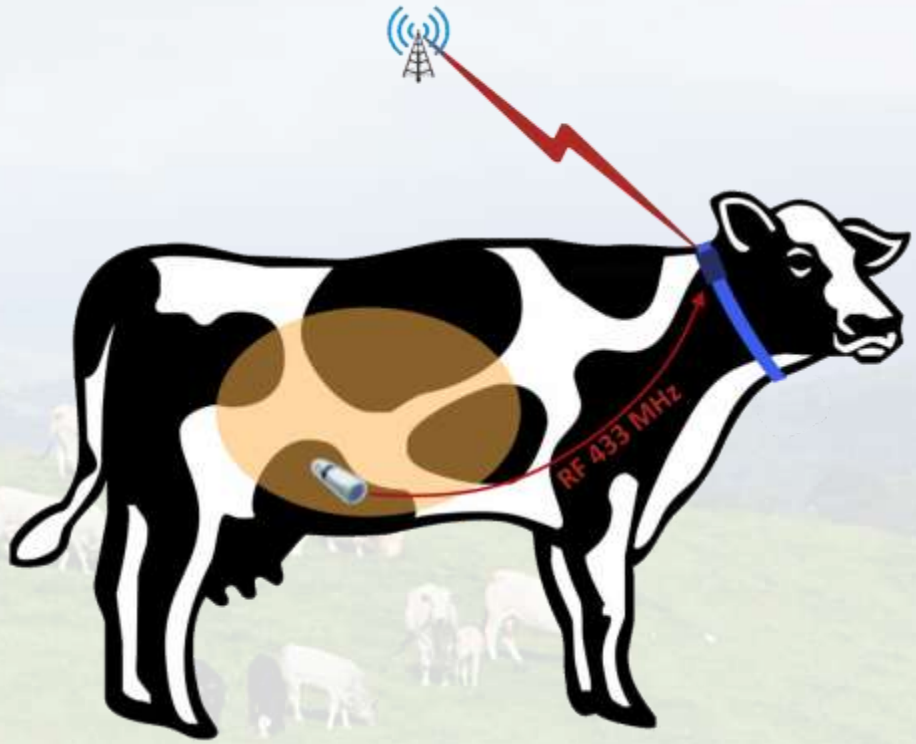
Radio waves propagation

- RF transmission from liquid ruminal environment is problematic
- Signal strength decreases significantly with increasing frequency
- "Blockers" at 1.75 and 2.5 GHz

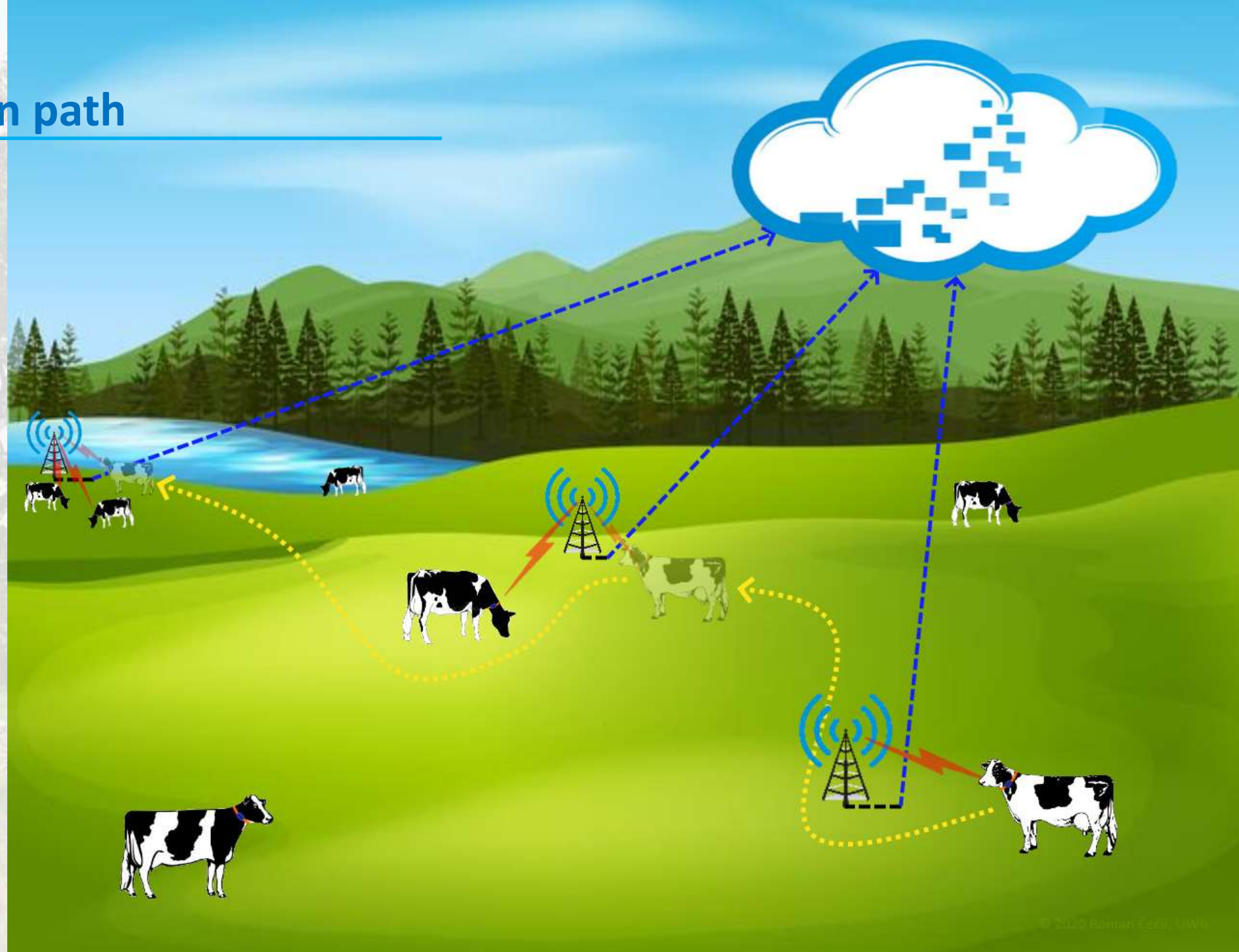


Communication links

- **Key improvement:**
  Introduction of collar device serving as a re-transmitter for ruminal data
- Rumen-to-collar communication is based on low-enery custom protocol in 433 MHz band
- Collar-to-gateway communication uses BLE 5.0 in 2.4 GHz band, or the same custom protocol at 433 MHz that is used for rumen-to-collar link
- Collar device – once there, it collects other interesting data – rumination, activity, rest



Communication path

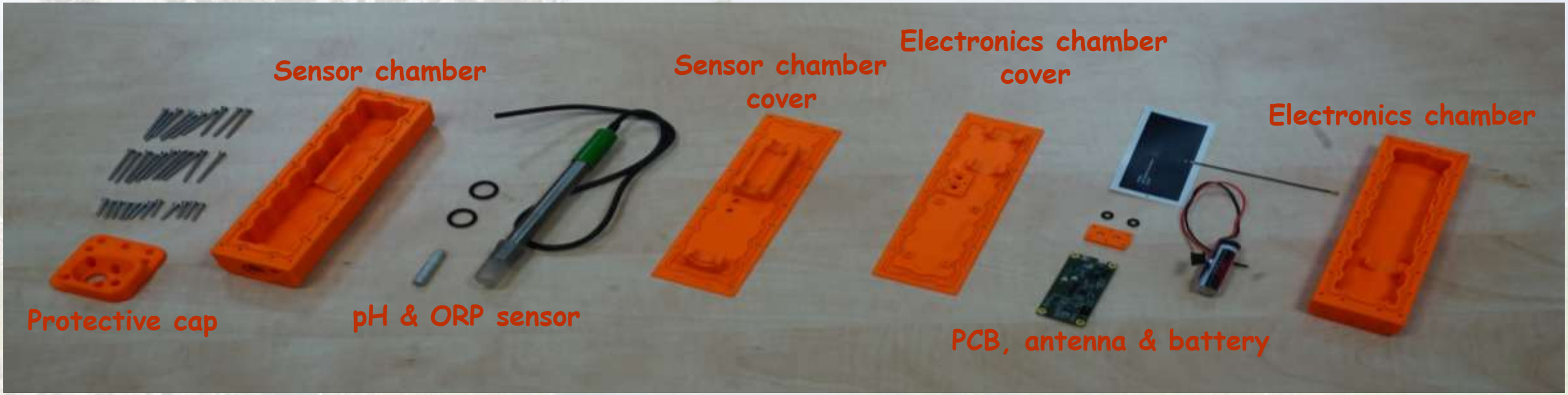


Ruminal probe – PCB & features

- ARM Cortex M4 MCU with integrated 433 MHz RF transceiver
- PCB designed to support both standard and differential pH sensing
- Precision low-power amplifier used – LT 6079
- 12-bit ADC used to sense pH and ORP
- For temperature sensing is used dedicated digital IC with 0.1 °C absolute accuracy

Ruminal probe – Capsule

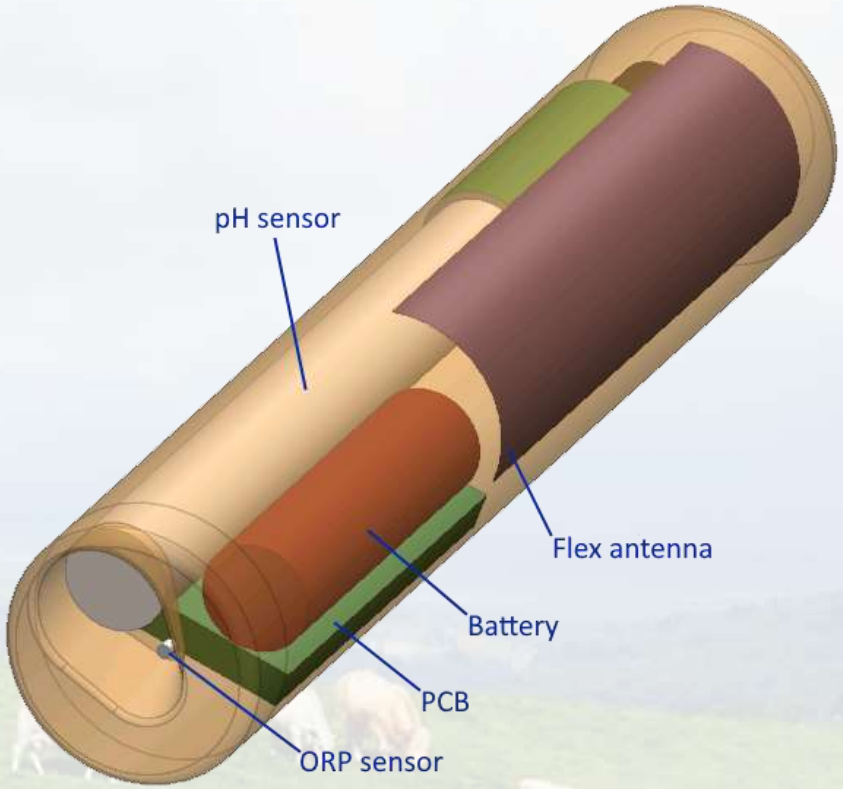
- Designed for fistulated cows to allow easy access to the electronics
- After successful review of electronics and firmware functionality it will be miniaturized
- 3D print, resin coated to prevent liquid leakages
- Two chamber design - electronics separated from the sensors



Ruminal probe – miniaturized version

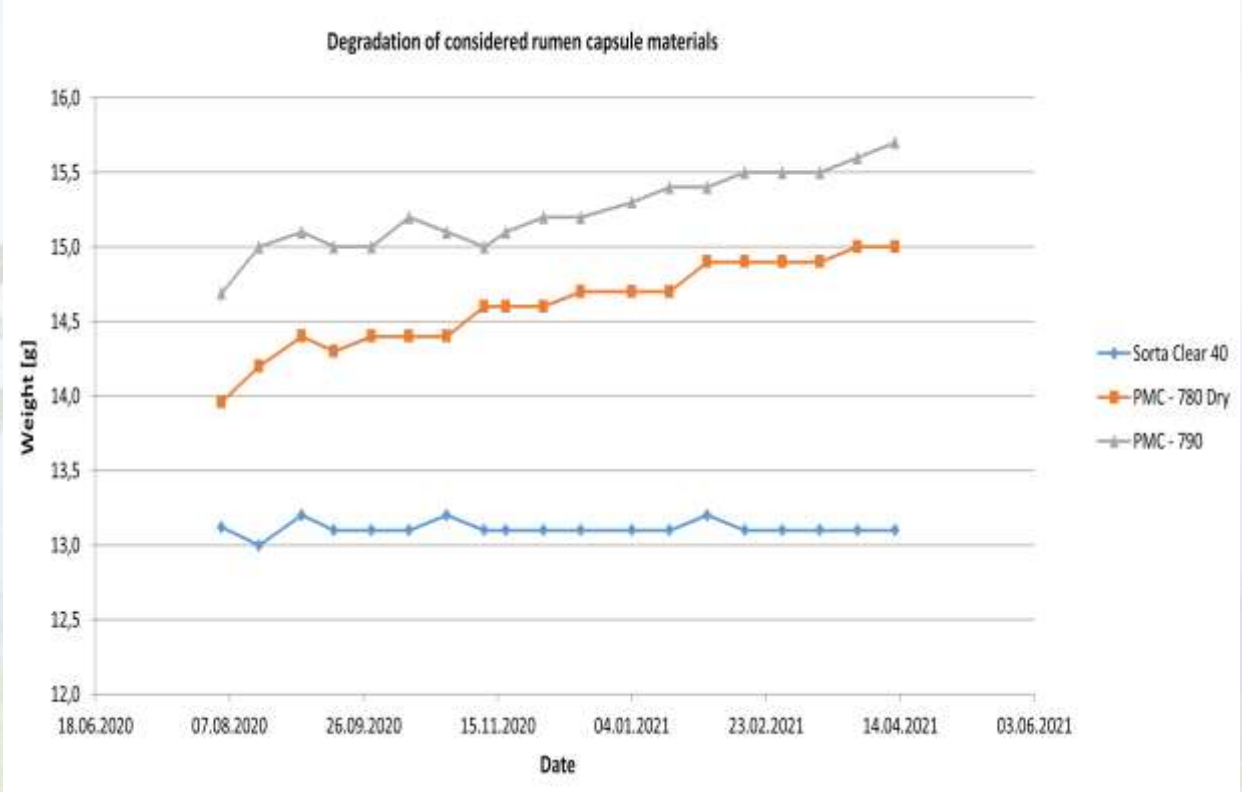
- Final version targeted for oral insertion
- PCB and capsule mechanical design finished

- Problem: global lack of electronic components



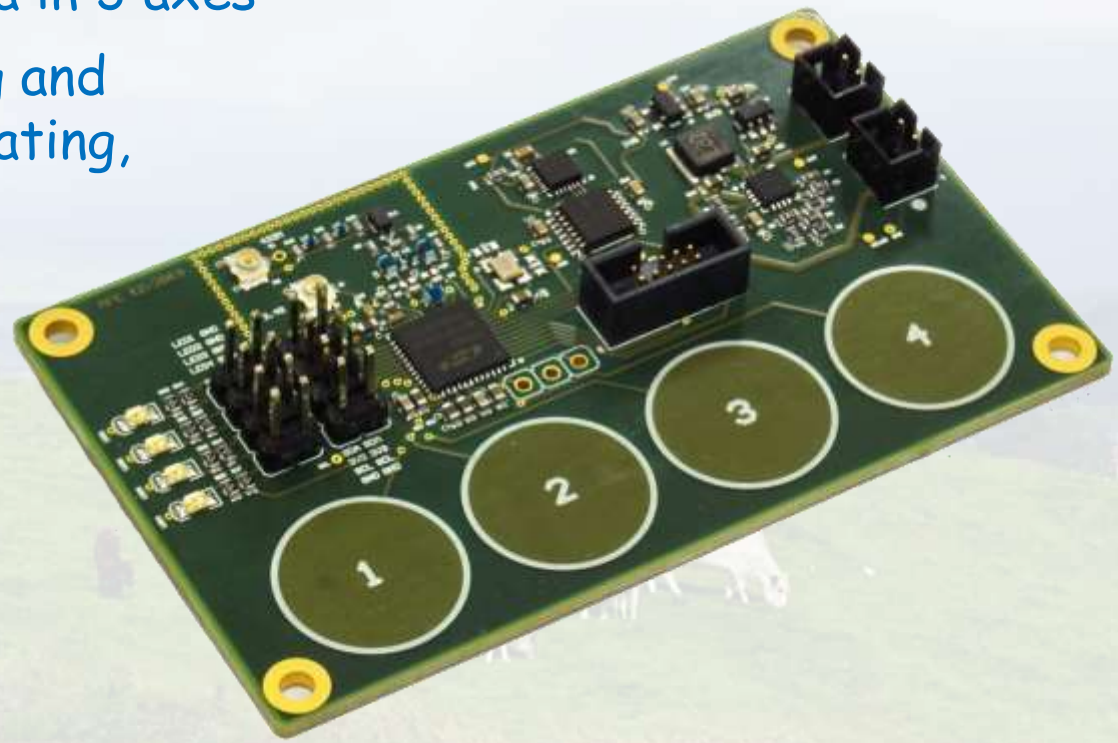
Long-term material degradation test

- To select suitable material for rumen capsule housing several food-industry approved materials have been immersed into rumen for 9 months
- Test cylinder were periodically observed for optical degradation and weight change
- No dissolving, however the PMC materials are absorbing water (mass increase)
- Additive silicone Sorta Clear 40 was selected
- Final capsule seems to be too soft -> 2 layer design or material reconsideration



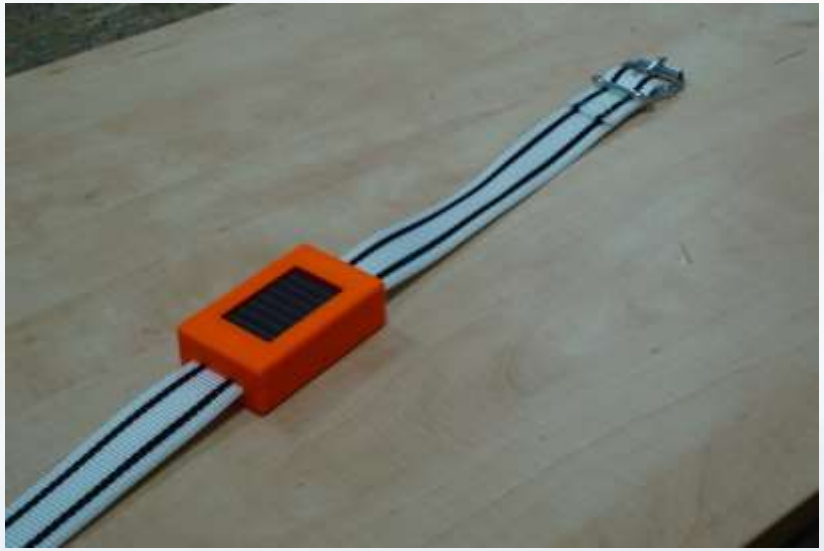
Collar device – PCB & features

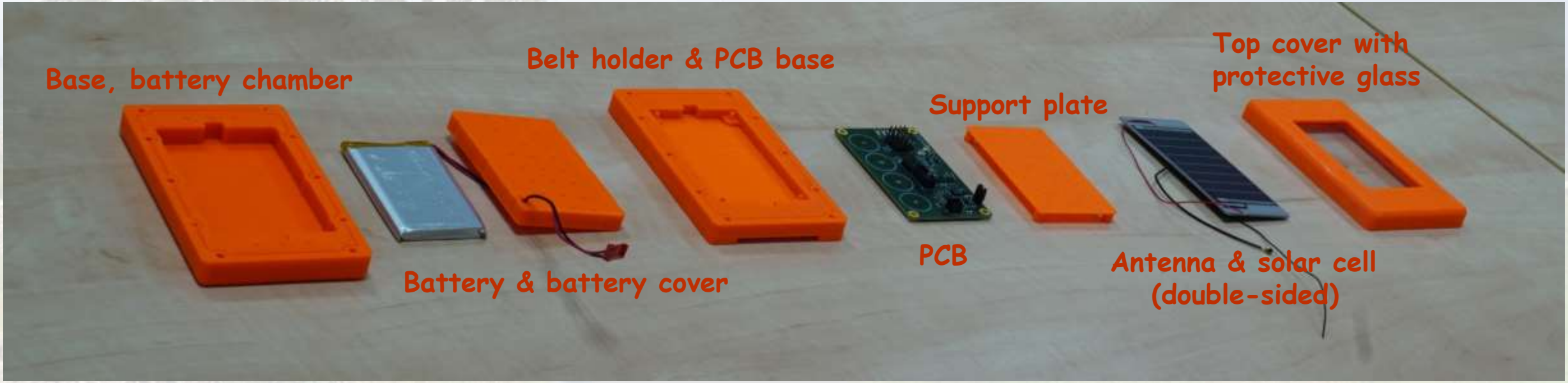
- MCU: single chip ARM Cortex M4 MCU with integrated dual band RF transceiver (433 MHz/2.4 GHz)
- 9-axis IMU unit to capture raw accelerometer/gyroscope/magnetometer data in 3 axes
- Planned activity: accelerometer data filtering and classification to quantify animal activities – eating, rumination, activity, vitality, sleep, …
- Li-on recheargable battery powered
- Solar panel for automatic charging vs wireless charging - energy balance still to be evaluated



Collar device – Housing

- 3D-print used for prototyping
- Stacked structure with separated chambers for battery, electronics and holding belt
- Water-proof – silicone O-rings between all layers





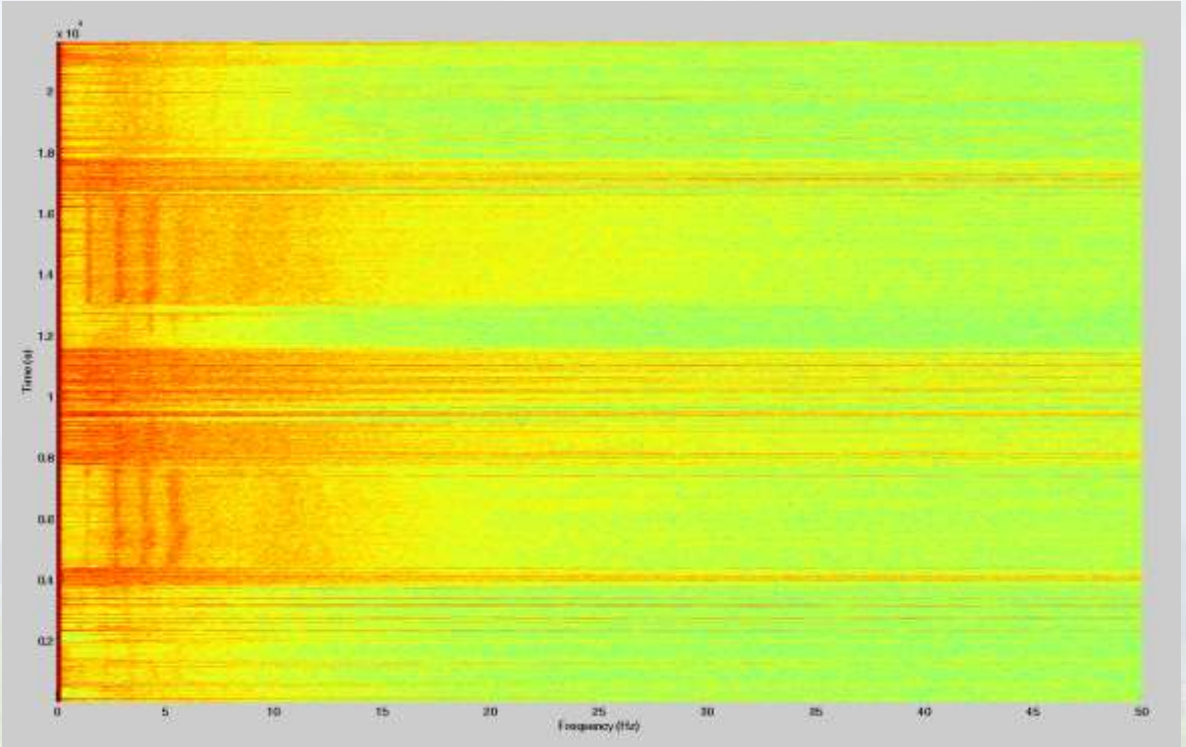
Collar device – Raw accelerometer data capture for analysis

- Special collar firmware that streams raw accelerometer data – used for behavior analysis
- Used to capture data for later analysis & classificator design
- Sampling rate 100 Hz
- 2 min buffer in case of RF link loss

- Application for online data visualization
- Export to CSV format
- Animal activity annotation – predefined buttons for common activities, custom notes

Behavior classification – ethological trial

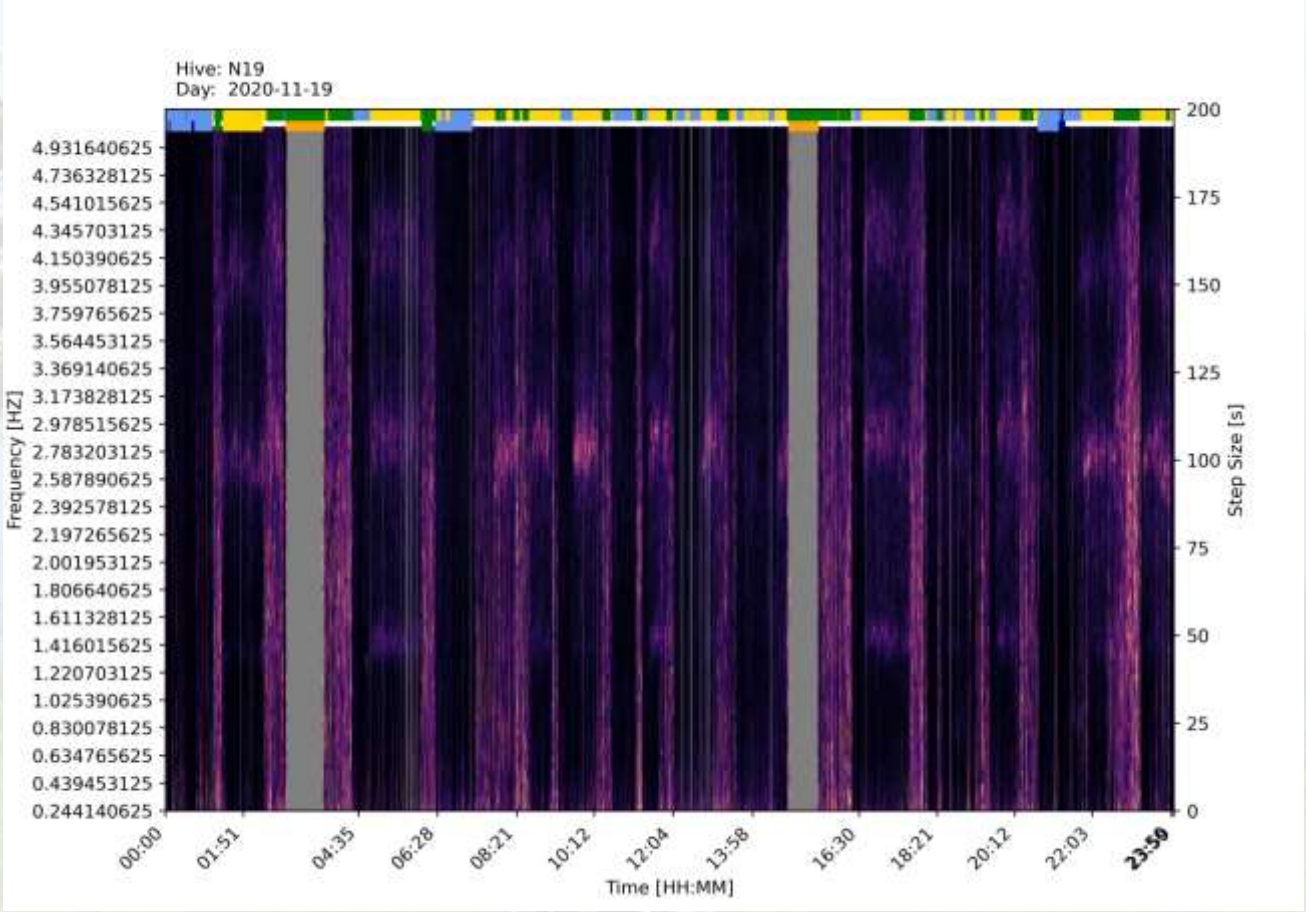
- 2 weeks long ethological trial – continuous capture of accelerometer data and simultaneous video-recording of animal activity on 3 cameras
- 0.5 TB data collected & annotated by human observer
- Behavior types: sleep, rest, rumination, eating, walking, unassigned
- Result: the behavior patterns are clearly recognizable -> it is possible to teach NN for automatic behavior classification



Behavior classification – trained NN

- NN structure for automatic behavior classification designed & trained
- High classification reliability when comparting to ground-truth data

- Current status: Offline data classification on PC
- In progress: Porting AI algorithms to the collar device (in cooperation with IMAG)



ECSEL Joint Undertaking

Thank you!

- Questions
- Comments
- Other

UNIVERSITY
OF WEST BOHEMIA

Ing. Roman Čečil

rcecil@ntis.zcu.cz