

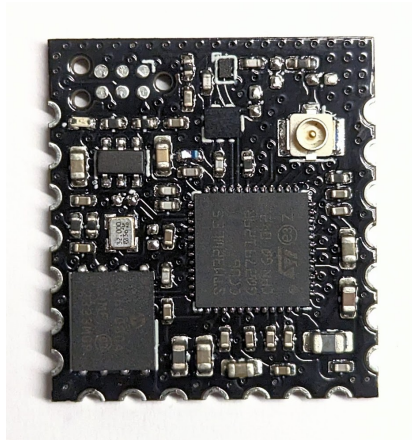
# Sensor Network for Smart Agriculture

Jiří Maňák

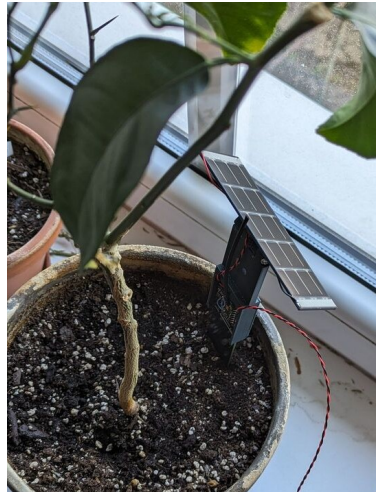
June 9, 2024

# Goals

1. Create a universal platform:  
LoRa Module and Firmware



2. Demonstrate its capabilities:  
Wireless soil moisture sensor



# Goals

## 1. Low-power LoRa Module

- ▶ A platform for rapid application development

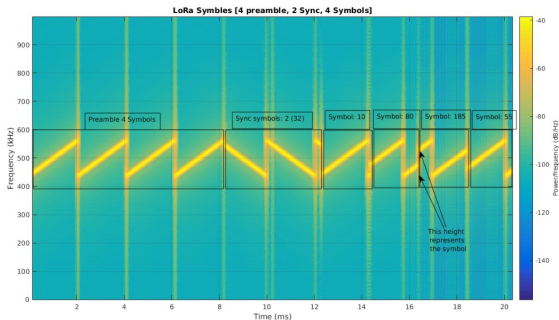
## 2. Custom soil moisture sensor network

- ▶ Able to cover large-enough area (kilometers)
- ▶ Zero-maintenance
- ▶ No external dependency on commercial networks
- ▶ Potentially extensible with more sensor types

# Cover large-enough area with no external dependency

## ▶ LoRa

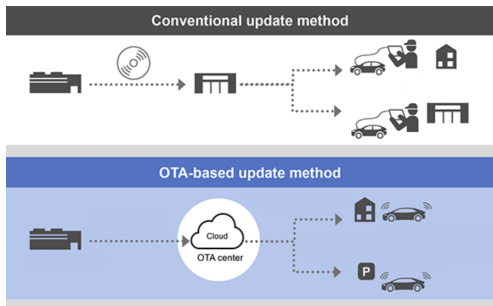
- ▶ Long range (kilometers)
- ▶ Low power (5 mA receive)
- ▶ Custom protocol
  - ▶ Low duty-cycle
  - ▶ Not reliant on LoRaWAN
  - ▶ Efficient



LoRa signal - Frequency/Time, [1]

# Zero-maintenance and extensible

- ▶ Solar power
  - ▶ No infrastructure required
  - ▶ Self-sufficient
- ▶ Over-the-Air updates
  - ▶ New features and improvements
  - ▶ Long-term support
  - ▶ Unusual for LoRa nodes



Conventional × OTA update, [2]

# Soil Moisture Sensor

Absolute soil water content measurement is impractical

- ▶ High power draw
- ▶ Bulky
- ▶ Expensive

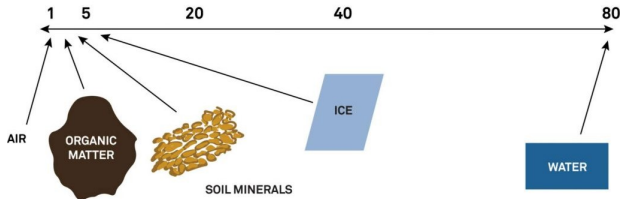
Properly calibrated relative measurement is sufficient for monitoring purposes

→ Capacitive soil moisture sensor

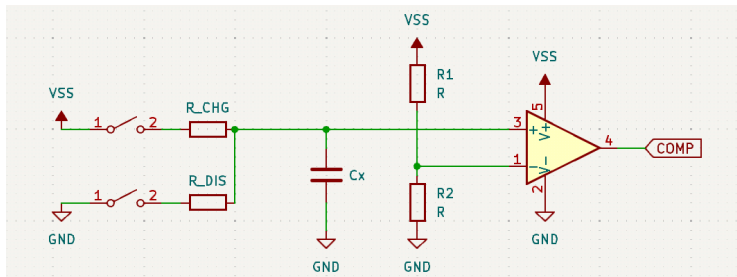
# Soil Moisture Sensor

$$C = \frac{\epsilon_r \epsilon_0 S}{d} \quad [\text{F}]$$

$$\tau = RC \quad [\text{s}]$$

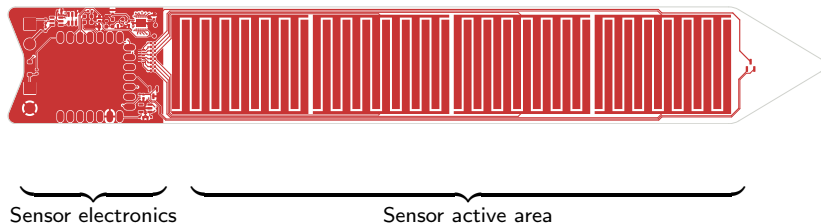


Dielectric constant  $\epsilon_r$  of materials found in soil, [3]



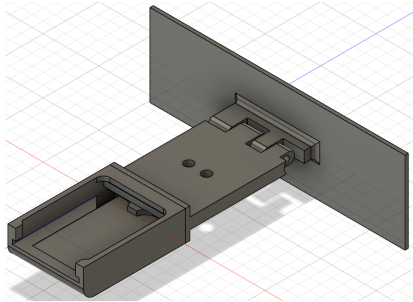
# Soil Moisture Sensor

- ▶ PCB construction
- ▶ 4 capacitive zones (15 cm total depth)
- ▶ 330 mAh lithium cell, 150 mWp solar panel

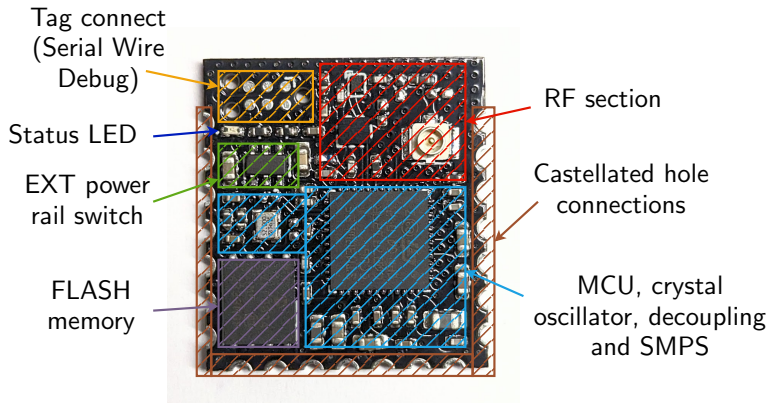




# Soil Moisture Sensor



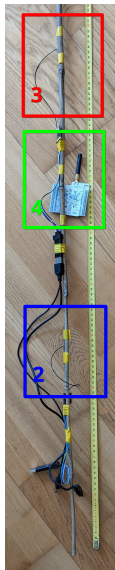
# LoRa Module



- ▶ **STM32WLE5CC**
- ▶ 868 MHz, 15 dBm
- ▶ **20.32×22.48 mm**

- ▶ 1 MB FLASH
- ▶ 2.3–3.5 V
- ▶ 16 IO pins

# LoRa Module Range Test

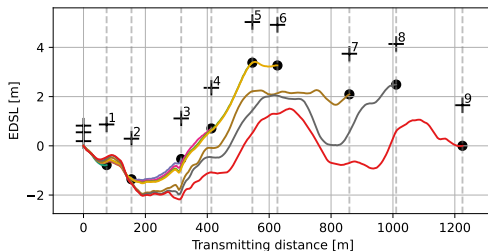
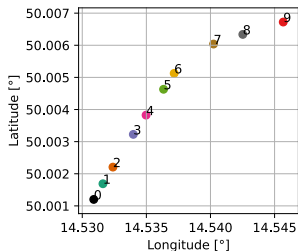
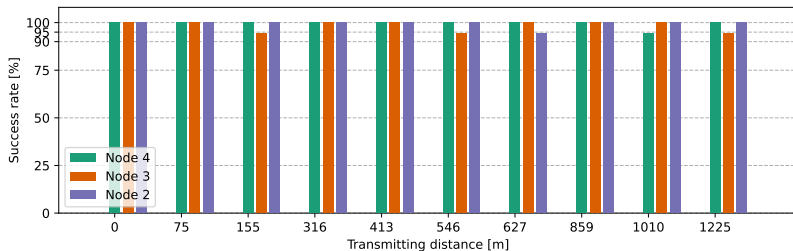


Node 2

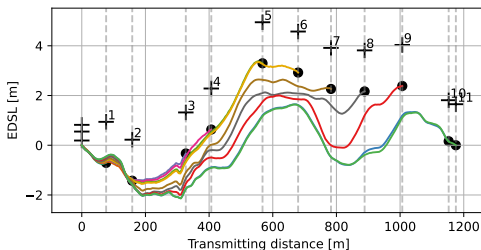
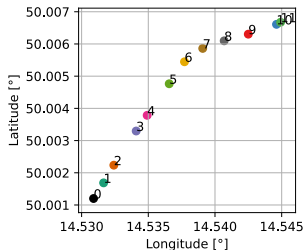
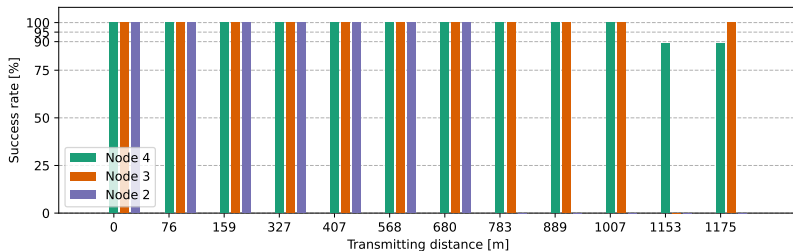


Node 3

# LoRa Module Range Test - SF11

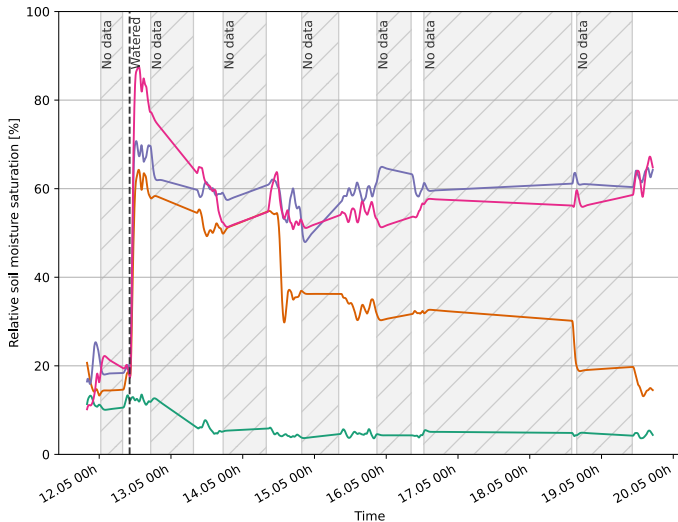


# LoRa Module Range Test - SF5

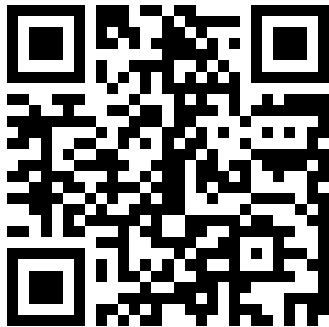


Node 2 - 20 cm, Node 3 - 80 cm, Node 4 (Nucleo) - 50 cm, 0.125 s round-trip, 3 kbps, Page 41, Section 4.4.4

# Soil Moisture Sensor Validation



## Live Demo



(or visit the link)

# Conclusion




This thesis brought

- ▶ **STM32 LoRa Module - a low-power platform for connected sensors**
  - ▶ module-runtime Rust package - HAL, protocol, async executor; enabling rapid application development with emphasis on reliability
  - ▶ Optimized for low duty-cycle operation
  - ▶ Over-the-Air update capability with rollback
- ▶ **Soil moisture sensor - an application of the module**
- ▶ Backend service combining soil moisture sensor data with weather forecast to optimize watering schedule

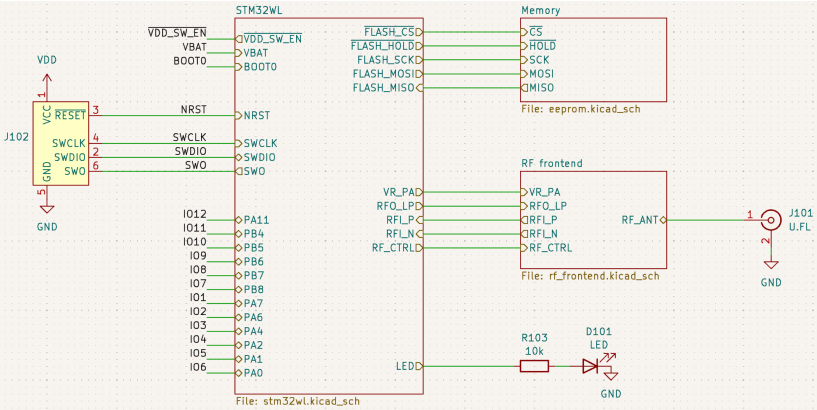
All publicly available at <https://github.com/manakjiri>



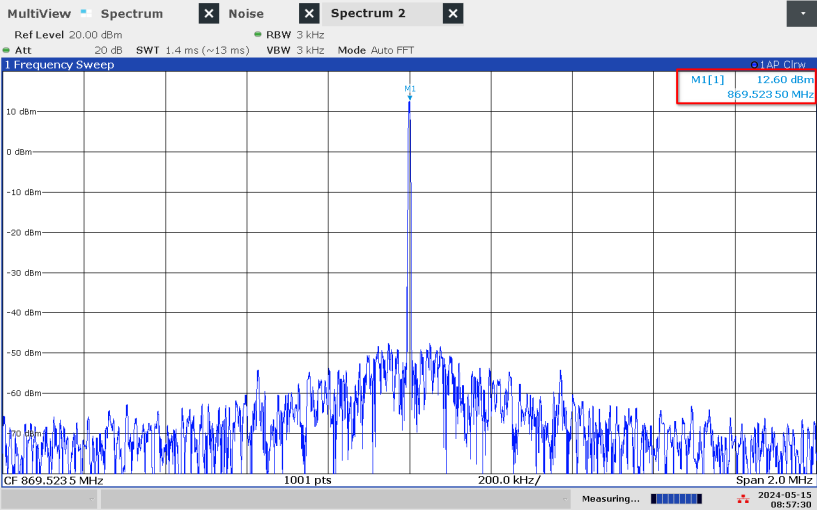
# References I

-  Giuseppe Panza, “What LoRaWAN and ” Chirp Spread Spectrum” (CSS) technology have in common? Part III | LinkedIn.” [Online]. Available: <https://www.linkedin.com/pulse/what-lorawan-chirp-spread-spectrum-css-technology-have-giuseppe-panza-hz5dc/>
-  Mobility Connected, “What are OTA Updates?” Jan. 2024. [Online]. Available: [https://www.hitachi.com/products/it/lumada/global/en/spcon/uc\\_00866s/](https://www.hitachi.com/products/it/lumada/global/en/spcon/uc_00866s/)
-  METER Group, “Soil moisture sensors—How they work. Why some are not research grade - METER Group,” May 2023, section: Measurement Insights. [Online]. Available: <https://metergroup.com/measurement-insights/soil-moisture-sensors-how-they-work-why-some-are-not-research-grade/>

# LoRa Module

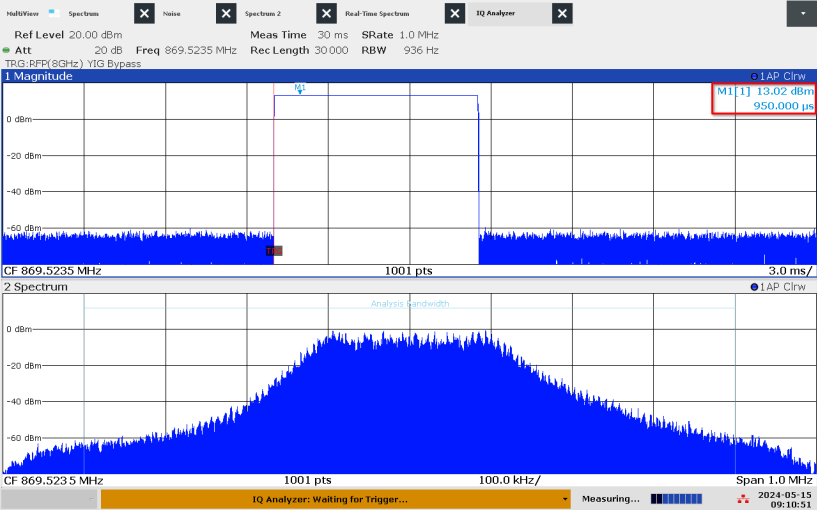


# LoRa Module RF



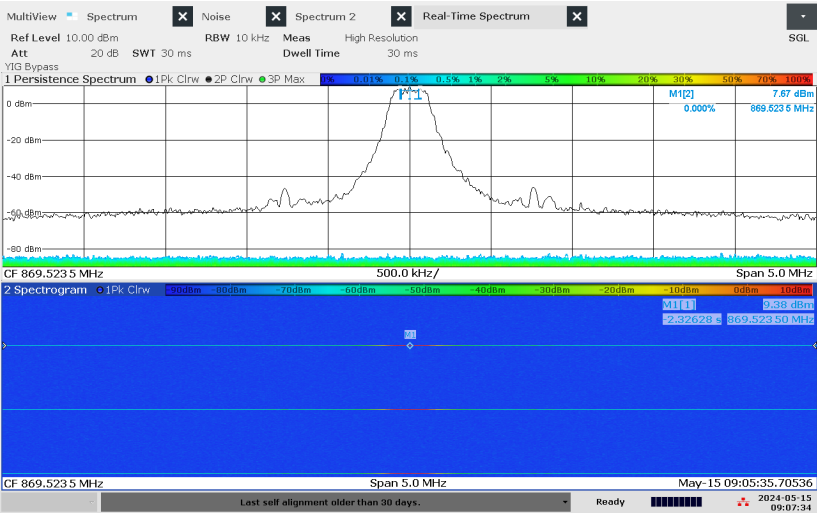
08:57:31 AM 05/15/2024

# LoRa Module RF



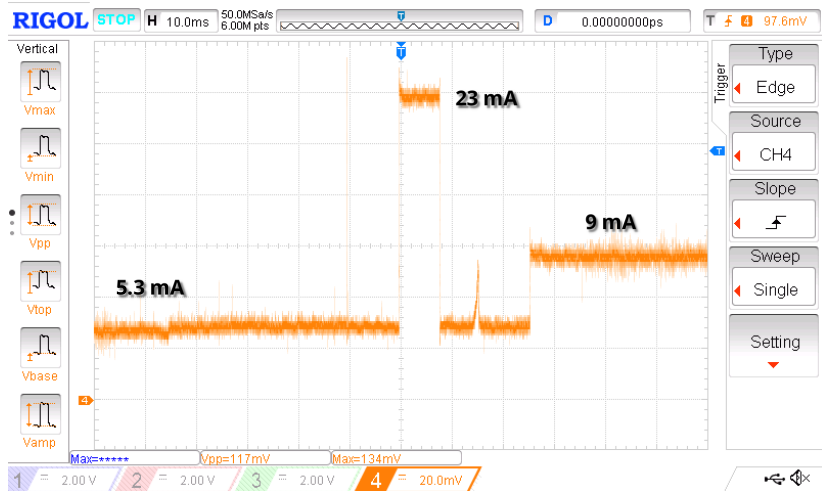
09:10:51 AM 05/15/2024

# LoRa Module RF



09:07:35 AM 05/15/2024

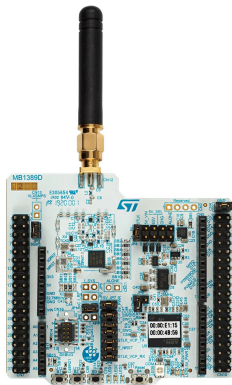
# LoRa Module Power



# LoRa Module



STDES-WL5U4ILH



Nucleo-WL55JC

# Existing solution?

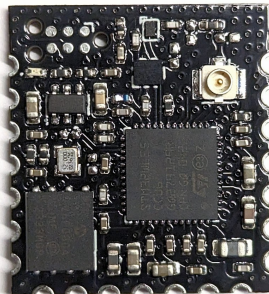


Seed Studio Wio-E5

>

?

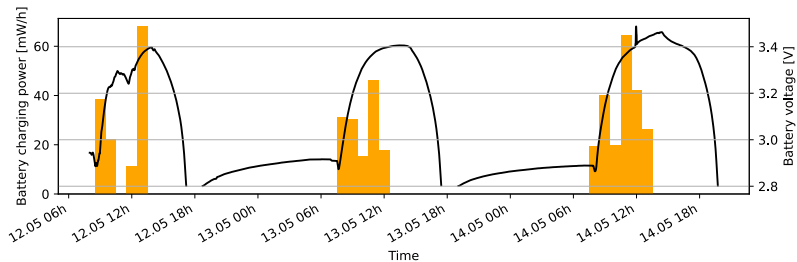
<



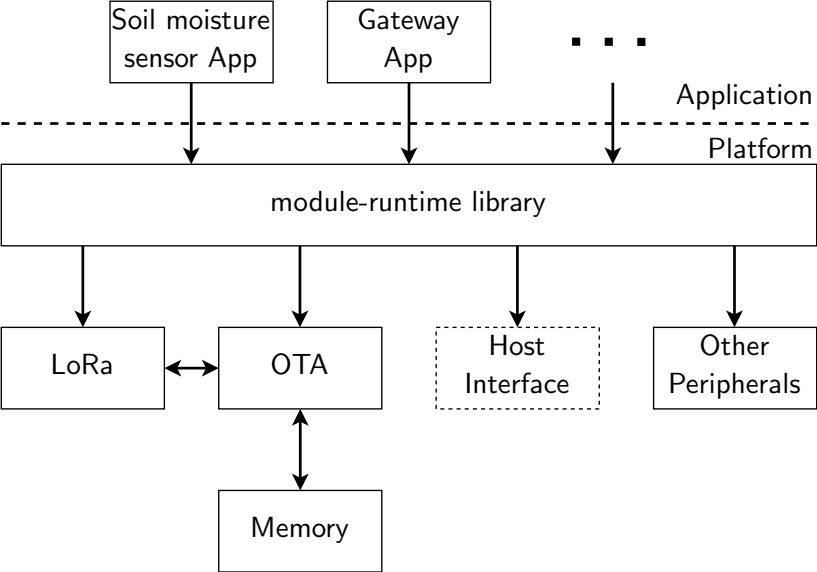
My LoRa Module



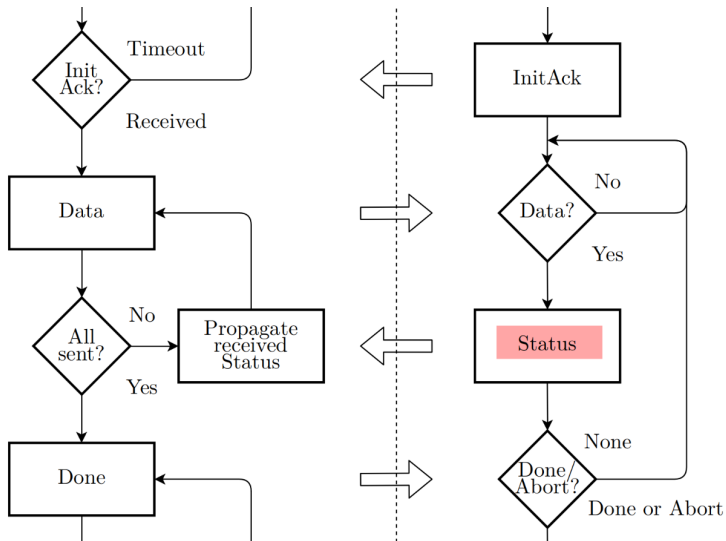
# Solar Power



# Firmware



# Over The Air Update



Page 36, Figure 4.9

## LoRa Module

- ▶ 2.8–3.3 V nominal voltage range,
- ▶ low power design - support for switchable power rails,
- ▶ target the EU868,
- ▶ wide temperature range
- ▶ minimize the amount of specialized hardware,
- ▶ support for OTA updates,
- ▶ integrated RF,
- ▶ host communication interface,
- ▶ minimal footprint,
- ▶ low cost.

Page 15, Section 3.2.3

# Full Cap Measure Circuit

