RFID tomorrow & wireless IoT
Dusseldorf, September 27th-28th

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RFID-Based Sensors for Construction 4.0

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BIM: Building Information Modeling

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- The BIM concept envisages virtual construction of a facility prior to its actual physical construction
- Sub-contractors can input information with opportunities to pre-fabricate some systems off-site
- Use of BIM extends throughout the building life cycle
- Incorporate dynamic information such as sensor measurements

Demand for IoT in Construction

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Identification:
track individual prefabricated blocks

Localization:
control correct place of installations

Sensing:
observe curing processes and

lifetime monitoring of stress & ageing

Challenges for IoT in Construction

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- Lifetime of building = 30+ years
  - Batteryless solutions or ultra low power with primary battery
- Sensor embedded in materials ≠ air
  - Robustness and adequate sensing surface needed
- Radio transmission through material ≠ air
  - Link budget must include attenuation and reflection losses
- Antennas matched to material properties ≠ air
  - Retuning under material conditions is necessary

Embedding Wireless IoT in Material

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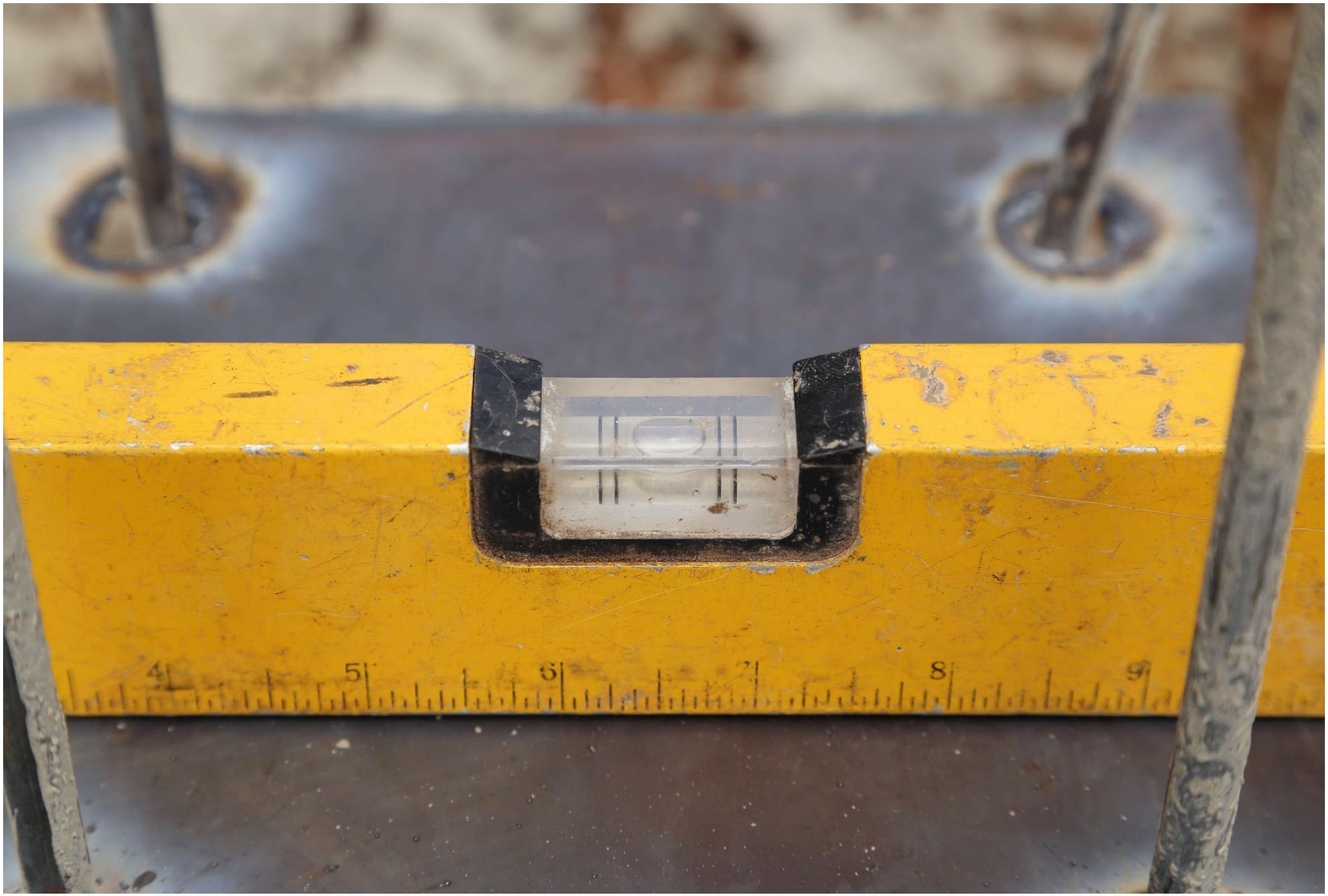

HF or UHF Technology ?

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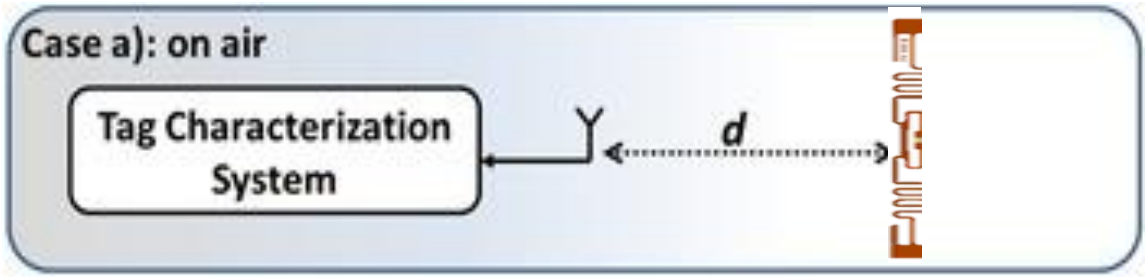
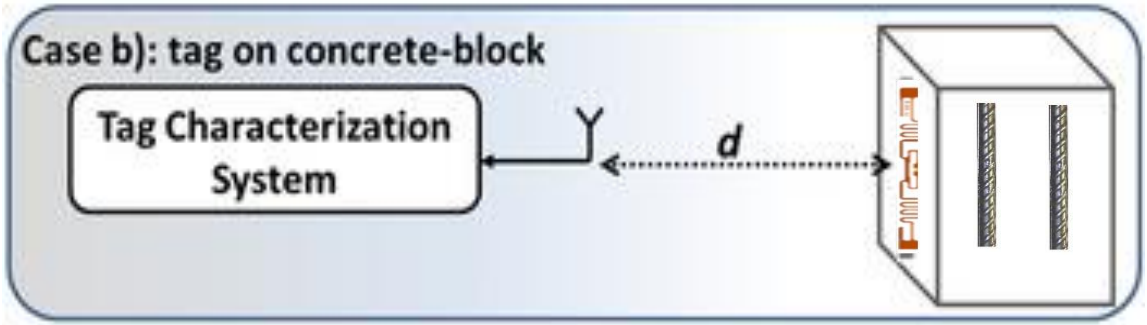
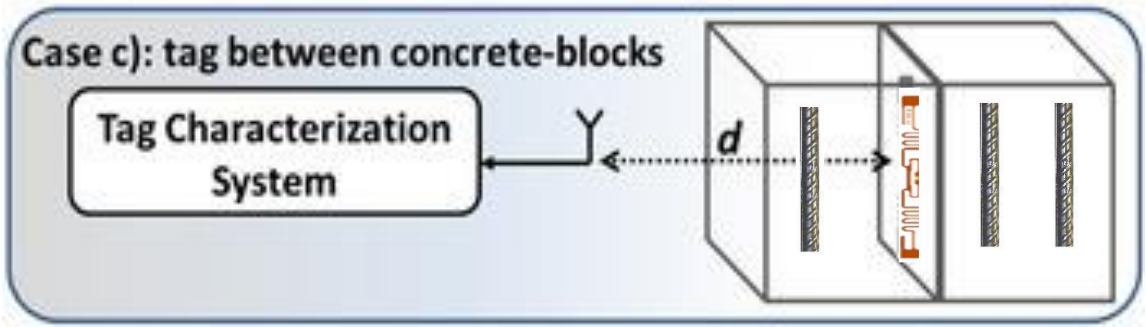
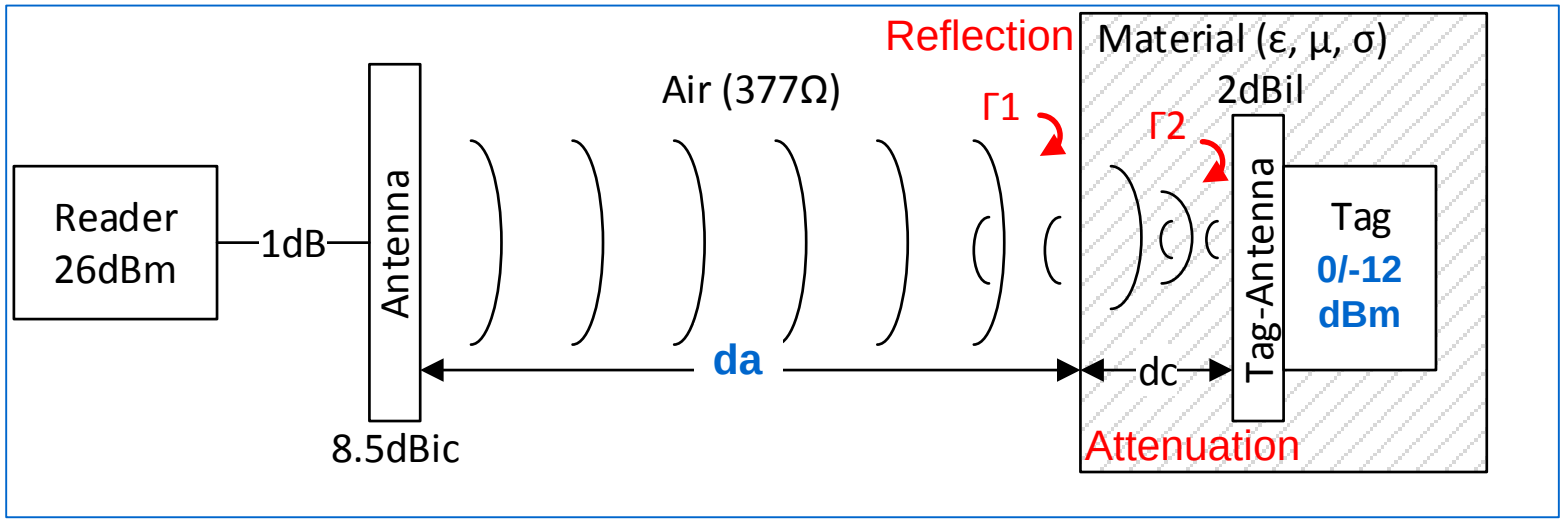
Case	HF	UHF
	Read Distance < 1 m	Read Distance < 10 m
	No influence	Reflection & Detuning on metal and dielectrica
	Detuning in presence of metal only	Reflection & Absorption & Detuning

UHF is more Challenging than HF…

…but read distances for construction site often exceed HF



e.g. Flat Roof with small Gravel

Example 20 cm gravel with variable water content	ID Read (-12 dBm) distance da [m]	Sensor operating (0 dBm) distance da [m]
Air reference	4.8	1.2
Dry gravel	3.3	1.0
Moist gravel	2.8	0.8
Gravel with water level at 3.3 cm	1.8	0.5
Gravel with water level at 6.6 cm	1.5	0.4
Gravel with water level at 10 cm	1.2	0.3

Example I UHF RFID Tag

Robust chemically inert tag e.g. Bric from *Xerafy reaches:*

- On metal up to 6 m
- In air up to 4 m
- In concrete up to 2 m

Example II: Embeddable RFID Sensor

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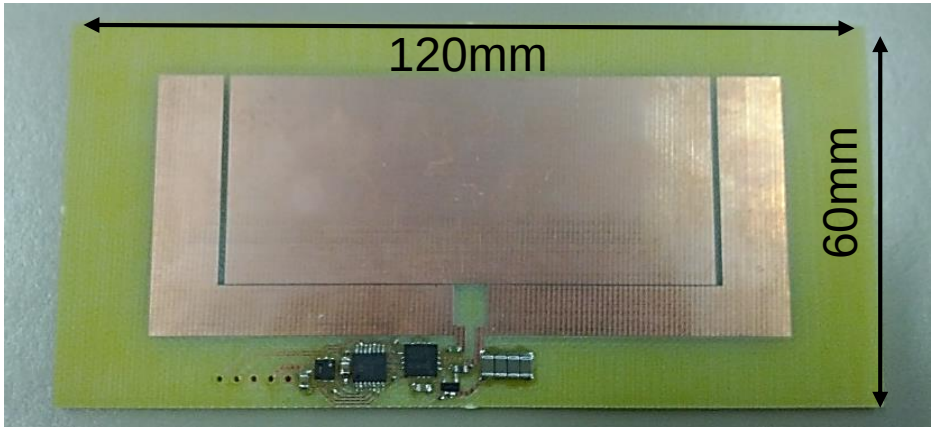

- RFID Temperature/ Humidity sensor
- Harvests energy from UHF field
- Bent dipole with parasitic patch*
- Operating distance 2 m
- Embedded in Concrete

- Design is made Platform Tolerant with additional layers
- ε_r of surrounding material plays now minor role, Detuning is reduced
- Tag thickness increases to > 10 mm

*Low Profile Planar Platform Tolerant UHF RFID Tags, M. A. Ziai, Proc. IEEE Int'l Conference on RFID-Technology and Applications, 2010

The Way of Using Data Loggers

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RFID or Bluetooth Technology ?

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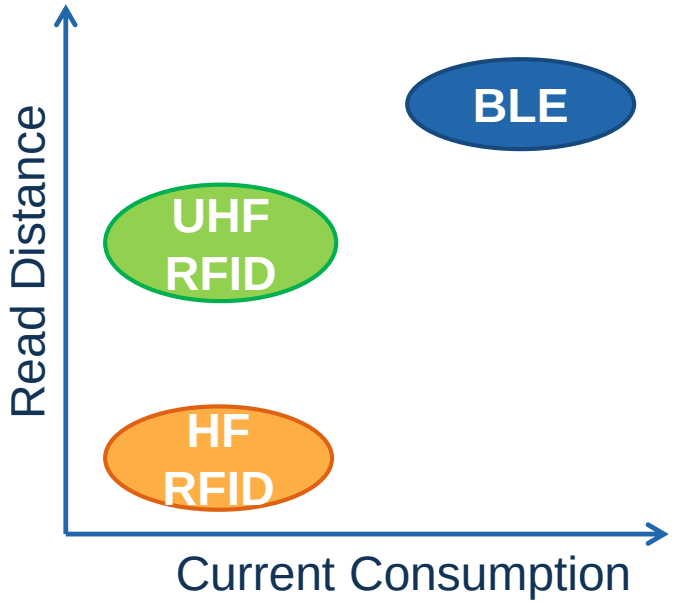
Assumptions: Read Interval > 10s, Response Time < 10s

RFID based sensor

- Current consumption <500nA
- Read distance up to 8m (UHF)

BLE based sensor

- Current consumption approx. 5µA
- Read distance is 10…20m



Remember Lifetime > 30 years also for the battery*

→ RFID is the right choice, battery used for logging only

→ RFID may be useful for BT wake-up

* e.g. Primary batteries from Tadiran PULSEPLUS or XOL serie

UHF-RFID based Sensor/Logger

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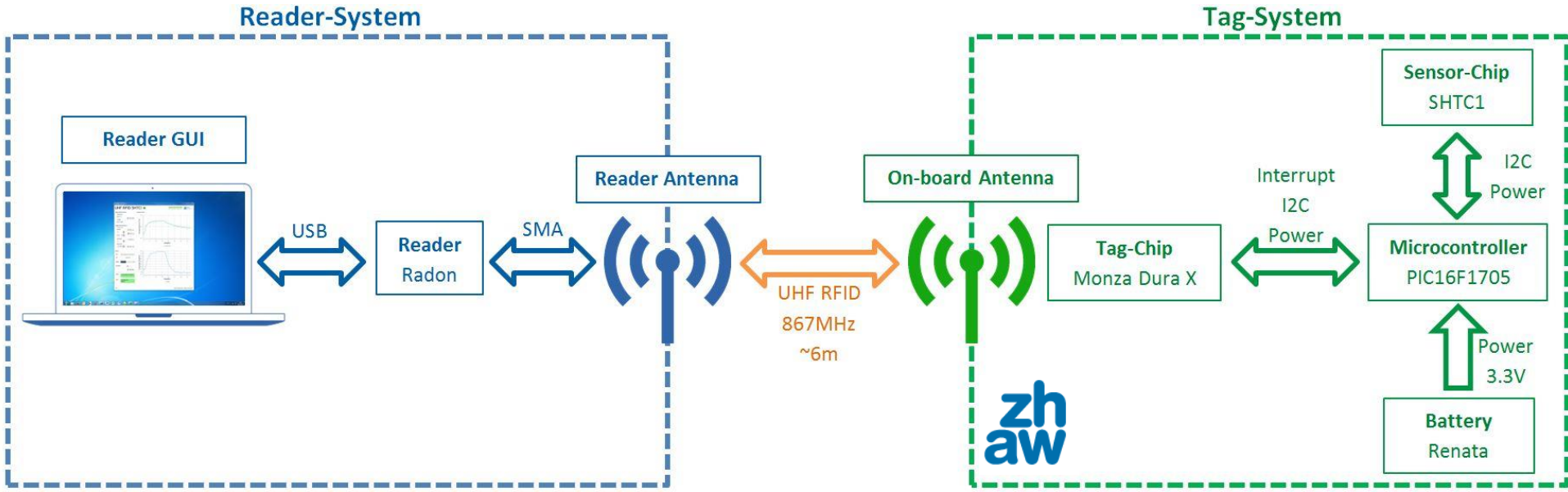


ZHAW Sensor/Logger was designed for *long-term monitoring of temperature & humidity* in roof timber constructions

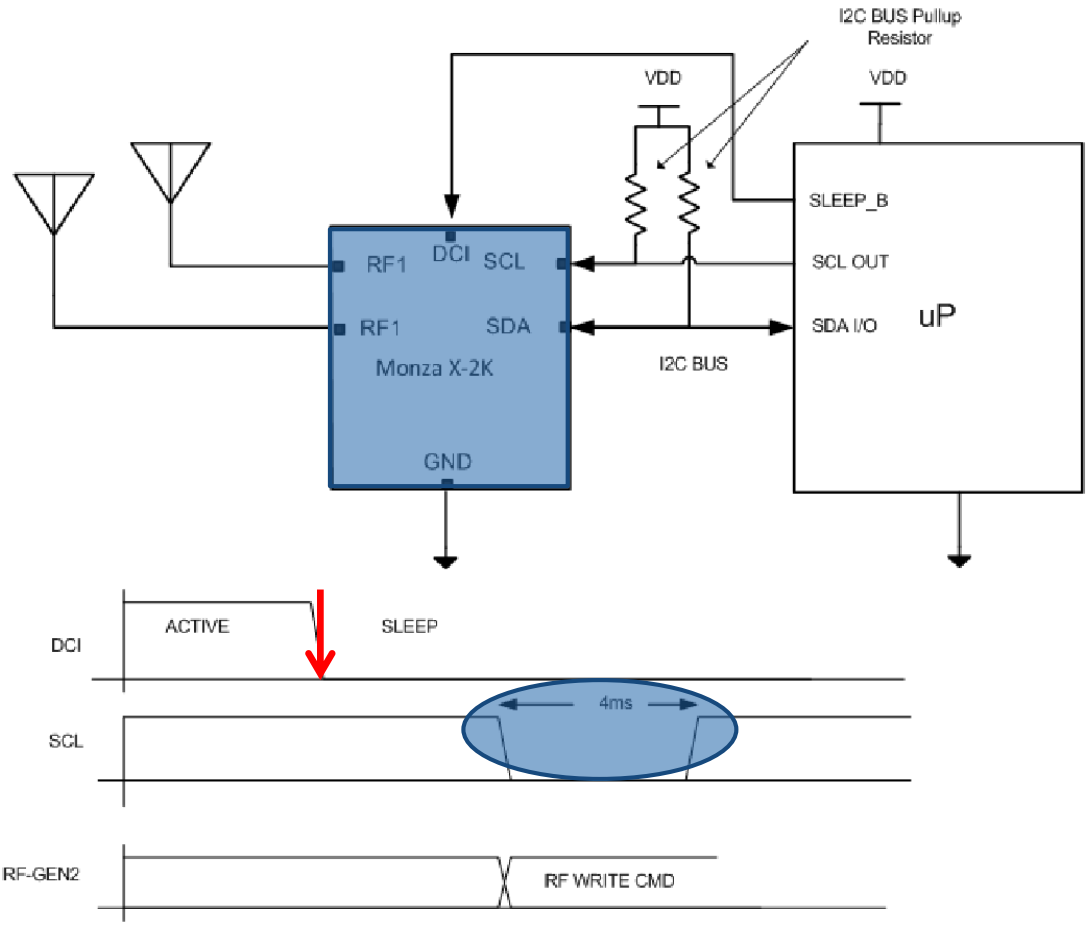
RFID Front-end based on Impinj Monza X Chip Sensitivity:

Operation	Passive	Active
Read	-17 dBm	-24 dBm
Write	-12 dBm	-24 dBm

UHF Wake-up with Impinj's Monza X

Programming Logger and Data Read out using Wake-up from RF-Field:

- Monza X is in passive mode:
- DC_RF_Enable Bit controls bus
- Reader writes WWU Bit to tag
- I²C Line SCL goes low for 4 ms
- SCL falling edge wakes-up uC
- Sensitivity -12 dBm due to write



Read Data from RF-Field:

- Monza X in active mode:
  DCI supplied form uC
- Read/Write sensitivity -24 dBm

Perfomance of UHF-RFID based Sensor/Logger

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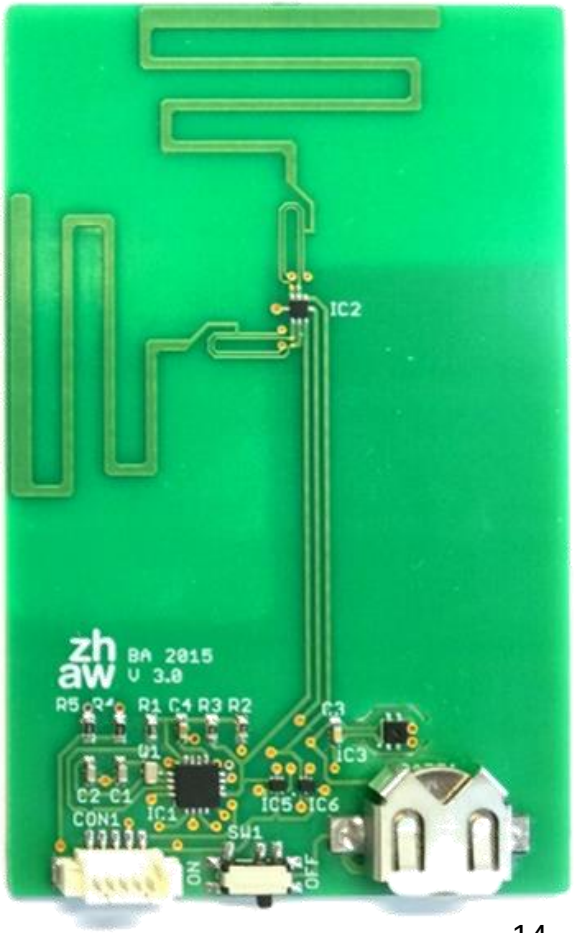
RFID is the best IoT connection for semi-passive sensors or loggers with long read-out intervals but fast reaction time

- Dual-Monopole-Antenna Gr = -3 dBi
  →Independent tag orientation
- Measured Tag sensitivity of – 11dBm
  → Wake-up distance* 4m
  →Read data distance* 6m (active 8m)
- Credit card size 55 x 86mm
- Single read mode operation
- Logging mode operation
- Battery lifetime (CR2430) > 25 years
  for sensing intervals > 1 hour



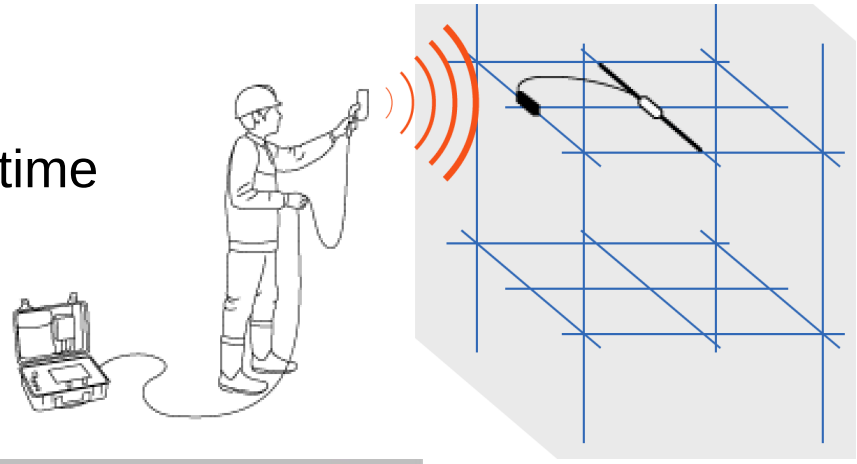
*4 W EIRP Reader with carrier suppression, sensitivity limited by tag antenna

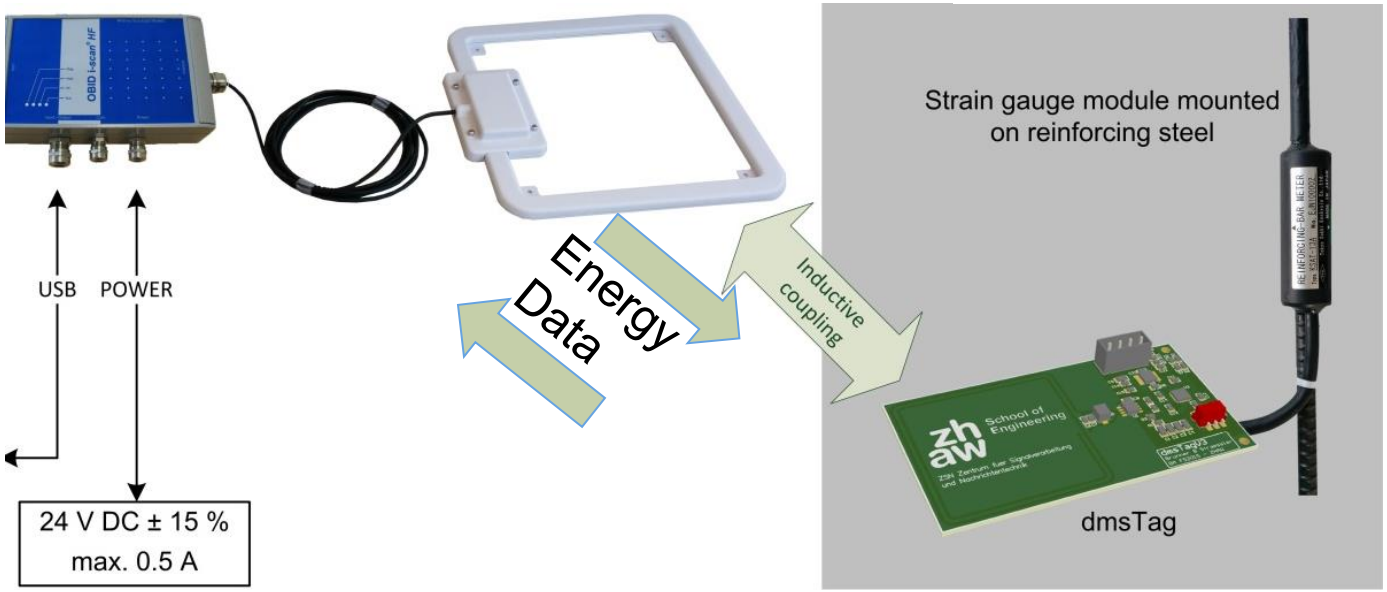
True Passive RFID Sensing

True Passive Real-time Sensing

e.g. Strain and temperature survey in reinforced concrete

- Observation of concrete curing
- Periodic dynamic stress tests over lifetime
- Works also with other sensors





Why HF-RFID is the Better Solution

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Specifications

- DC-power needed: 3 mW
- Measuring rate 100 Hz
- Credit card size sensor
- Portable reader
- Embedded in reinforced concrete
- >30 years lifetime

UHF

- 4 W EIRP → 3 mW @ d = 1m with isotropic sensor antenna
- Efficiency of rectifier 30% → 1 mW DC Power
- Distance for 3 mW DC-power calculates to 58 cm
- Antenna Loss up to 10 dB → Distance down to 18 cm
- Reflection and Absorption Loss up to 6 dB → Distance down to 9 cm

HF

- Tolerant against non metallic surroundings including water
- Main advantage: near zero reflection and absorption losses
- Needs careful optimizing of antenna design to get enough distance

Link Budget and Coupling Calculation

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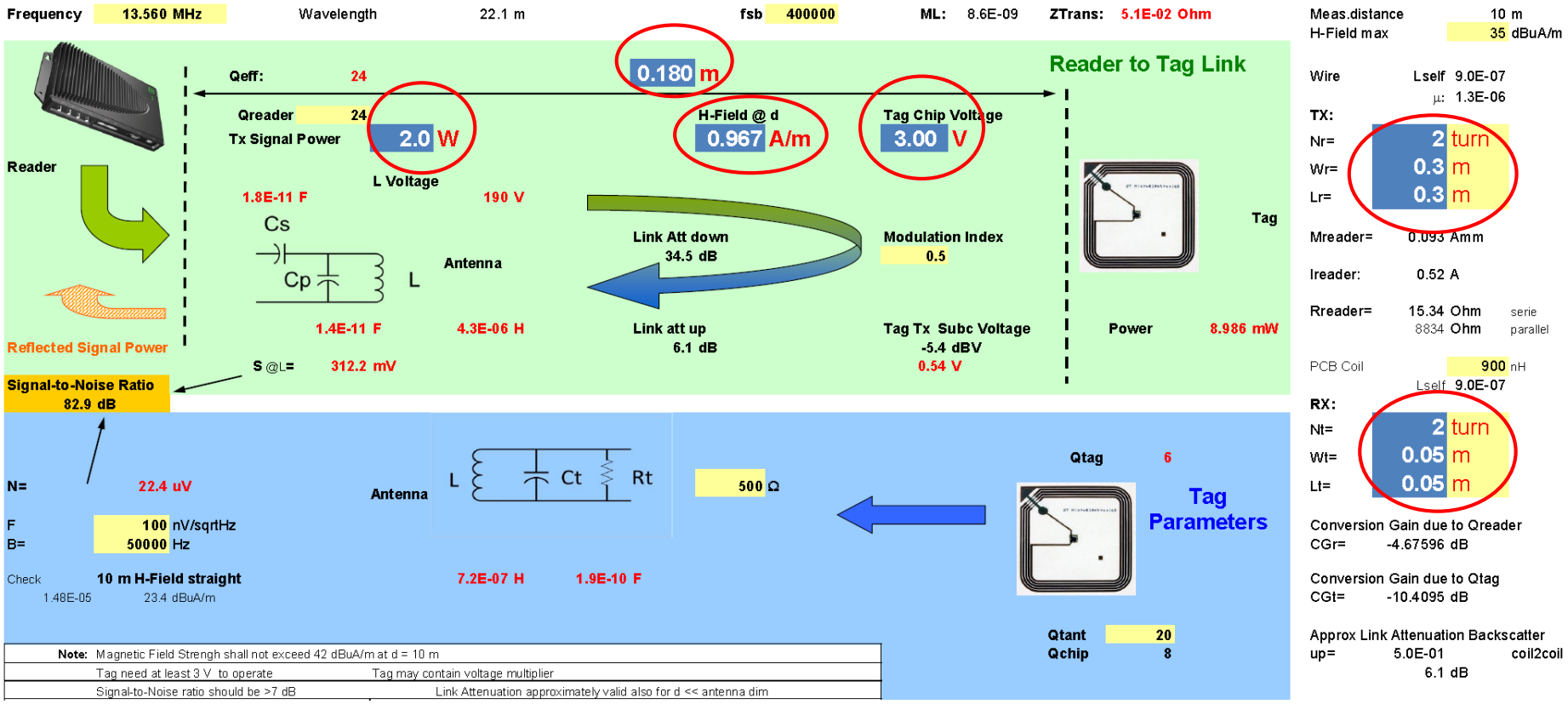
HF 13.56 MHz RFID…an iterative design involving many parameters



→ Loaded Tag Antenna: Optimum number of turns is 2

→ Theoretical Distance for Sensing is 18 cm

«Find» and «Measure» Distances

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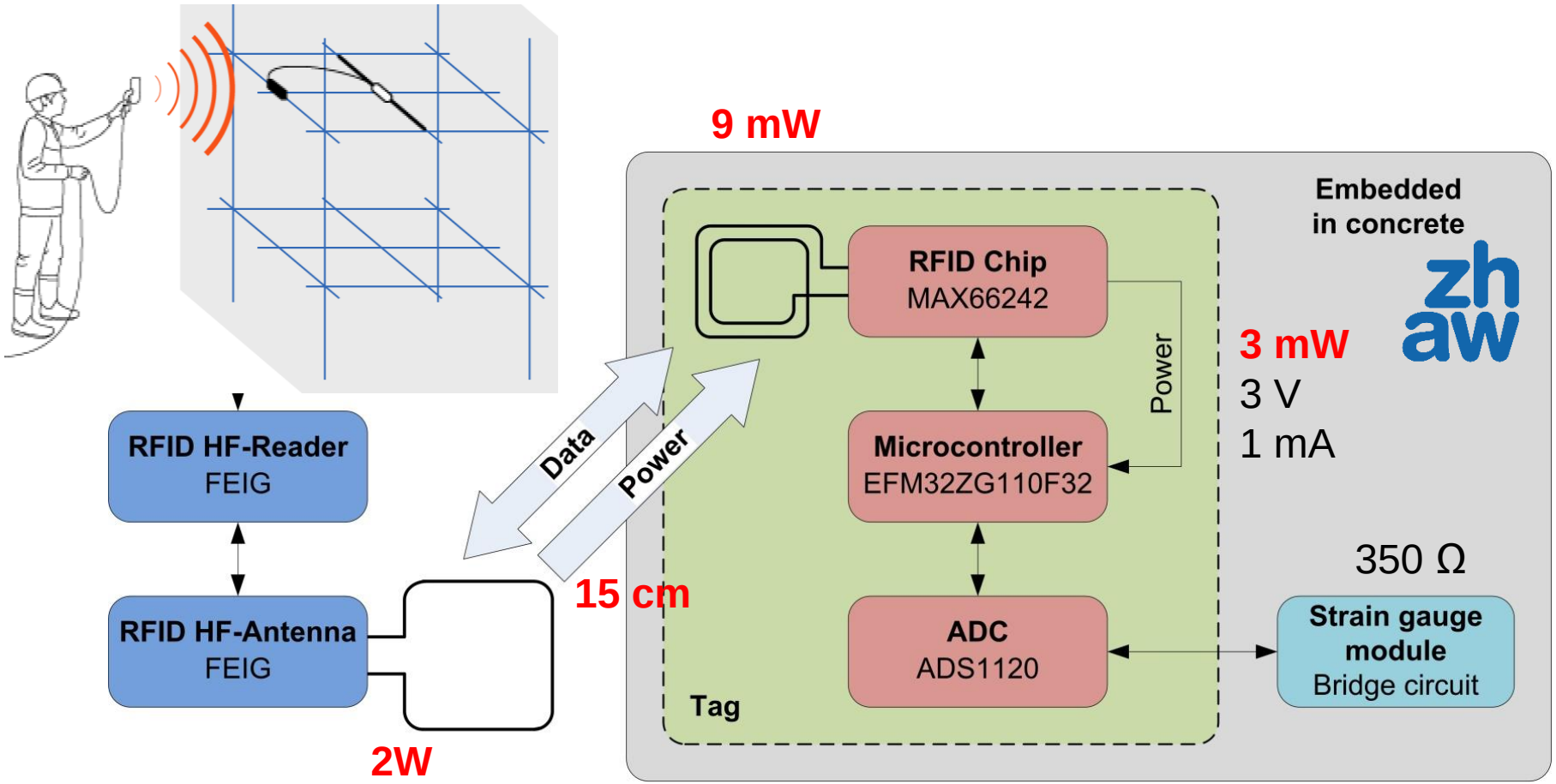

Measured Distance for ID read	40 cm
Calculated Distance for sensing	18 cm
Measured Distance for sensing	15 cm

HF-RFID: Influence of Reinforced Steel on Tag Antenna

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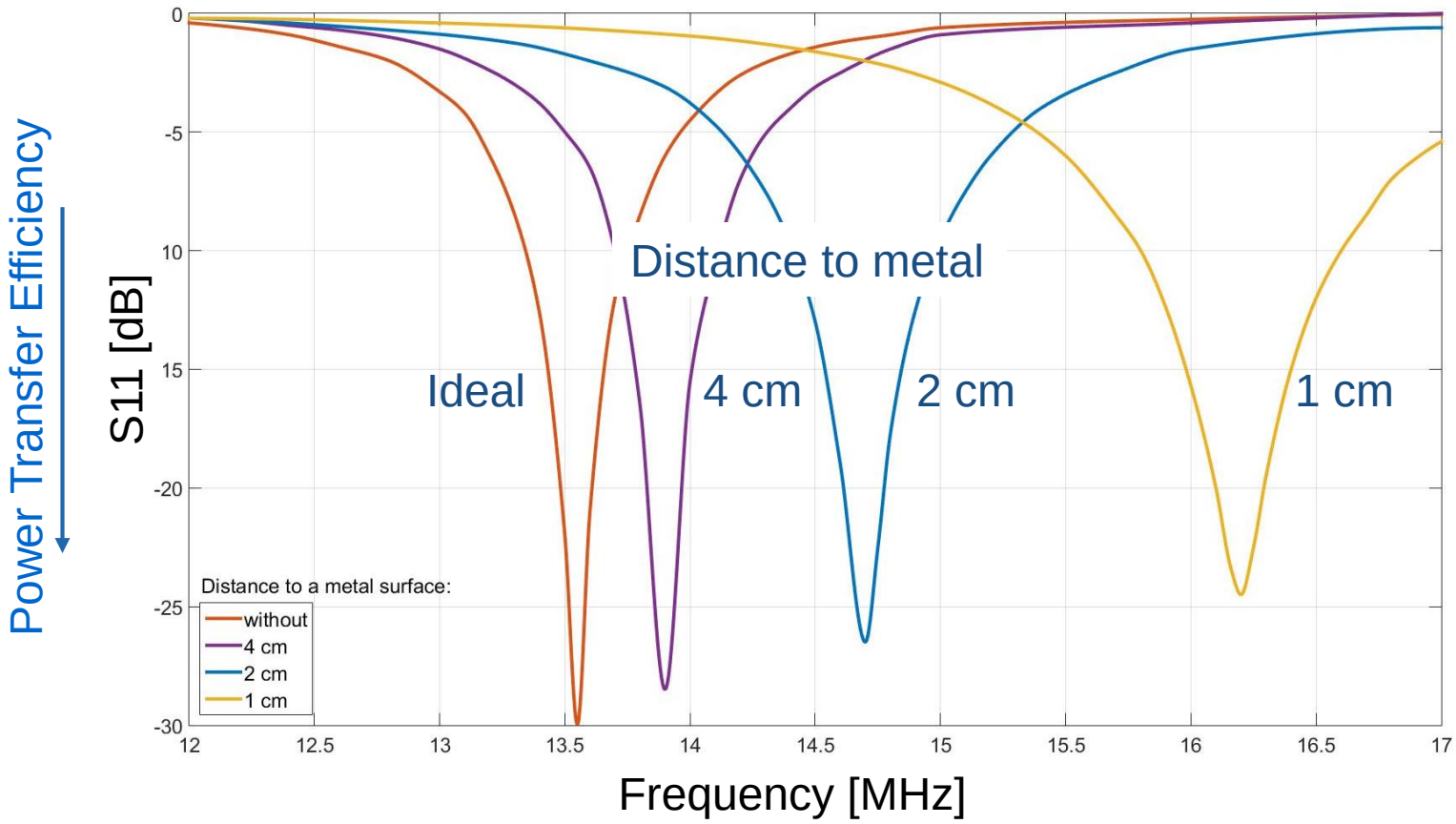
- Resonance frequency is shifted to higher frequencies
- Decreasing the efficiency of the energy harvesting
- Q-factor of the tuned antennas is reduced

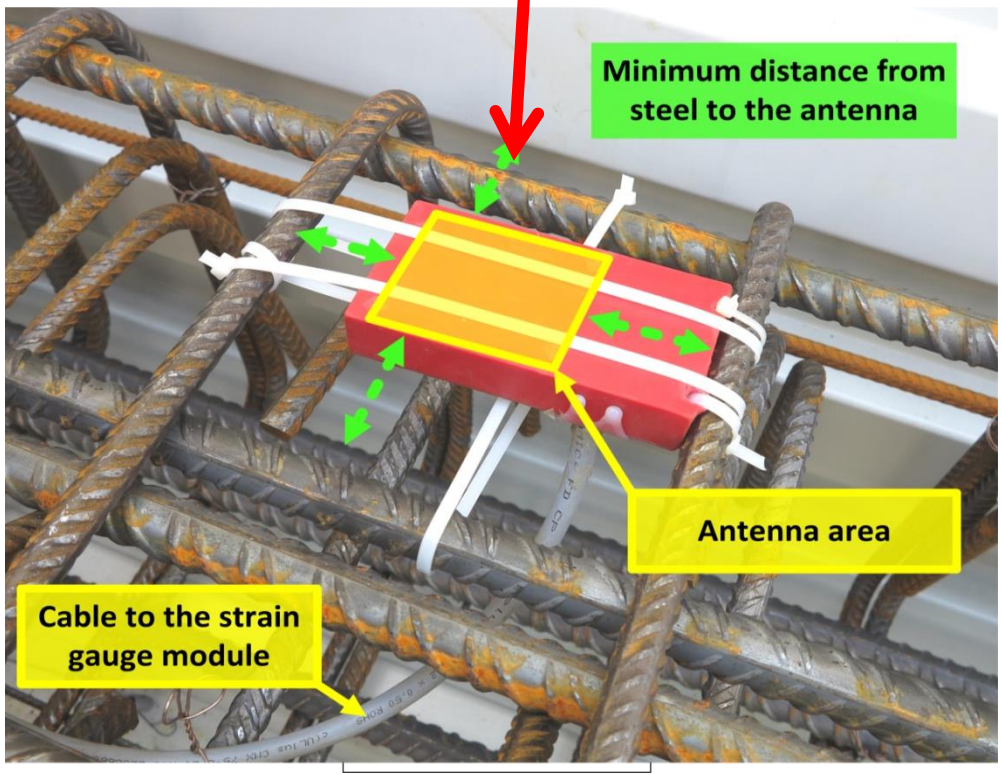


Resulting Performance

- RFD Chip Max66242
  operates down to:
  - 100 mA/m for read
  - 500 mA/m for write
  - 1250 mA/m for Harvesting

- Tag antenna 5 x 5cm
  with 2 turns (720 nH, Q = 20)
- Reader antenna 30 x 30cm
  (4.3 µH, Q = 24, 2 turn)
- 2 W Reader TX power

→ Sensing range of 15 cm
→ ID Range of 40 cm



Application – Bridge Stress Monitoring

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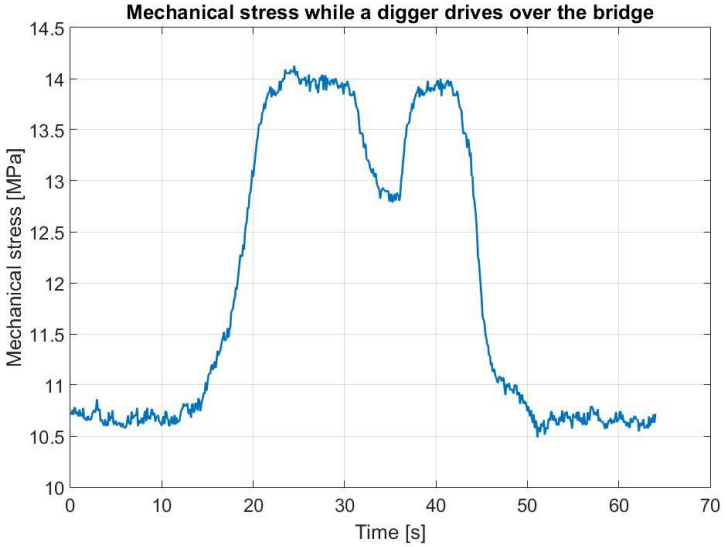
Sensor features:

- Measure mechanical stress of reinforced steel
- Wireless link (HF-RFID ISO-15693)
- Completely batteryless
- Maximum real-time measuring rate: 100 Hz

→ RFID Concept is the best for passive sensors and opens opportunity to connect constructions to the IoT



Video - Bridge Stress Monitoring

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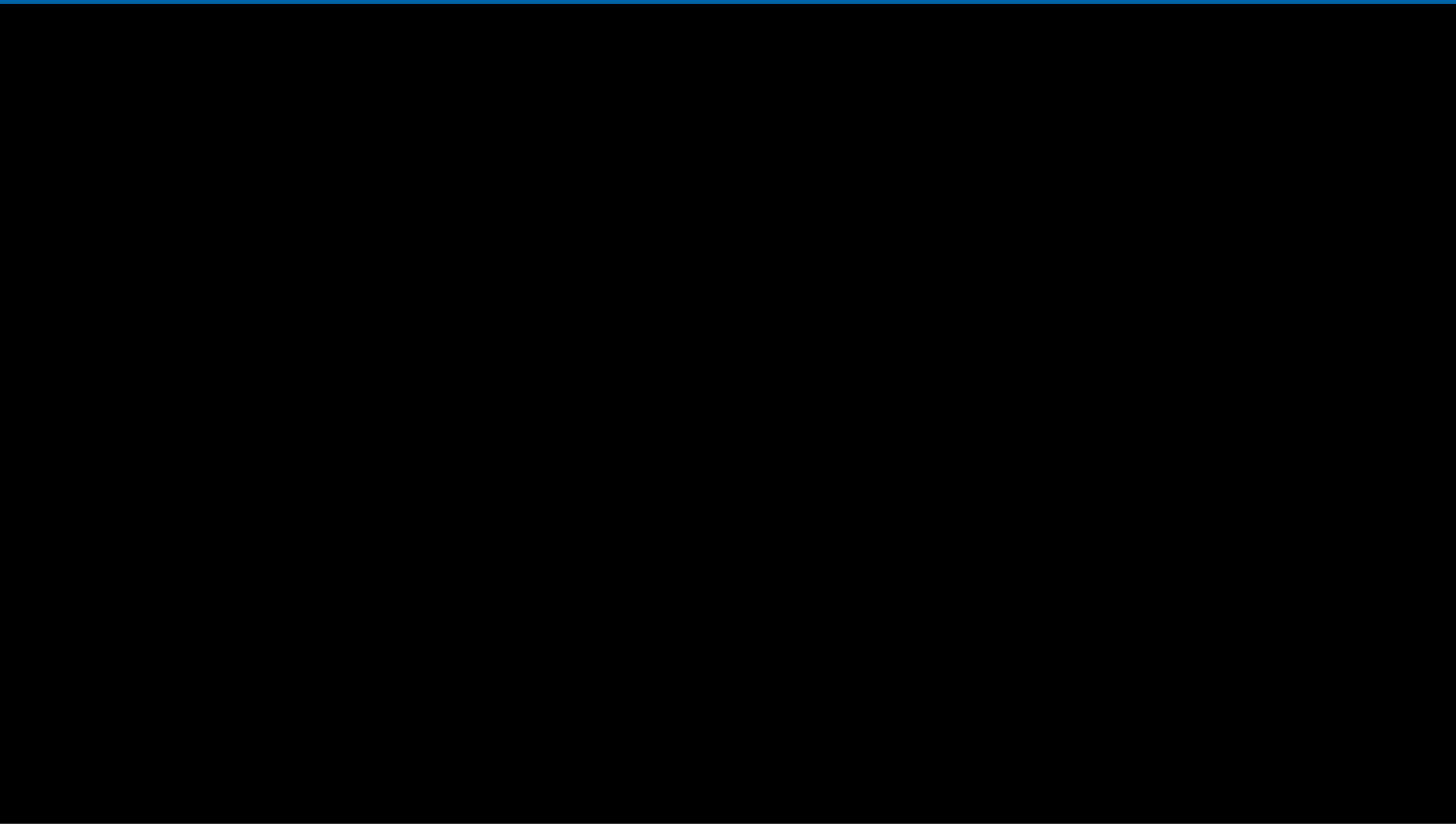

Summary

- Construction 4.0 has fast growing needs for Identification and Sensing
- Tag and sensor are often embedded in material
  - Careful antenna design and propagation calculation
- Read distance are typically in the long range
  - UHF preferred but delivers less power than HF
- Lifetime > 30 Years
  - RFID enables completely batteryless IoT solutions
  - Batteryless wake-up through RFID for active Radio (BLE)
  - Solutions with Primary battery for RFID based data logger apps