Multipurpose use of radiofrequency sources for probing passive wireless sensors and routing digital messages in a wireless sensor network

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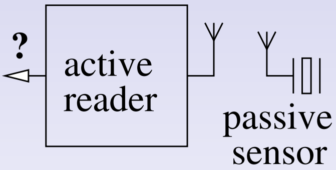
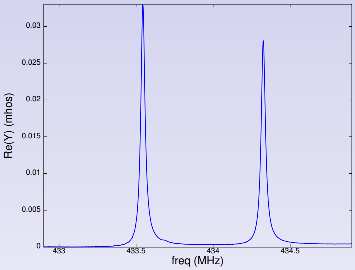
Introduction





Objective:

- Alternative strategy to energy harvesting: no energy at all !
- Passive transducer acts as sensor remotely characterized
- Reader must communicate recorded data on the physical property
- Since the transducer is an analog radiofrequency component, use of the **same hardware** for digital communication
- wireless sensor network (WSN) ⇒ port the software to an executive environment ("operating system" like)
- demonstration on high temperature (550 °C) measurement

Basics of SAW resonator interrogation

- sensor appears to the user as an **electric dipole** characterized by a sharp resonance in the **RF range** (wireless probing)
- physical principle is the measurement of the velocity of a surface acoustic wave (mechanical vibration) propagating on a **single crystal substrate** (quartz, lithium niobate, langasite ...)
- sensor is **passive** (no local battery source)
- resonance **frequency** is characteristic of the physical property under investigation
- **frequency sweep monostatic RADAR**
- separate emission (sensor load) and listening (sensor discharge) steps
- if the emitted pulse spectrum overlaps the sensor resonance, returned signal at f_0

SAW resonator interrogation characteristics

- time constant defined by the sensor Q factor: Q/π periods is 6 μs $\Rightarrow$ load/unload duration is 30 μs, and at least two measurements to identify resonance frequency
- basic frequency sweep measurement (no assumption on resonance frequency): $f_0/Q/3$ frequency step $\Rightarrow$ 128 steps or **7.5 ms**.

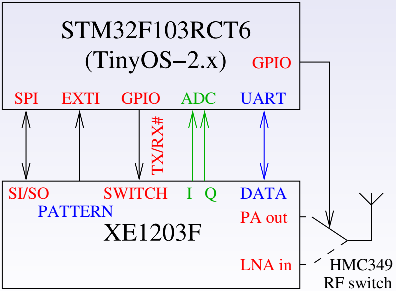
→ **short measurement time** compatible with very low duty cycle $\Rightarrow$ low power consumption if sleep mode is low power

→ **passive transducer** (no need for energy harvesting on the sensor site)

→ emphasis on a **low power** reader electronics with enhanced capability

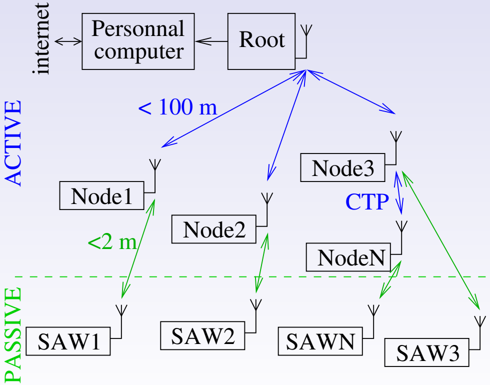
Reader compatible with wireless sensor network applications

- Use of a commercially available radiomodem as frequency source and receiver
- Thanks to the long returned signal time constant, even low bandwidth radiomodem is compatible with the measurement
- I and Q analog outputs ⇒ rich dataset for signal processing
- switch between two modes: passive (batteryless) acoustic sensor transducer characterization through a wireless link (medium range, 0.1-10 m), and digital data communication over a wireless sensor network (long range, 1-100 m).

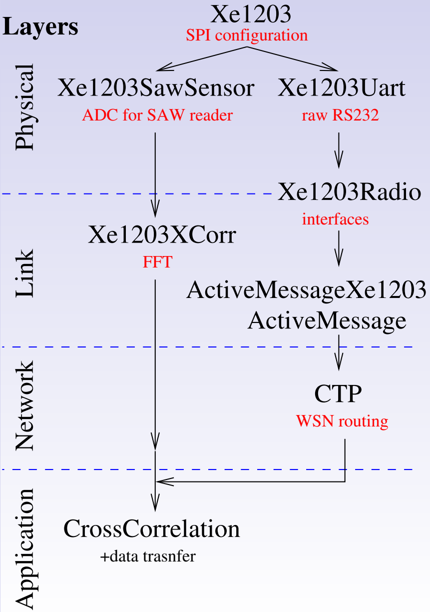


TinyOS port to STM32

Wireless digital data communication
⇒ complex communication protocol targetted at automated message routing in a dynamic network of SAW readers
⇒ port of TinyOS to the STM32 microcontroller (ARM Cortex M3 core)
⇒ port of the control software to TinyOS



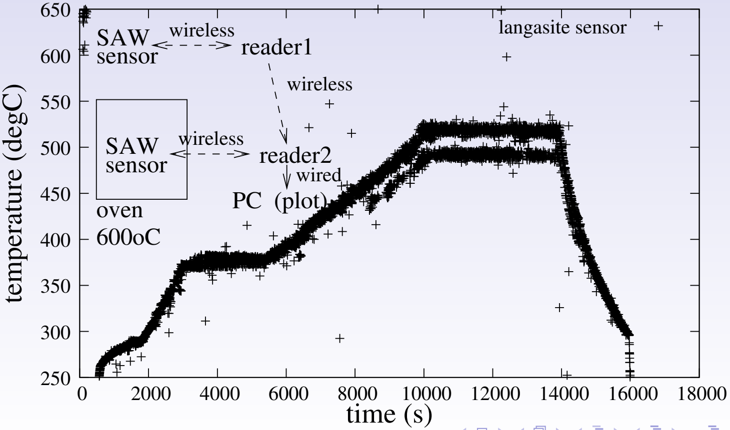
TinyOS port to STM32



- multiple software interfaces linking the low level drivers (A/D converters and radiomodem) to the TinyOS functionalities
- the standard expected message is in the ActiveMessage structure
- this format allows the use of the CTP routing protocol (TinyOS)
- dedicated signal processing functions for sensor caracterization

Measurement example

- A sensor is located in a high temperature oven (T> 500 °C) ⇒ wireless sensor avoids wiring issues
- The recording station is located in a remote location
- A second reader records the room temperature and transmits data through the WSN.



Power consumption budget

Battery powered remote reader ⇒ aim of reduced power consumption

Operation mode	Consumption (mA)
RF digital communication	140
Probing SAW resonators	80
Standby mode microcontroller and transceiver in reception mode	22.3
Standby all components	1.2

→ RF link is always highest source of power consumption
→ STM32 is hardly a low power microcontroller
→ leakage current towards some of the unpowered chips (RS232-USB interface)

Conclusion

- Acoustic wireless passive readers withstand harsh environmental conditions incompatible with silicon-based sensors
- Dual use of available radiomodem: WSN and probing acoustic sensors in a RADAR-like approach
- Digital communication through a digital wireless link
- Port to the STM32 of TinyOS for advanced routing capability

Perspectives: correct the omission of the MAC layer
⇒ conflict between all readers waking up at the same time and using the same frequency
⇒ conflict between digital communication and sensor characterization

All source codes at
`http://sourceforge.net/projects/tinyosonstm32`

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