

WIRELESS PASSIVE STRAIN SENSORS BASED ON SURFACE ACOUSTIC WAVE (SAW) PRINCIPLES

PWST Workshop
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Company Information

- ▣ Privately held
- ▣ Self funded
- ▣ Management:
 - Dr. Alfred Gnadinger, President and CEO
 - Dr. Viorel Olariu, Vice President and CTO
- ▣ Headquartered in Colorado Springs, CO
- ▣ www.albido.com

Technical Vision

- ▣ To develop miniature, lightweight, passive, remote , wireless sensors for Condition Based Maintenance (CBM) and Structural Health Monitoring (SHM) applications
- ▣ To develop sensors that will transmit encoded, sensed information in a multi-sensor environment for a distance of several meters
- ▣ To develop a platform for many different sensor applications and for a wide range of operating environments

Albido's SAW Sensors

- ▣ Passive, Wireless, Coded
- ▣ Large bandwidth, high speed
- ▣ Large reading range
- ▣ Small, rugged, cheap
- ▣ Noise tolerant, no cross sensitivity
- ▣ Low loss and variable frequency
- ▣ Radiation hard for space applications
- ▣ Operate over wide temperatures and in harsh environments
- ▣ Measure physical, chemical and biological parameters

Albido's SAW Sensors

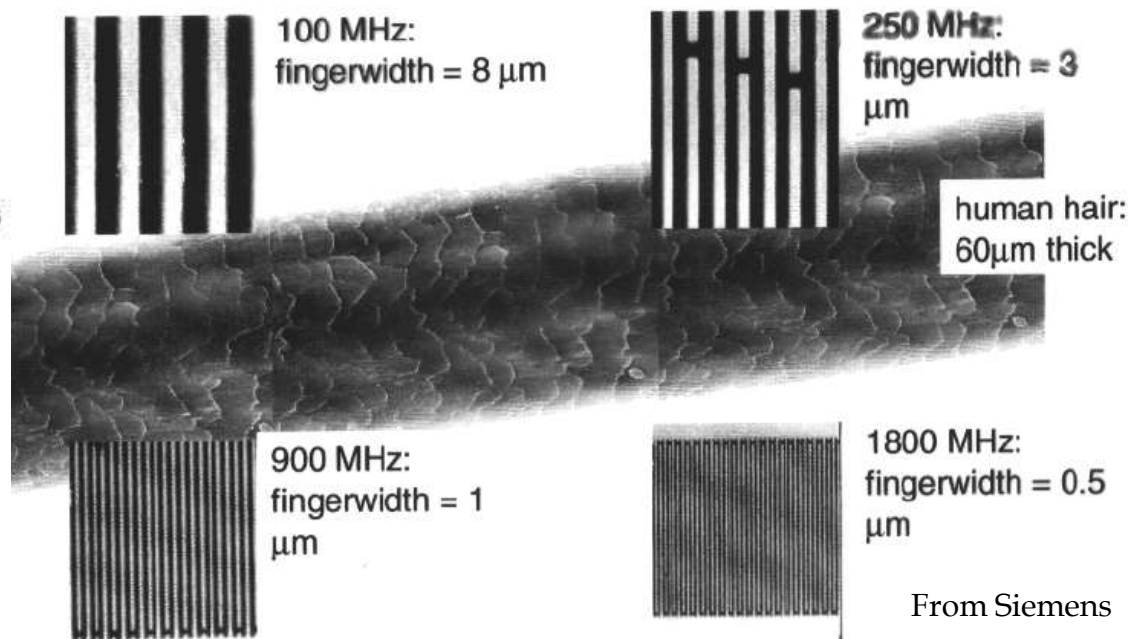
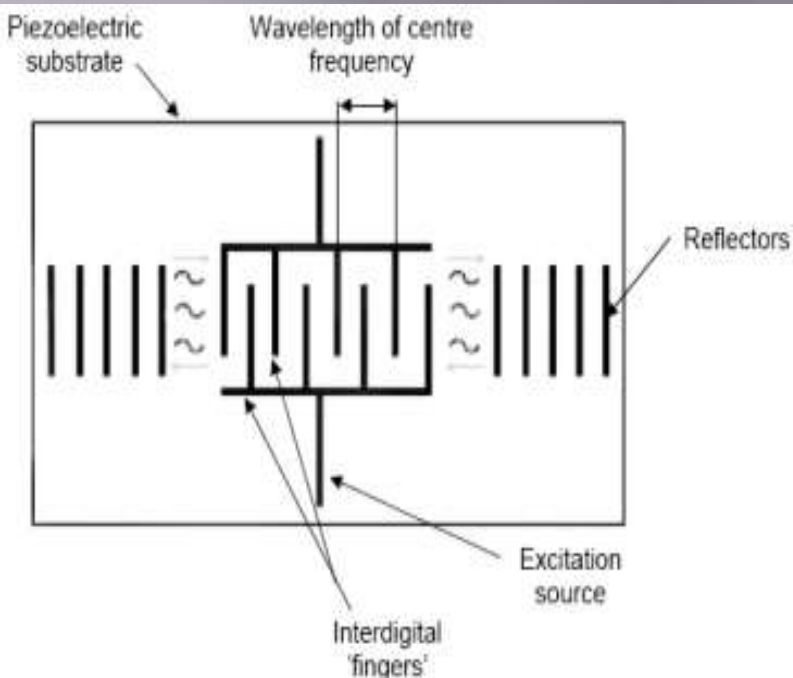
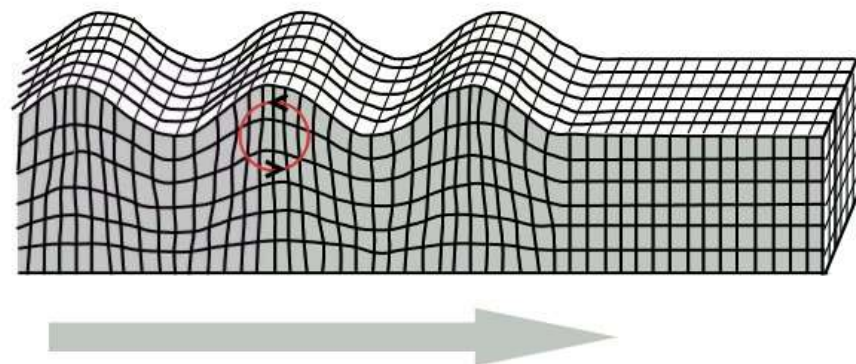
- ▣ Use surface acoustic wave (SAW) device technology to produce a spread spectrum, coded, passive sensor platform
- ▣ Use different piezoelectric materials such as quartz, lithium niobate, gallium orthophosphate, langasite, and/or ceramics to meet system requirements,
- ▣ Differentiate between the effect of strain (and other physical parameters) and temperature
- ▣ Develop wireless systems for measurement of physical parameters (such as strain), and temperature

What is a typical SAW Device?

A solid state device

- Converts electrical energy into a mechanical wave and vice versa on a single crystal substrate
- Capable of very complex signal processing in a very small volume

Rayleigh Wave

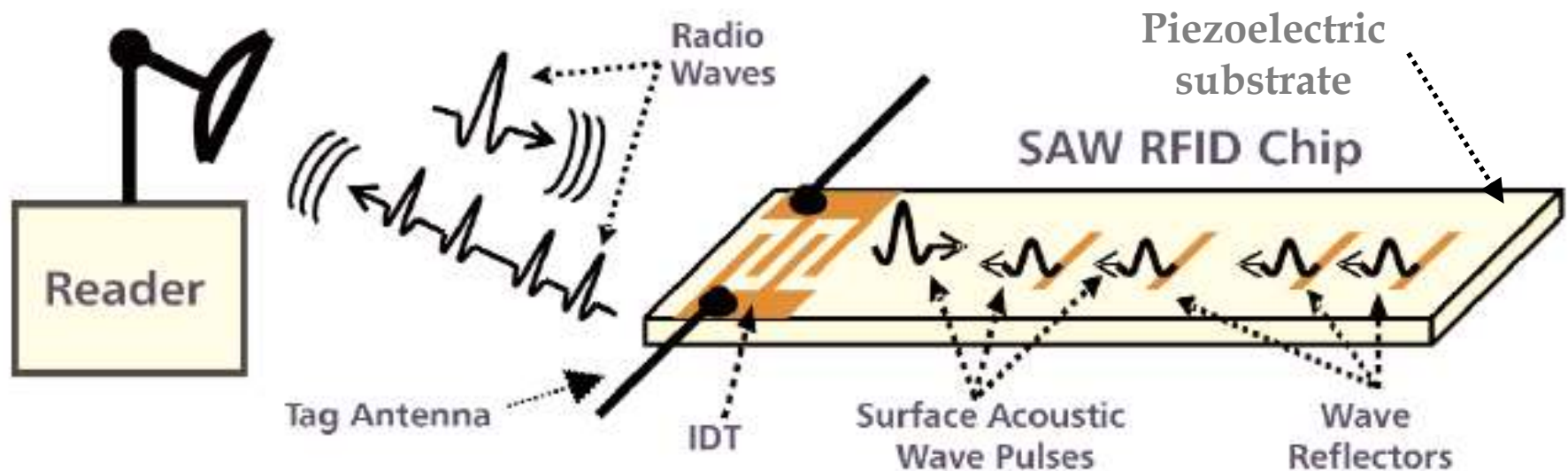


From Siemens

Why use SAW Sensors?

- ▣ Ability to both measure a stimulus and to wirelessly, passively transmit the information
- ▣ Frequency/time are measured with greatest accuracy compared to any other physical measurement
- ▣ Passive – No external power, long service life
- ▣ Operate from cryogenic to $\sim 1000^{\circ}\text{C}$
- ▣ Wide dynamic range
- ▣ Identification capability
- ▣ Small, lightweight, and conformal
- ▣ Adequate for work in harsh environment
- ▣ Radiation hard
- ▣ Easy to install on new or existing structures
- ▣ Low cost

Schematic of a SAW-based radio-link measurement system

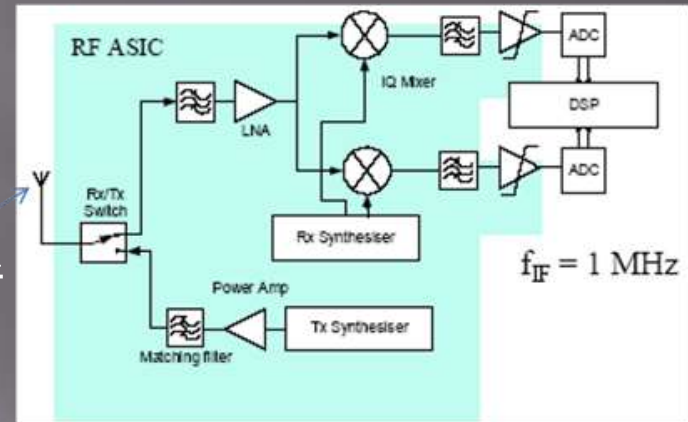


Example, SAW based torque sensor and radio communication link

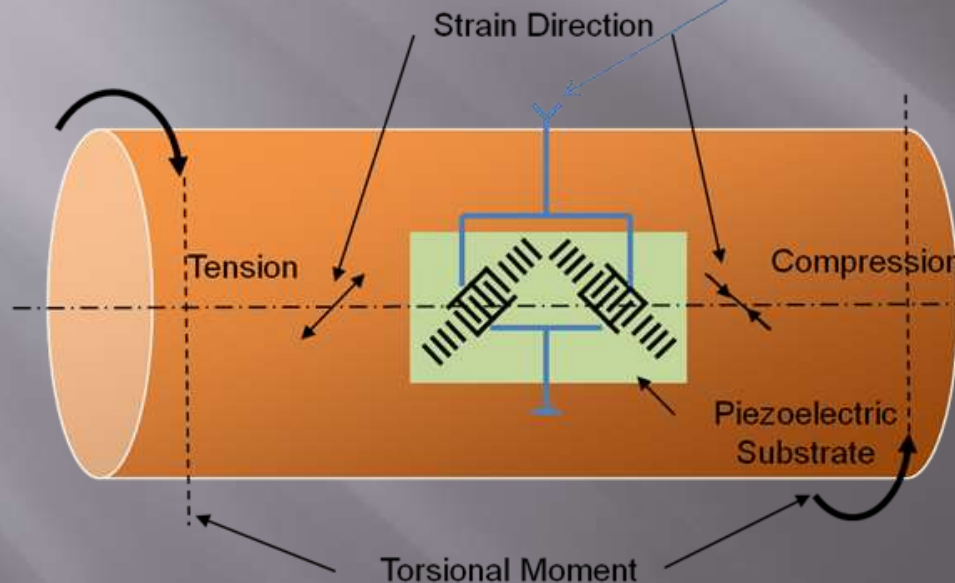
Measure:

- Static strain/torque,
- Rate-of-change of strain/torque

Minimum post-processing required



Reader

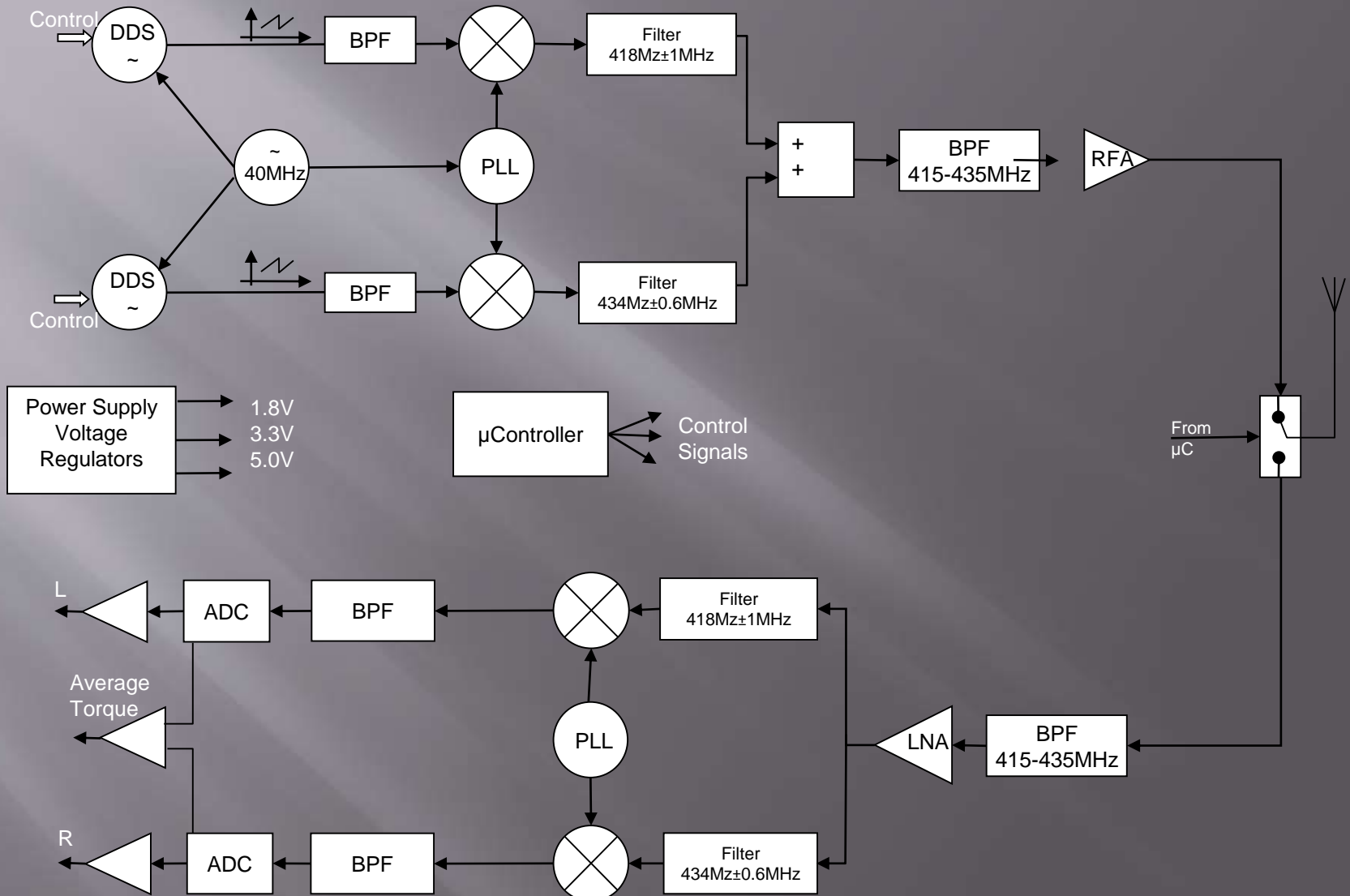


$$\tau = \frac{2 \cdot L}{v}; f_c = \frac{1}{\tau} = \frac{v}{2 \cdot L};$$

$$\Delta \tau = \tau \cdot S_y^t \cdot \Delta y;$$

$$\Delta f_0 = -f_0 \cdot (y_0) \cdot S_y^f \cdot \Delta y;$$

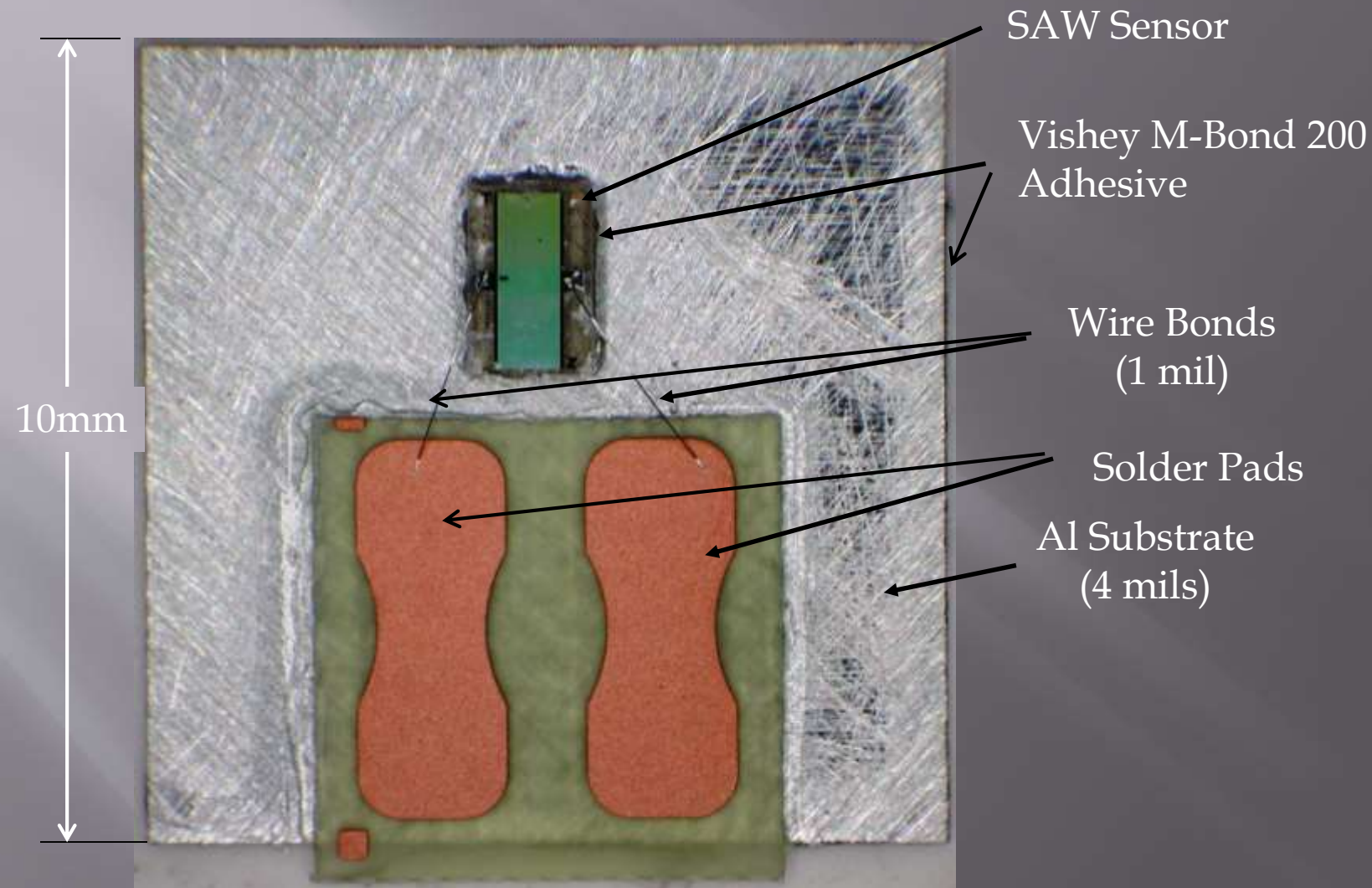
Block diagram of the reader unit



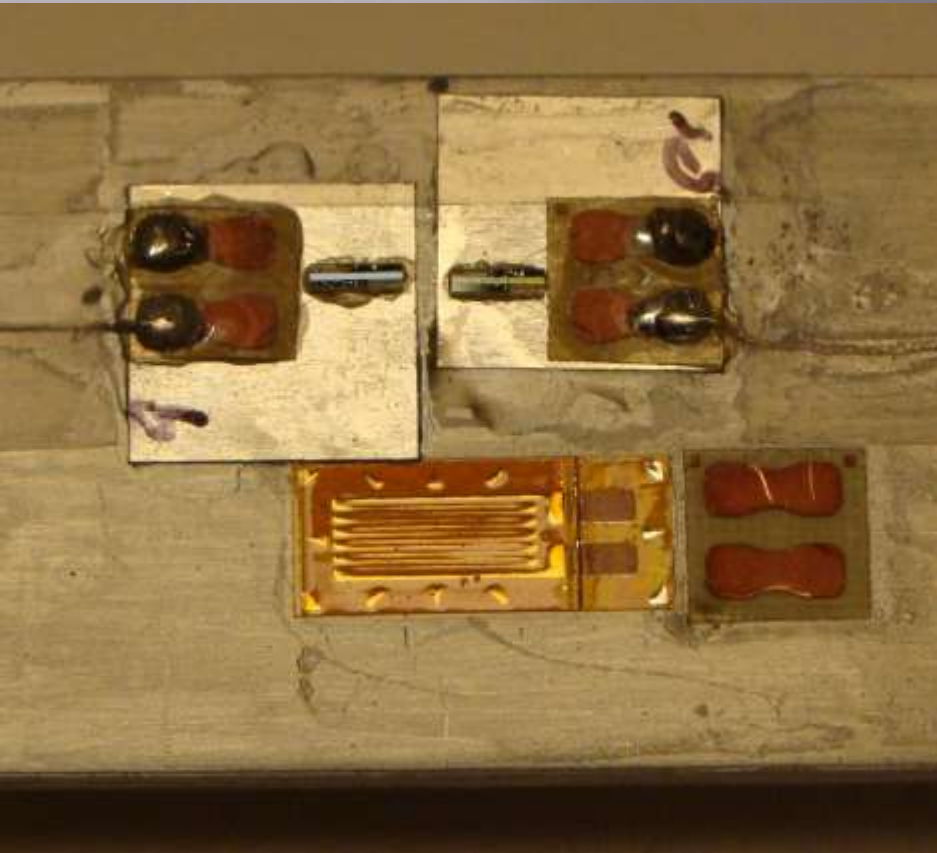
Reader unit board



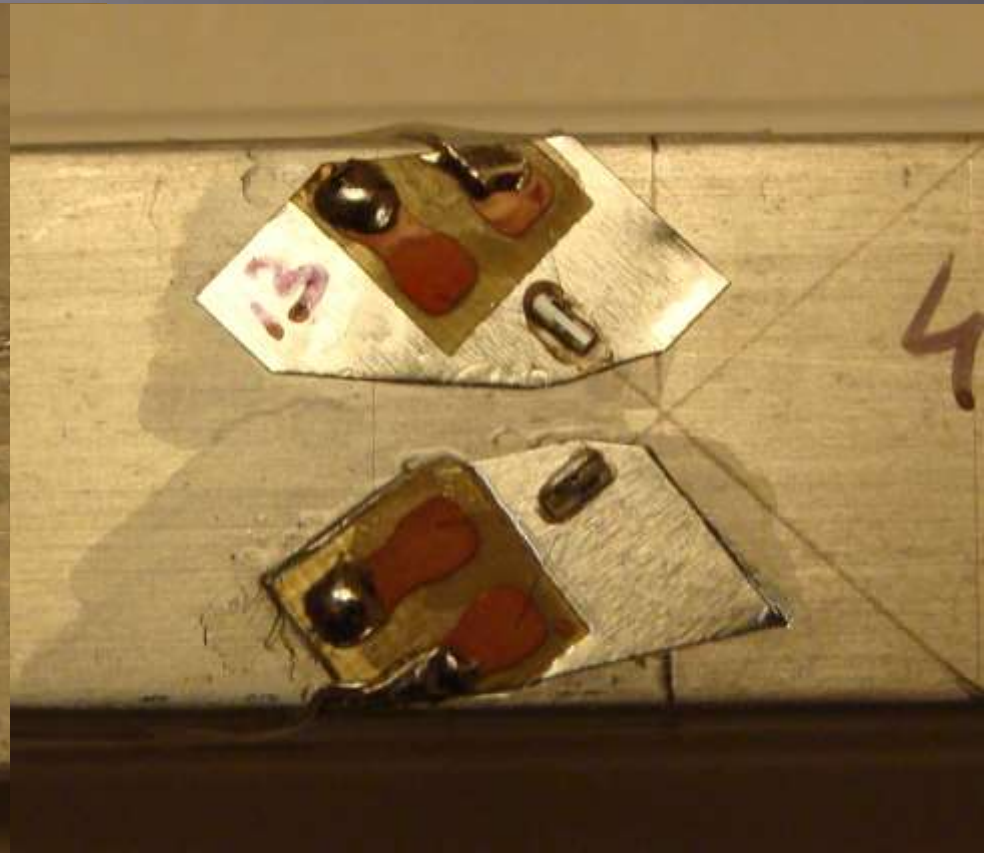
Experimental SAW Strain Sensor Assembly



Experimental Strain/Torque Sensor Assembly

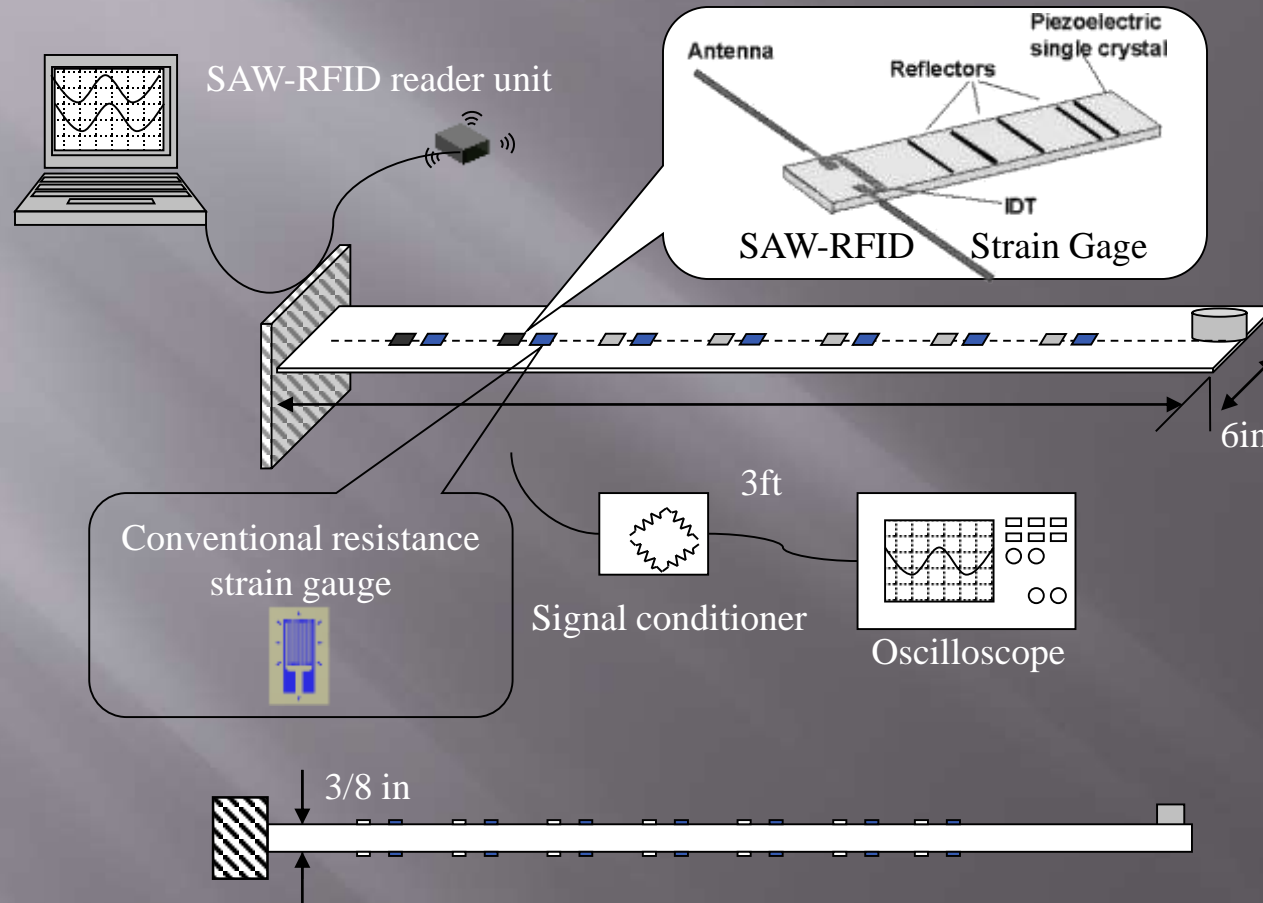


Strain measurement setup



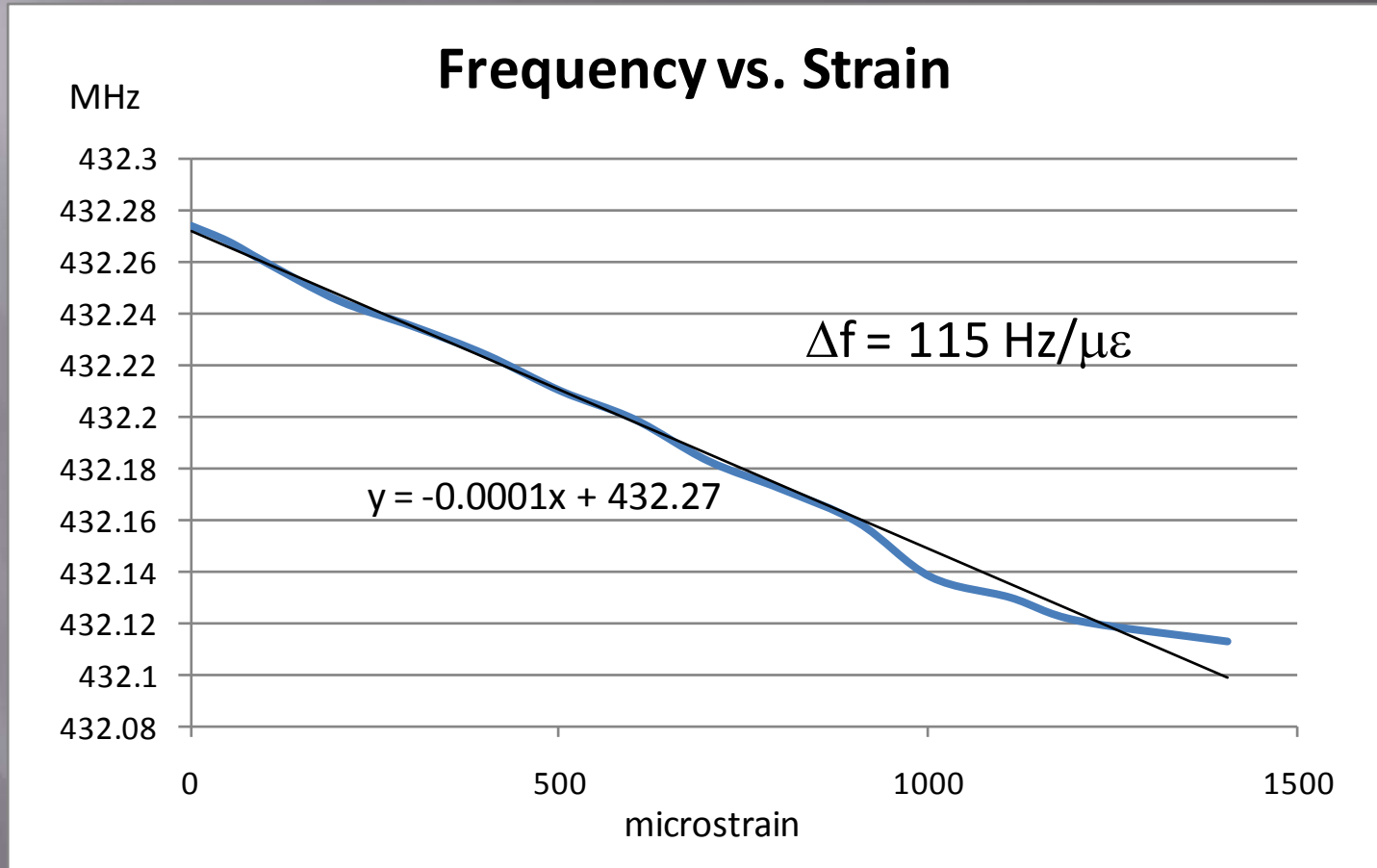
Torque measurement setup

Experimental Test Bench



Strain Measurements using Wireless SAW Sensors

Strain ($\mu\epsilon$)	Freq (MHz)
0	432.274
50	432.268
100	432.26
200	432.245
301	432.235
400	432.224
501	432.21
601	432.199
700	432.183
800	432.172
904	432.159
1002	432.138
1110	432.13
1202	432.121
1404	432.113



SAW Sensor Opportunities in Military and Commercial Applications

- ▣ Condition Base Maintenance (CBM) of machinery (motors, generators, pumps, gear systems, etc.)
- ▣ Distributed Wireless Sensor Network for CBM and SHM
- ▣ CBM and SHM in harsh environments (Extreme temperature, corrosive environment)
- ▣ DoD platforms which have key structural components that require torque, strain, or loads monitoring
- ▣ NASA and Aerospace industry
- ▣ Power plant turbo generators, Wind turbines
- ▣ Oil industry
- ▣ Automotive industry
- ▣ Transportation – rail roads, bridges, etc.
- ▣ Consumer market (e.g. fragile cargos)
- ▣ Medical and health industry (e.g. pressure sensors)
- ▣ Estimated market opportunity at about \$ 3 B/yr

Shortcomings of Wireless SAW Sensors

- ▣ Not suited for large area applications
- ▣ Sensitive to metallic environment
- ▣ Limited reading distance dependent on operating frequency
- ▣ Design of SAW sensor antenna is a challenge, again, dependent on frequency.

Summary

- ▣ Albido has developed a system capable of CBM and SHM, particularly of measuring high-bandwidth torque, strain, and temperature in extreme environments.
- ▣ The system uses **wireless, true passive strain sensors** based on SAW technology.
- ▣ The system employs a new method, developed by Albido, for compensating the errors induced in the SAW strain sensor by large temperature variations.
- ▣ Albido's products are wireless SAW sensors for CBM and SHM. Products also include Reader and Software.
- ▣ Since Albido's sensors are small, conformal, and cover a large temperature range, they can be used in stationary or moving structures.
- ▣ Market for Albido's products is large (several billion dollars), both commercial and military.

Acknowledgment

- ▣ The development of Albido's strain sensors was funded through the Office of Naval Research through STTR/SBIR contracts.
- ▣ The author wishes to thank ONR , and especially Dr. Scott Coombe, ONR.

Thanks