Passive Wireless Sensors

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RF Tags

- RF tags are everywhere now.
- Most passive tags are for ID only.
- Most passive tags are short range (<1m).
- Active tags can do much more.
- Active tags have batteries that wear out.

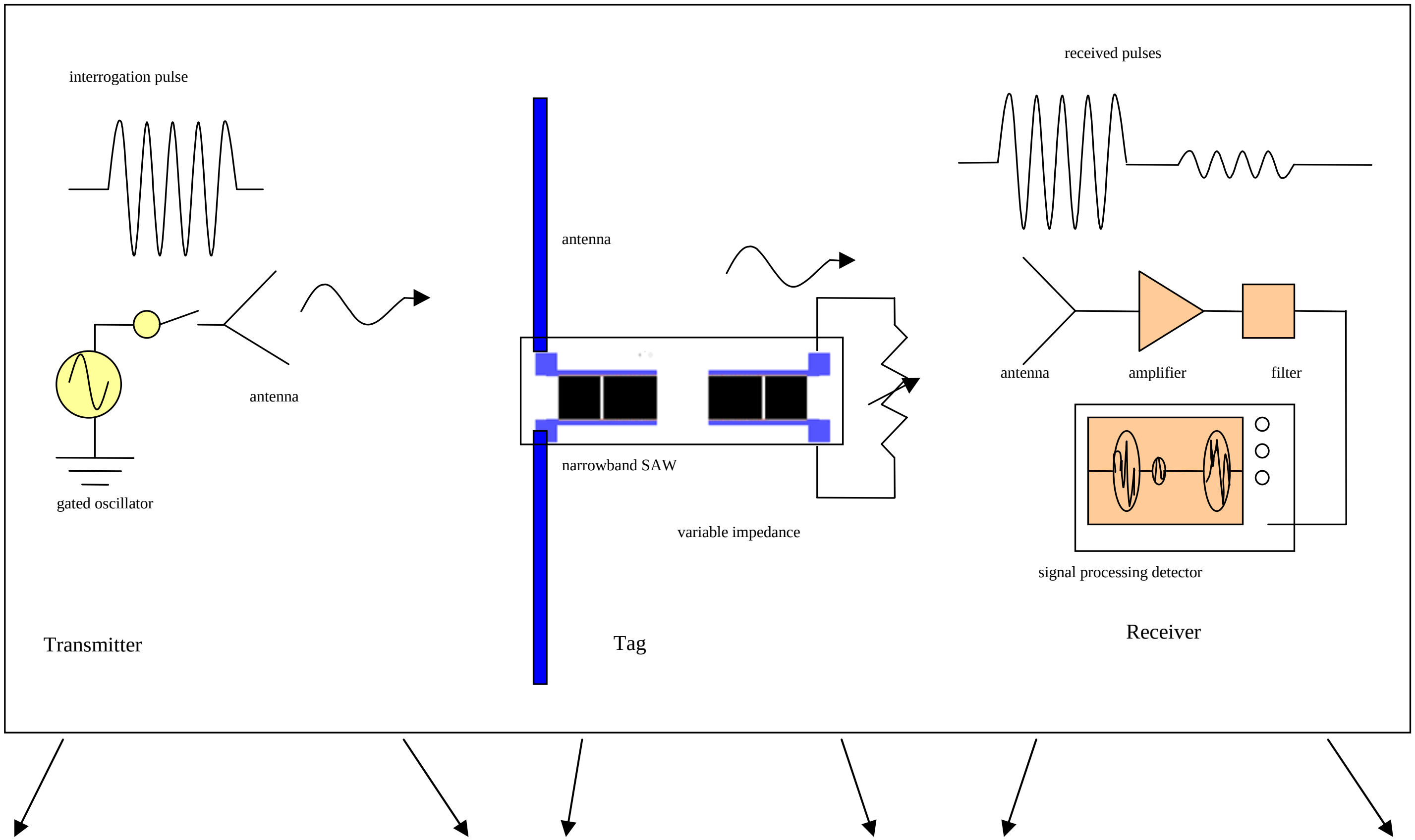
RF Sensor Tags

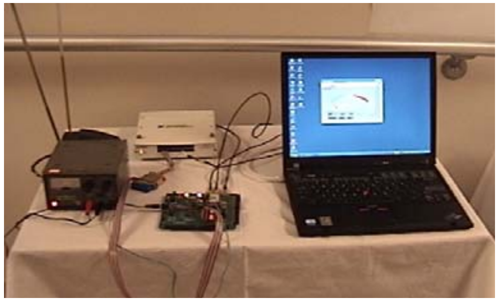
- Motivation: monitoring inflatable space habitat state-of-health.
- Specifications
  - Wireless.
  - No batteries or other power source.
  - Low RF power from interrogator (1 mW).
  - Free space - 10 meters range.
  - Measure high impedance piezo-type sensors.

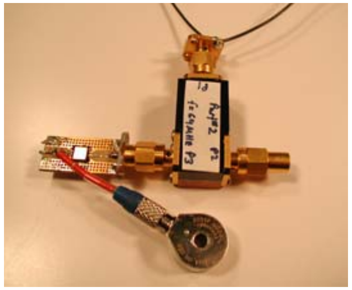
Sensor Tag Solution

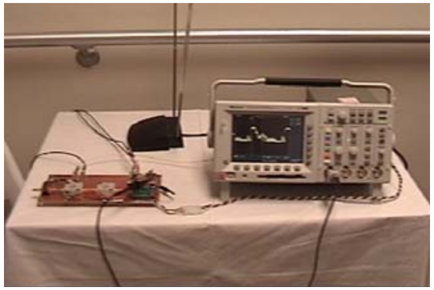
- Created a flexible test-bed to work with *any* impedance varying sensor.
- Used frequency multiplexing to achieve a simple, small multiple sensor space.
- Surface Acoustic Wave (SAW) devices to eliminate background clutter.
- Created a general purpose system that uses low, frequency and large antennas suitable for embedded sensors and infrastructure monitoring.

System components



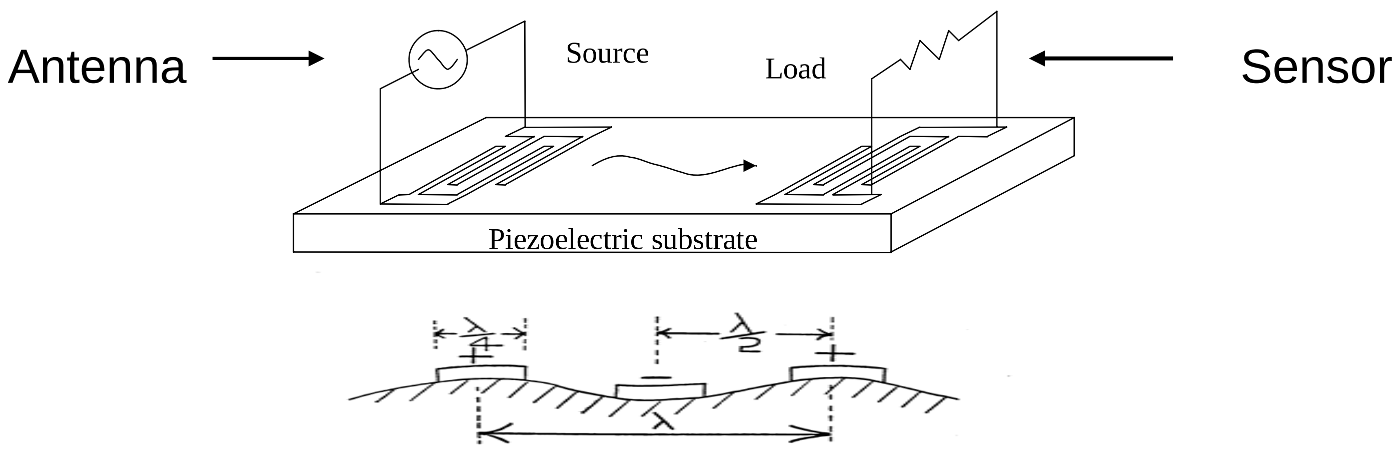






Received signal response with high sensor impedance.

Operation of a Surface Acoustic Wave (SAW) Based Sensor



Surface Acoustic Wave Device

SAW impedance measurements are determined by the acoustic mismatch:

$$P_{acoustic}(Z_{load}) = P_{acoustic}(@\,Z_{load} = 0) + \frac{2K^2}{\left(\frac{1}{Z_{transducer}} + \frac{1}{_{load}}\right)}$$

Free Space Range Formula

$$r := \frac{\lambda}{4\cdot\pi}\cdot\sqrt[4]{\frac{P_o\cdot G_t\cdot G_r\cdot {G_s}^2}{{S_{21}}^2\cdot SNR\cdot kTBF}}$$

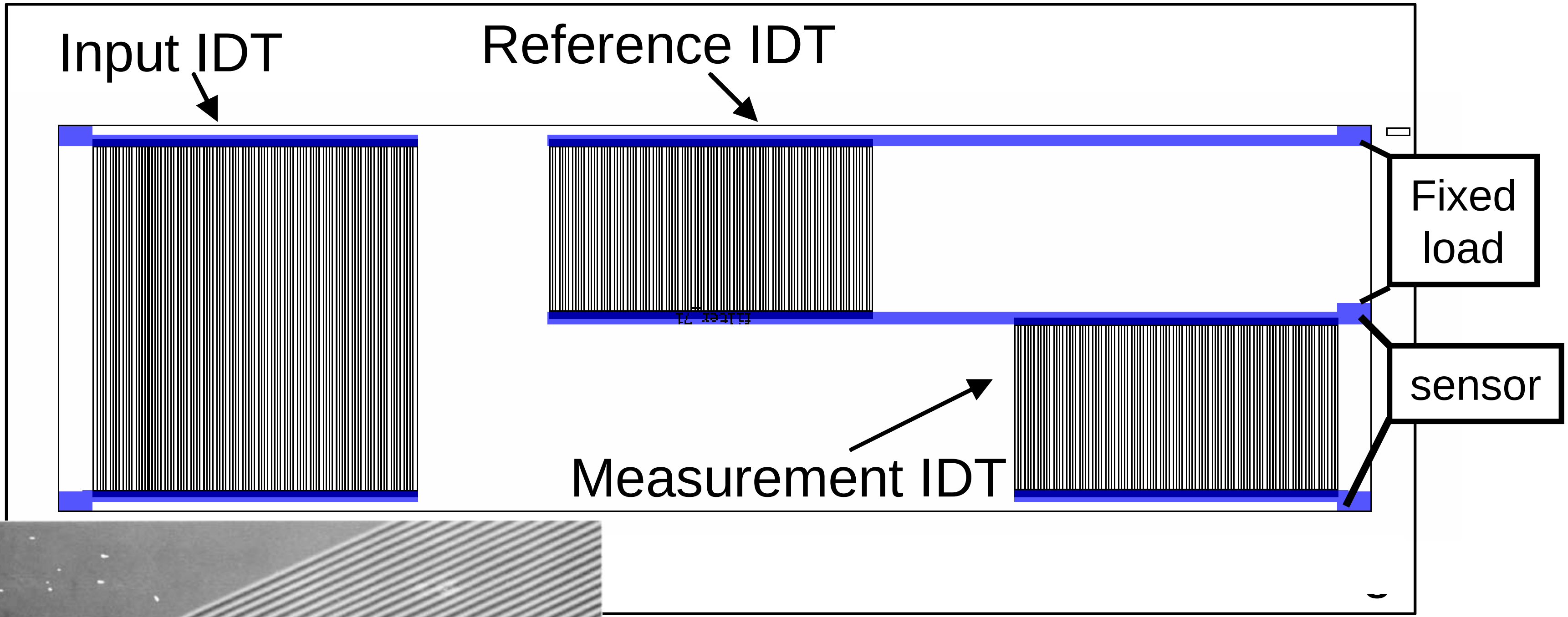
λ= wavelength of RF interrogation burst
Po = power of RF burst
G = antenna gain of t= transmitter, r = receiver, s = SAW tag
S21 = insertion loss of SAW tag
SNR = minimum detection signal to noise ratio
(kT)(B) = thermal energy in band width
F = receiver noise figure

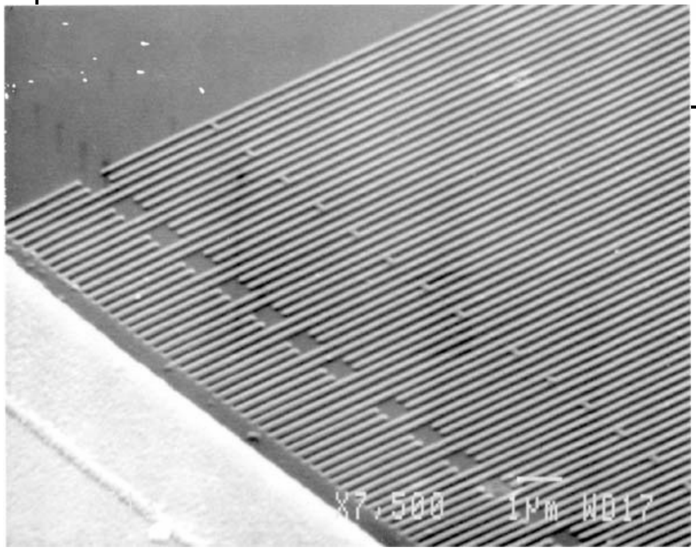
Range Example

- 69 MHz, all dipole antennas, insertion loss of tag is 13 dB, bandwidth is 600 KHz, SNR is 50 dB to get 8 bit accuracy on sensor, 3 dB standard receiver noise, free space.
- Transmitter power / Range

Transmitter power	Range
1 mW	10.8 meters
100 mW	34 meters
10 W	108 meters

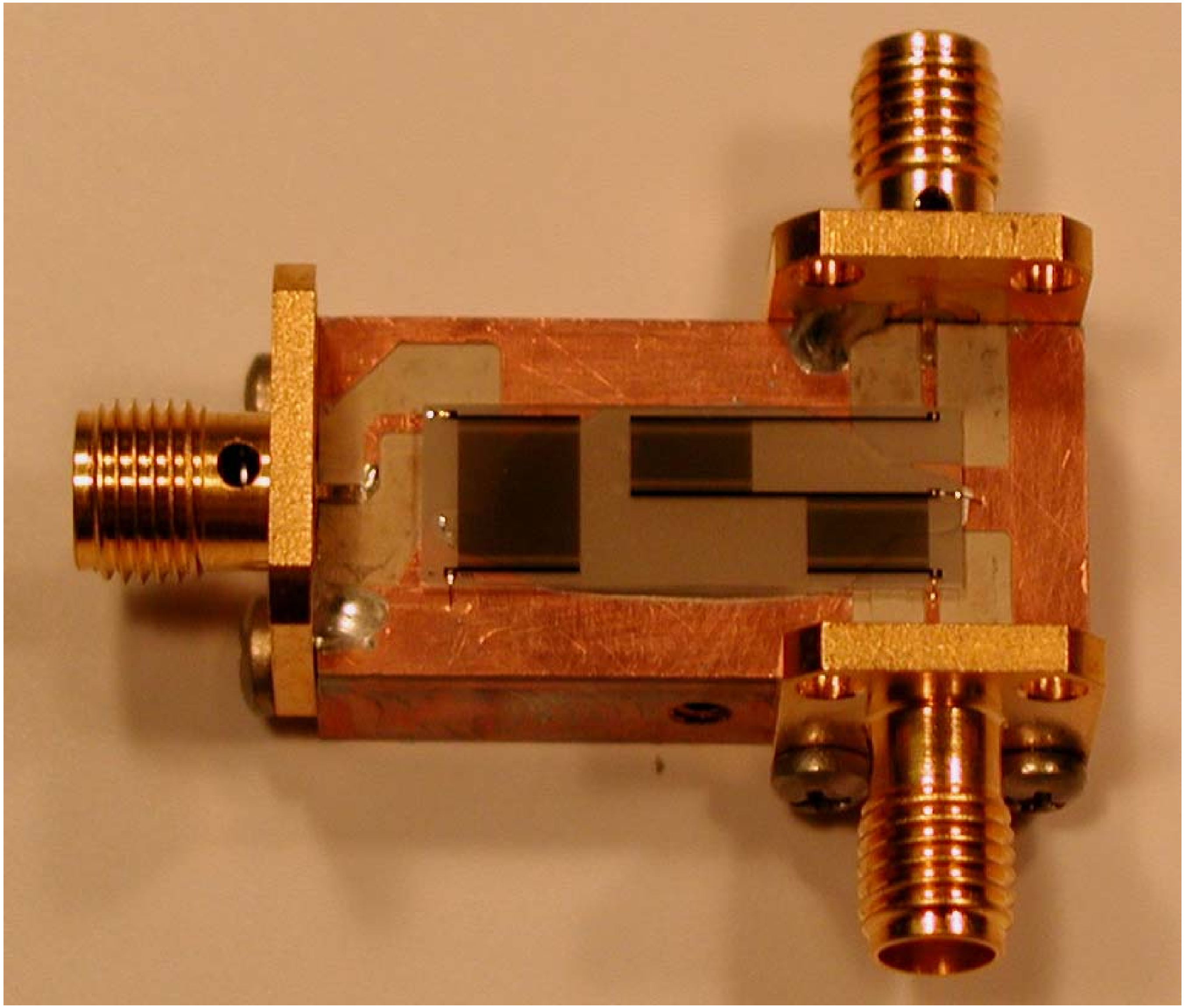
Surface Acoustic Wave chip design



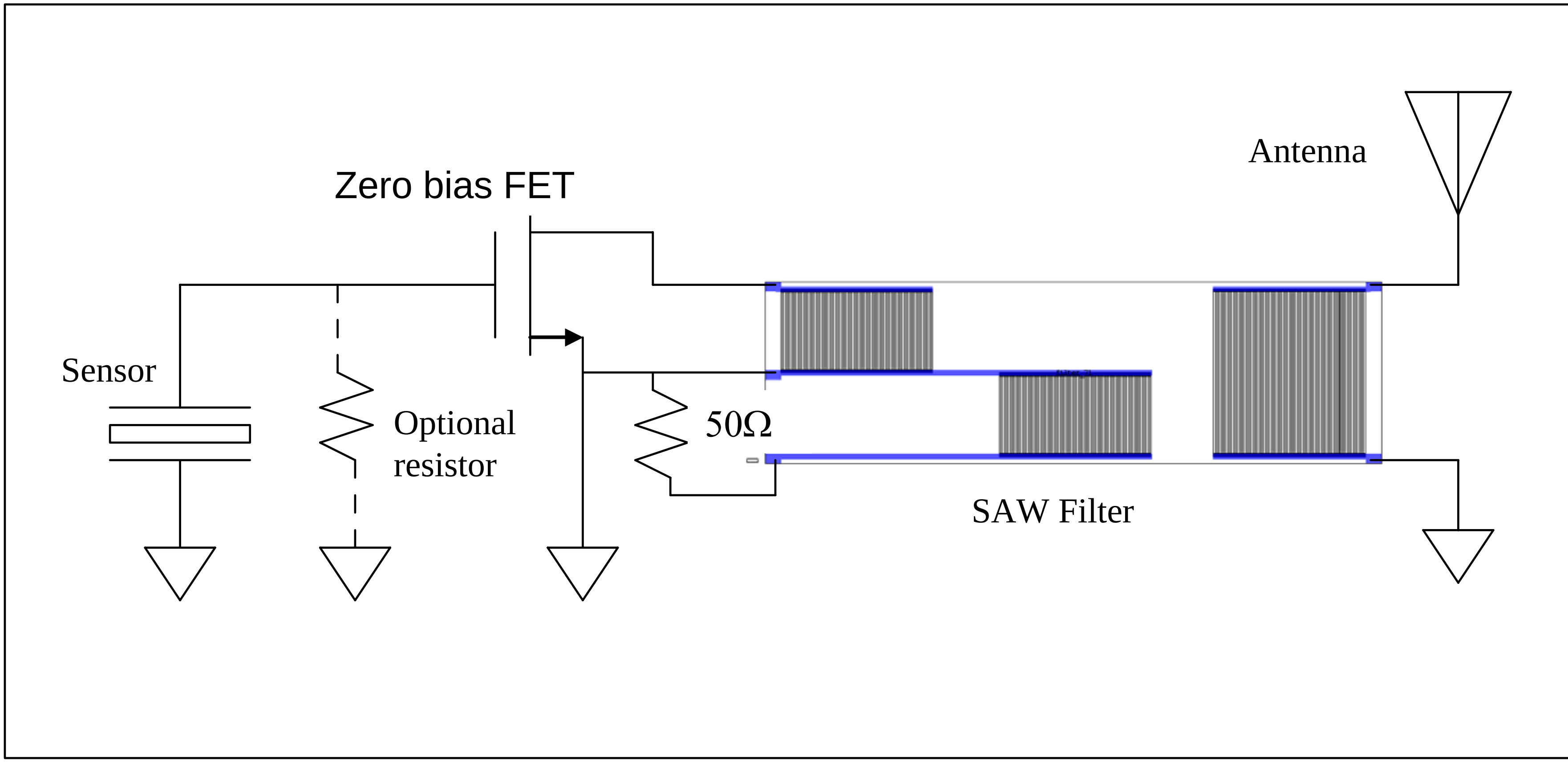


SEM image of fingers of SAW transducer

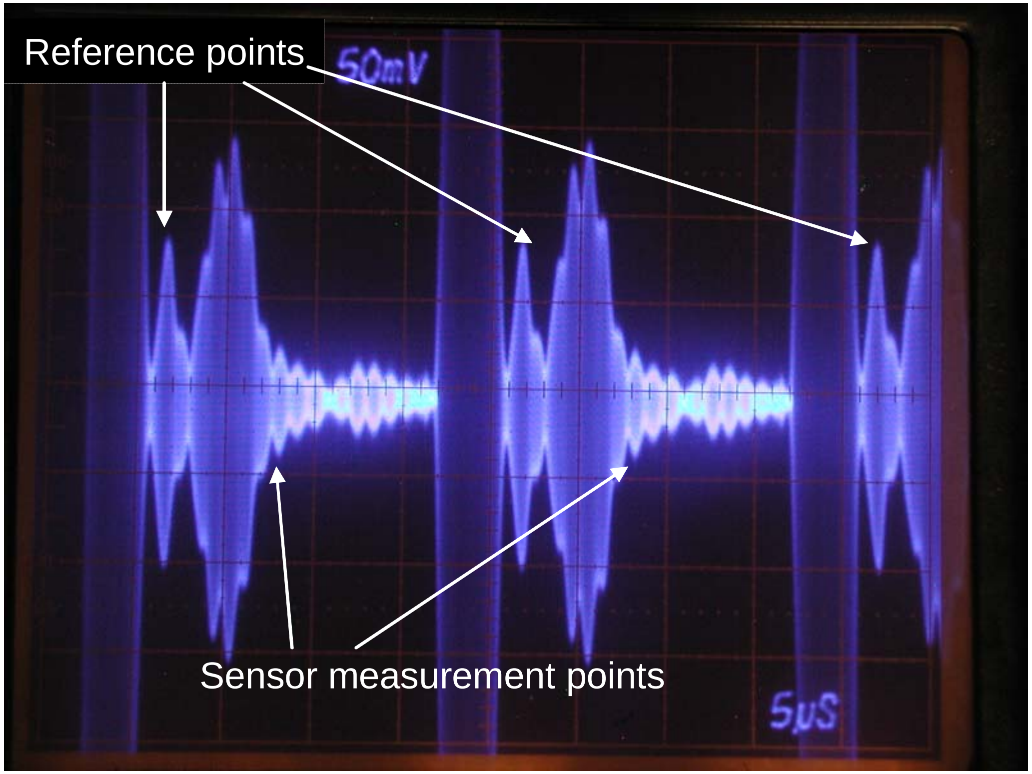
SAW Chip in Test Setup

- 

High Impedance Sensor



Large return signal from sensor



Sensors Demonstrated to date:

- Toggle switch (open or closed)
- Thermistor for temperature reading
- CdS optical detector
- Darlington photo detector
- Endevco 2221F accelerometer
- NASA acoustic emission sensor
- Inductive coil displacement sensor

Distinct Features of This System

- Simple, flexible system for evaluation of sensors.
- Long range (10 m).
- Works with both high impedance (100s M-ohm) and low impedance (0-500 ohm) sensors.
- Can evaluate other formats for many sensors (narrowband SAWs), reduced size antennas, higher power, longer range operation, etc.

Directions for Technology

- Applications will govern the optimizing criteria.
- Possibilities: higher frequencies, smaller antennas, code-division multiplexing, phase measuring sensors, directional antennas, other sensors (strain, chemical, mass, etc.).
- Approach: Find an application and choose the appropriate solution set.