# Passive Wireless Sensors

March 27-28, 2007 – IEEE RFID Conf & CANEUS discussion

By Sandia National Laboratories, Albuquerque, NM


Robert Brocato

Glenn Omdahl

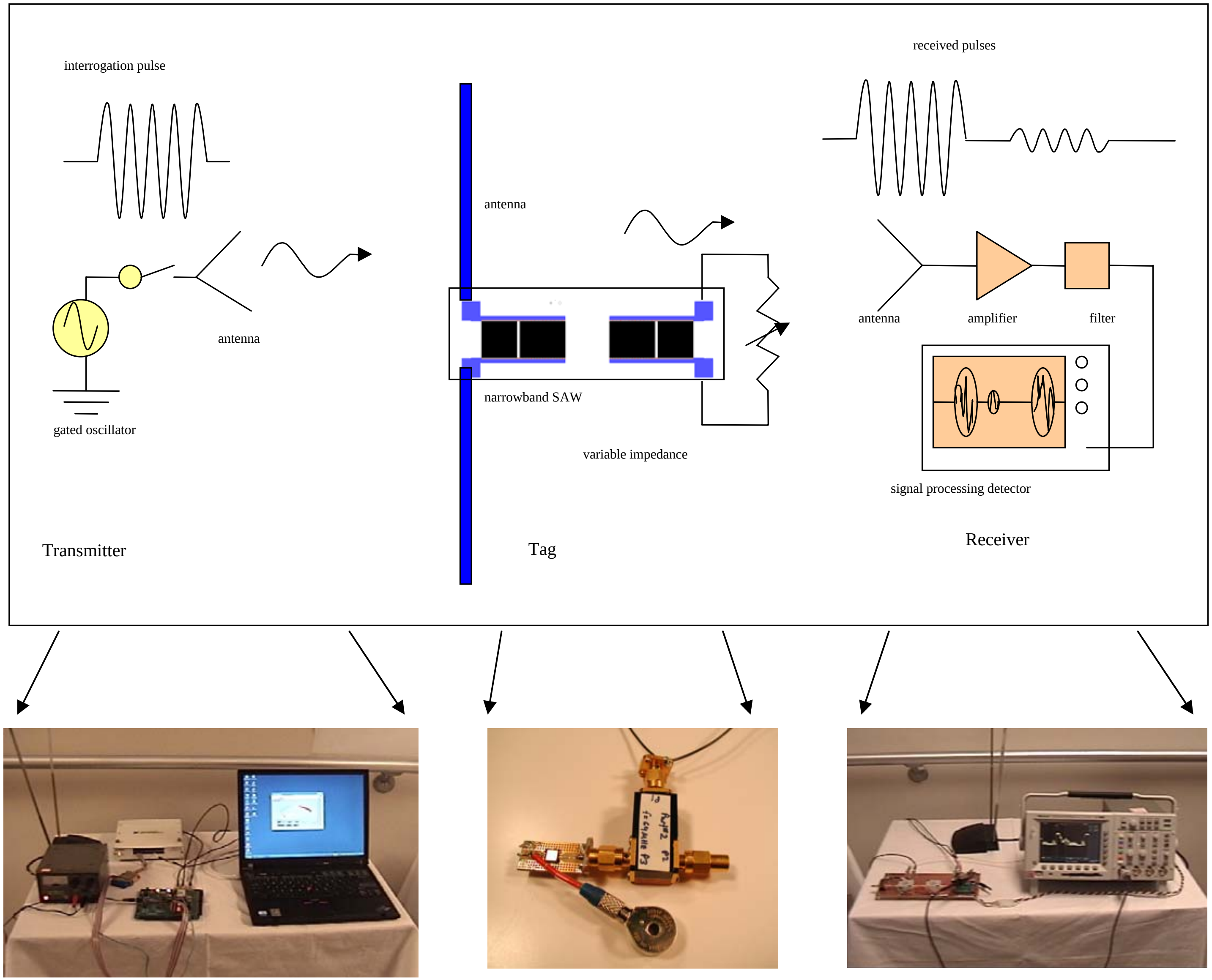
Chris Gibson

Dave Palmer, 505 844 2138,
palmerdw@sandia.gov

# Initial Motivation

- Sensors for inflatable space habitat
- Specifications
  - Wireless
  - Passive
  - Small sensor units + hand held interrogator
  - Sensors include temp, pressure, light, impact, acoustic
  - Low RF power from interrogator (1 mW)
  - Free space - 10 meters range
- Now also considering use for micro-meteroid impact and damage detection – high impedance sensors.

# System components




Received signal response with high sensor impedance.

# RANGE Formula

$$R = (\lambda/4\pi) \left( \frac{(P_o)(G_t)(G_r)(G_s^2)}{(S_{21})^2 (SNR)(kT)(B)(F)} \right)^{**0.25}$$

$\lambda$= 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 needed signal to noise ratio
(kT)(B) = thermal energy in band width
F = receiver noise figure

| Transmitted power $P_o$ | Detection range (8 bit sensor resolution) |
|---|---|
| 1 mW | 10.8 meters |
| 100 mW | 34 meters |
| 10 W | 108 meters |

# Range Example

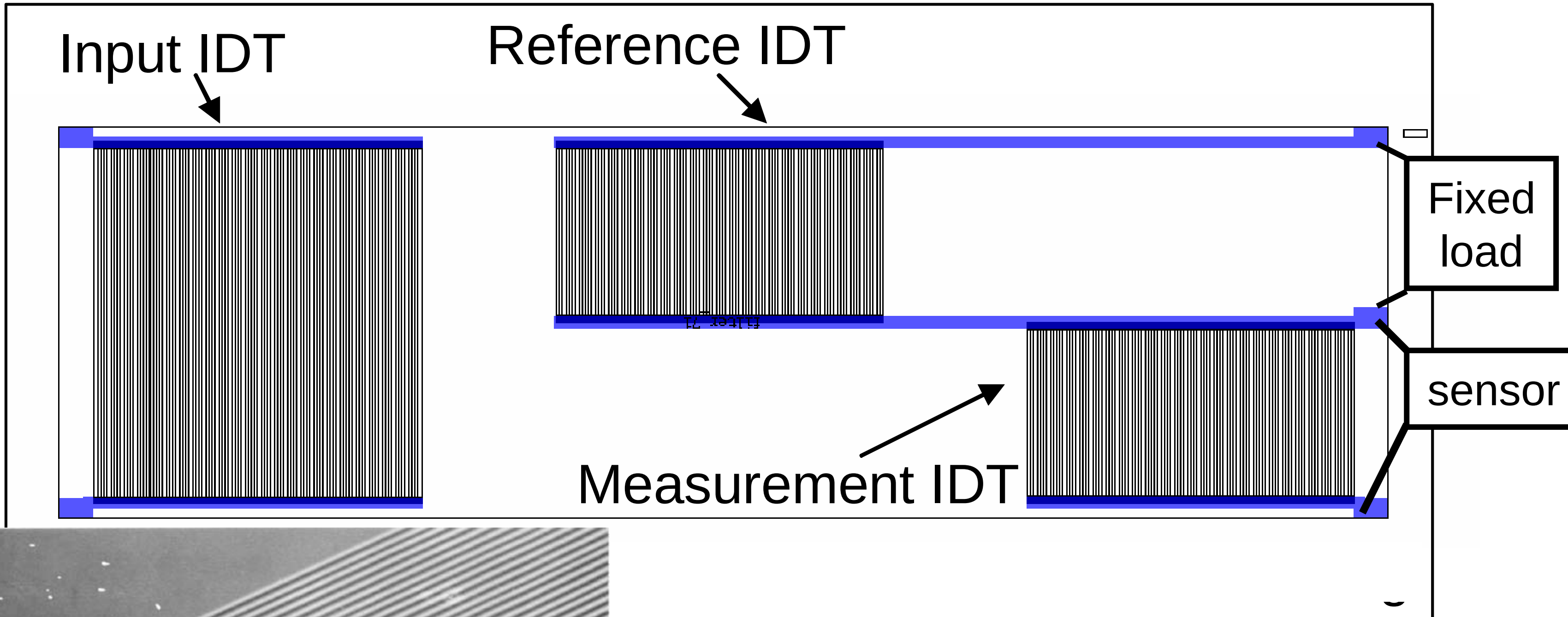
- 69 MHz, all dipole antennas, insertion loss of tag is 13 dB, bandwidth is 600 KHz, SNR is 50 dB to get 8 bit accuracy on sensor, 3 dB standard receiver noise, free space.
- Transmitter power / Range

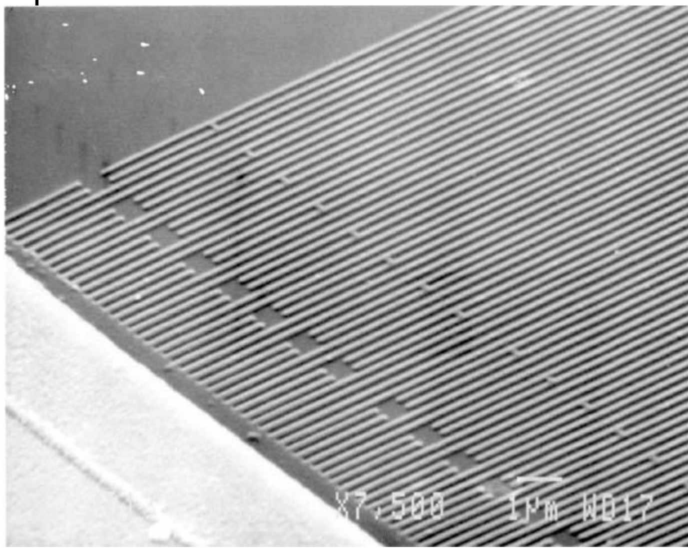
| Transmitter power | Range |
|---|---|
| 1 mW | 10.8 meters |
| 100 mW | 34 meters |
| 10 W | 108 meters |

# Range consideration

- Within a wing or space craft the range will be much further because the RF is guided by the structure.
- Using antennas with gain of 10 increases range by 10 (only at short wavelength is this tractable….)
- Higher  frequencies at fixed power lower range
- If you need only location tracking not 8 bit accuracy, the range increases x10

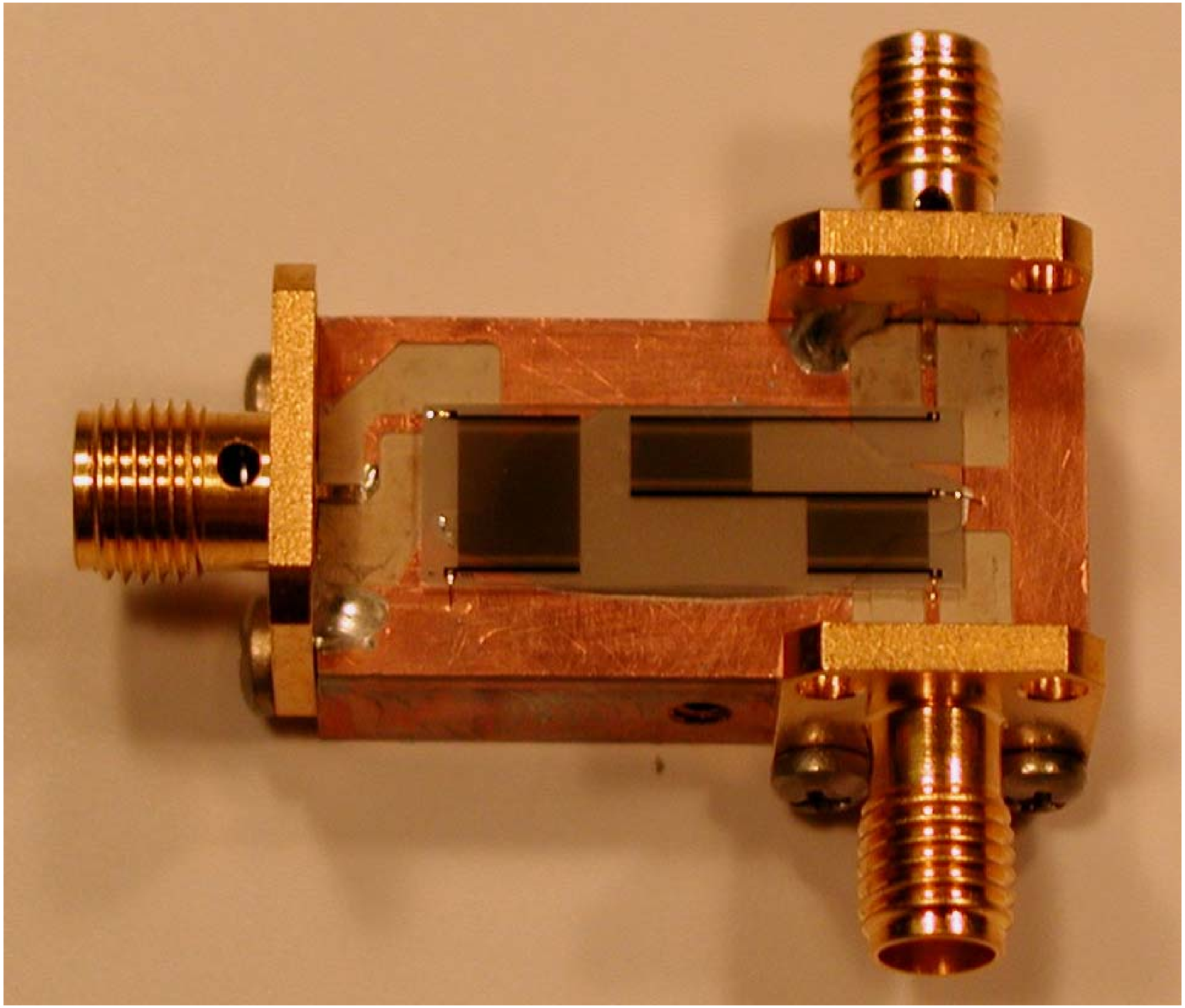
# Surface Acoustic Wave chip design



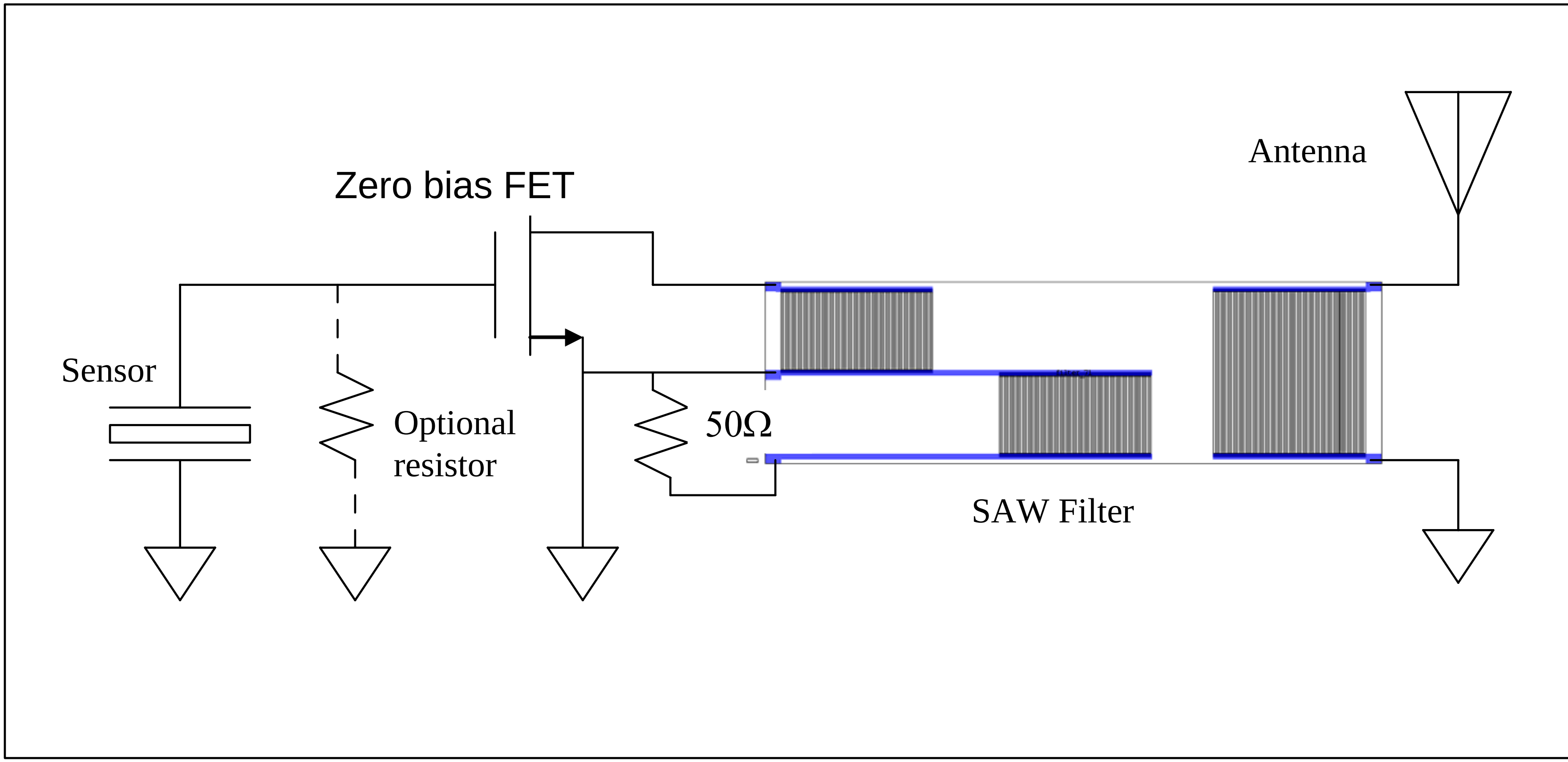



SEM image of fingers of SAW transducer

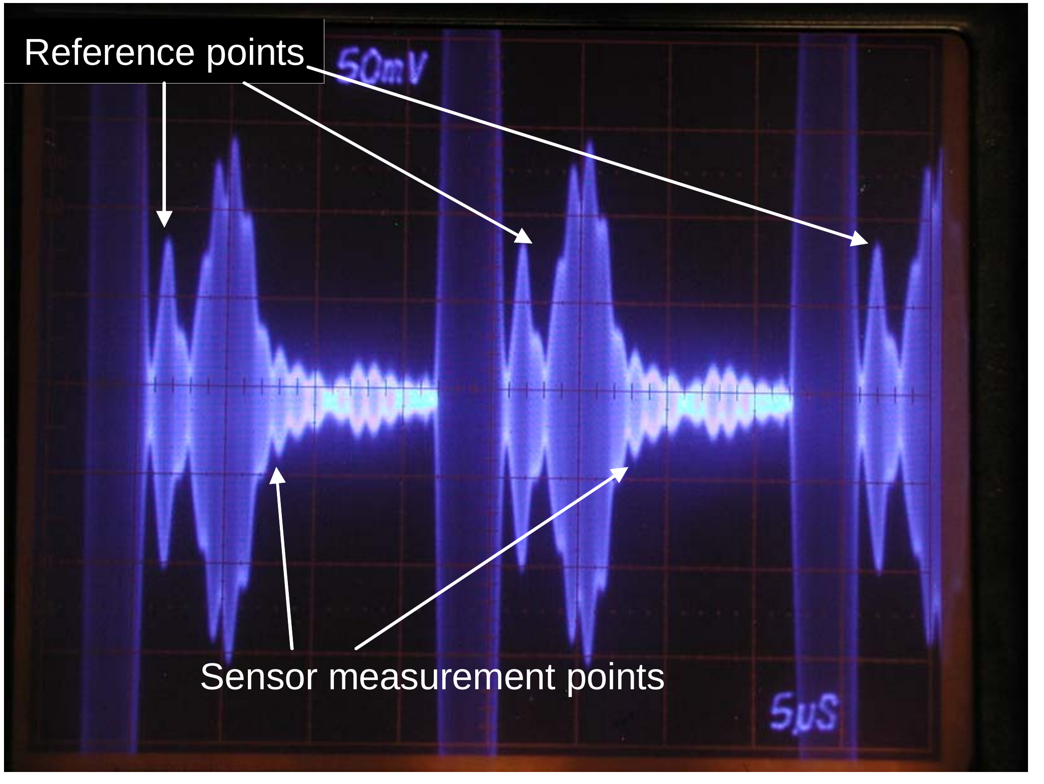
# SAW Chip in Test Setup

- 

# High Impedance Sensor



# Large return signal from sensor



# Sensors Integrated already

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

# Directions for Technology

- Matched SAWs designed and built to 5.6 GHz. Lower insertion loss devices for increased range.
- Integrated sensor and multisensor units chip size. For example, a thermistor on the SAW chip.
- Miniaturized interrogator (when application requires)
- Expand system to address 10-100 sensors: frequency/ delay/ code signal separation.
- Antenna optimized for each application
- Power scavenging on sensor chip for longer range communication.

# Contrasting Passive RFID

## Silicon

- Info in frequency side lobes
- Tag Needs 0.1 mW
- Commercial success, drive to low cost
- Target = ID/inventory, short range
- Simple packaging

## SAW

- Info in time delay signal
- no minimum power
- Limited production, high market cost
- Target = sensing, longer range
- Cavity packaging

*There are exceptions to all these generalities*

# Commonality in RFIDs

- System design easier if only a few tags at once within interrogator range
- Range and function improve if tag has battery or locally scavenges power
- Antenna largest component (70-950 MHz)
- Sensors could be integrated on wireless chip.

# Distinct Features of These RFIDs

- Long range (10 m) with only 1 mW from interrogator.
- Works with both high impedance (100s M-ohm) as well as normal (10-500 ohm) sensors.
- Can run multiple sensors with close frequency spacing ($f_o$/3000)
- Can also use code correlation to differentiate tags.