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Passive Wireless Sensors

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By Sandia National Laboratories

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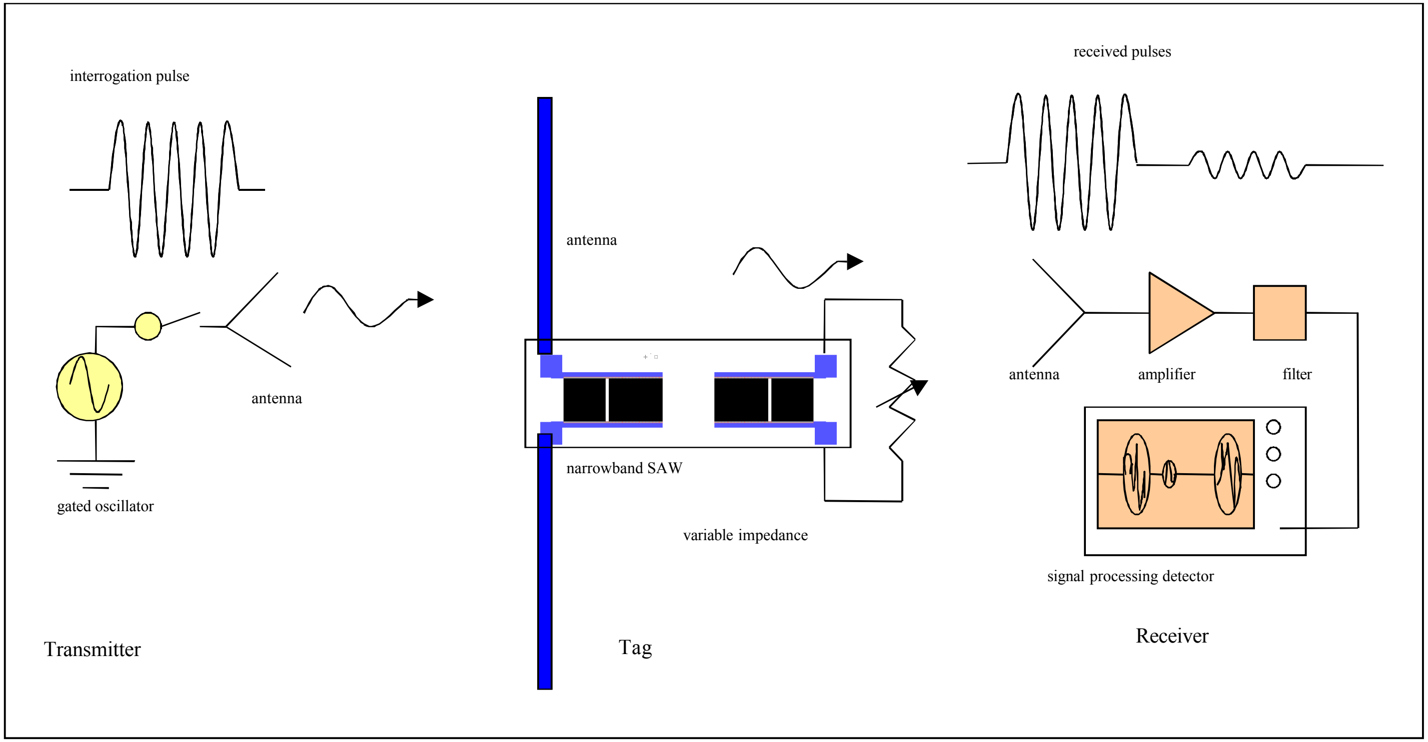
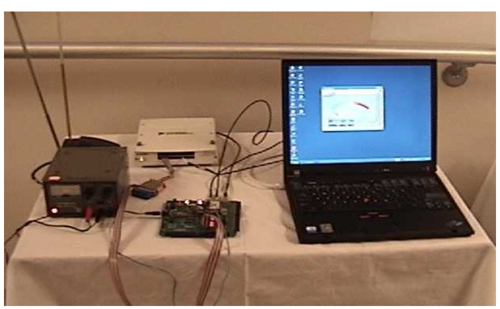
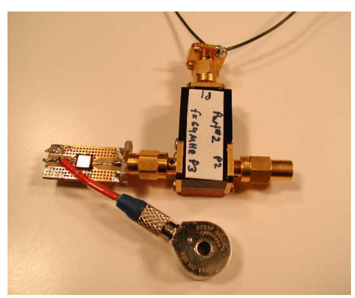
Initial Motivation

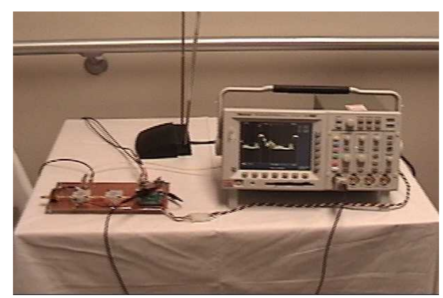
- Sensors for inflatable space habitat
- Specifications
  - Wireless
  - Passive
  - Small sensor units + hand held interrogator
  - Sensors include temp, pressure, light, impact, acoustic
  - Low RF power from interrogator (1 mW)
  - Free space - 10 meters range
- Now also considering use for micrometeroid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

System components









Received signal response with high sensor impedance.

RANGE Formula

$$R = (\lambda/4\pi)\sqrt[4]{\frac{(P_o)(G_t)(G_r)(G_s^2)}{(S_{21})^2(SNR)(kT)(B)(F)}}$$

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 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

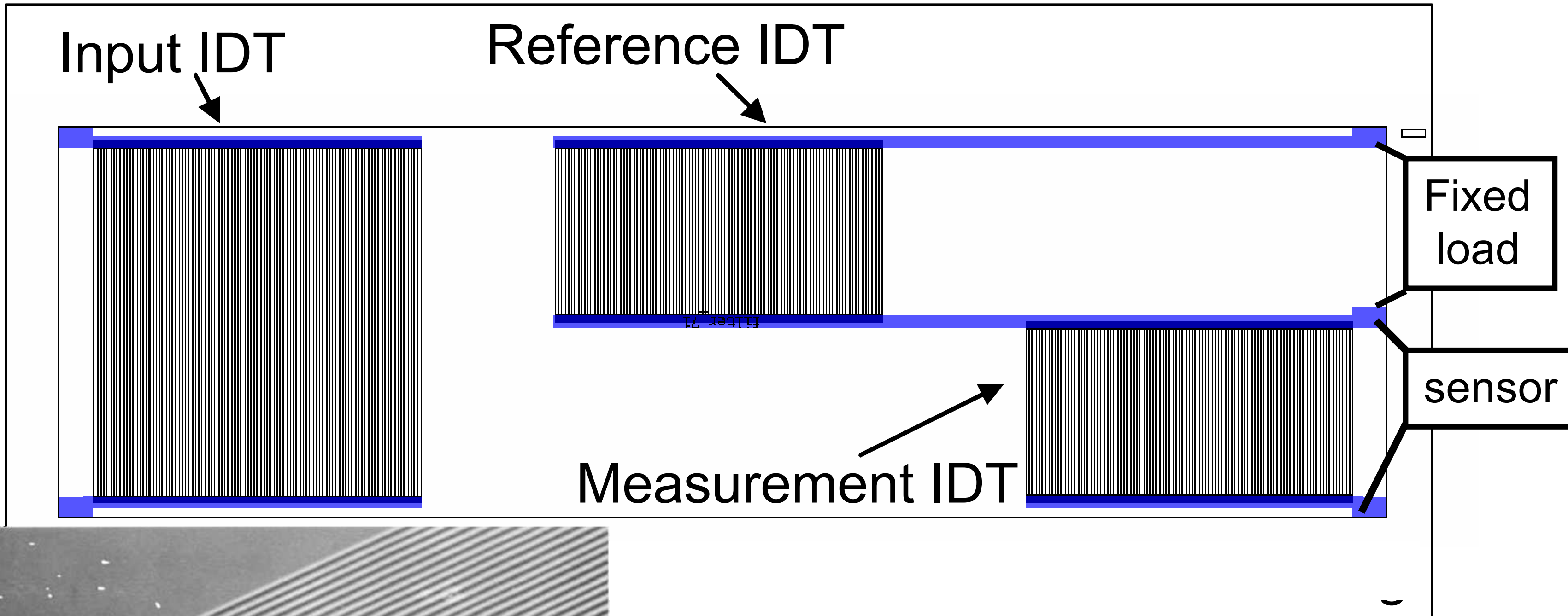
Range Example

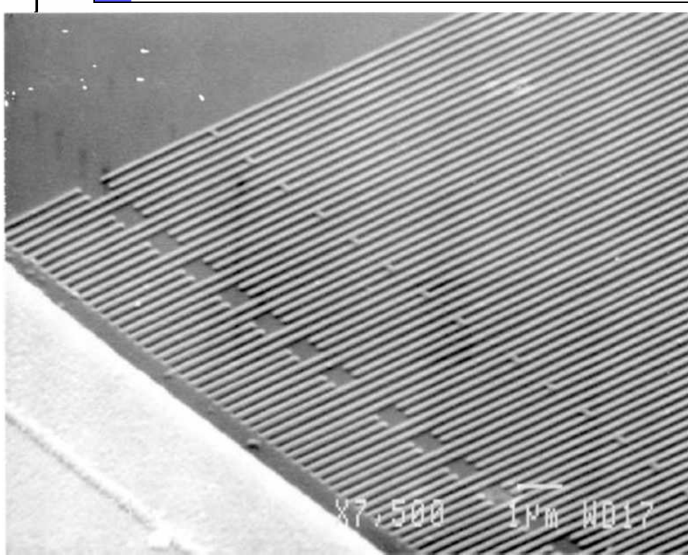
- 69 MHz, all dipole antennas, insertion loss of tag is 13 dB, bandwidth is 600 KHz, SNR is 50 dB to get 8 bit accuracy on sensor, 3 dB standard receiver noise, free space.
- Transmitter power — Range
    - 1 mW — 10.8 meters
    - 100 mW — 34 meters
    - 10 W — 108 meters

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

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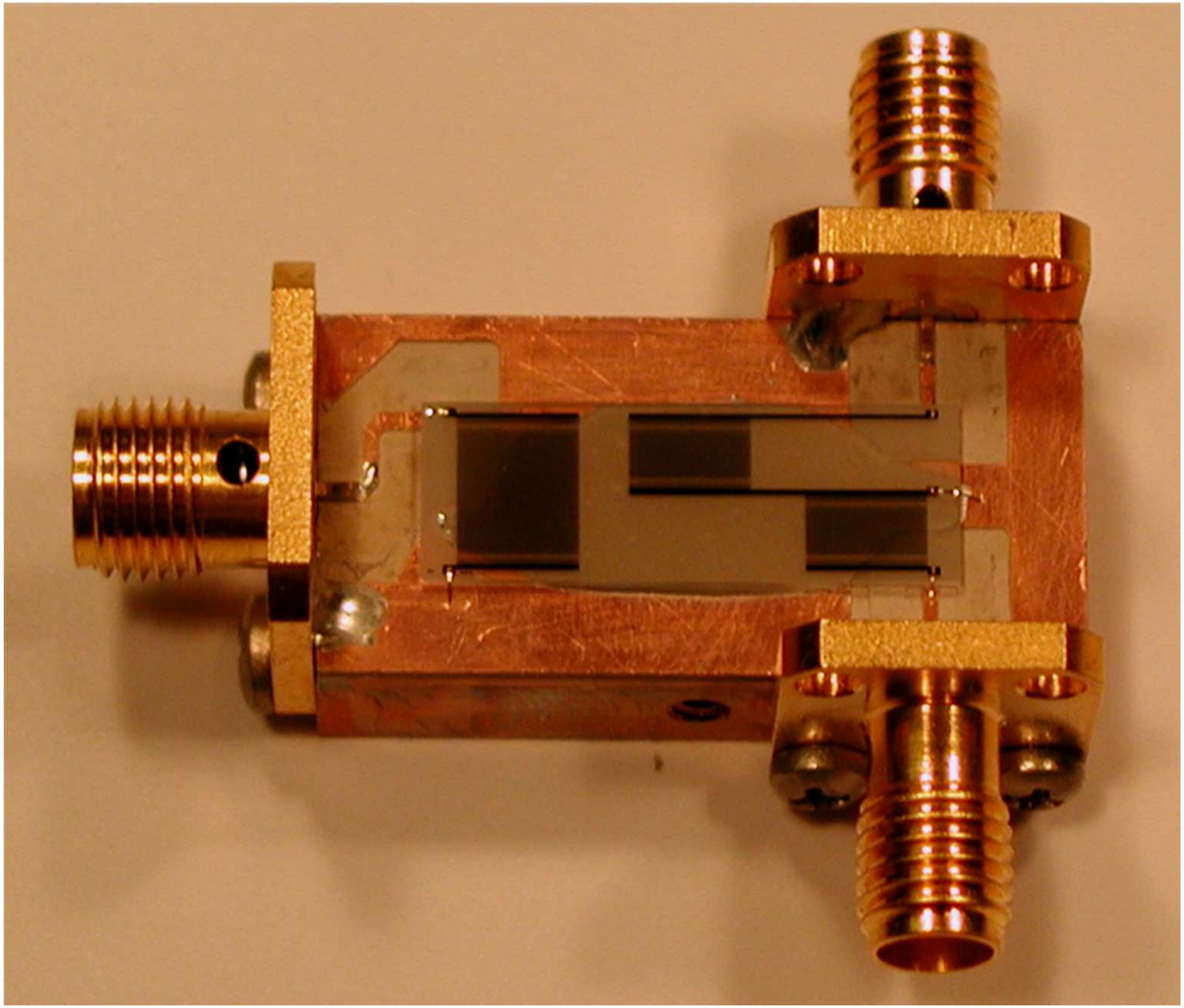
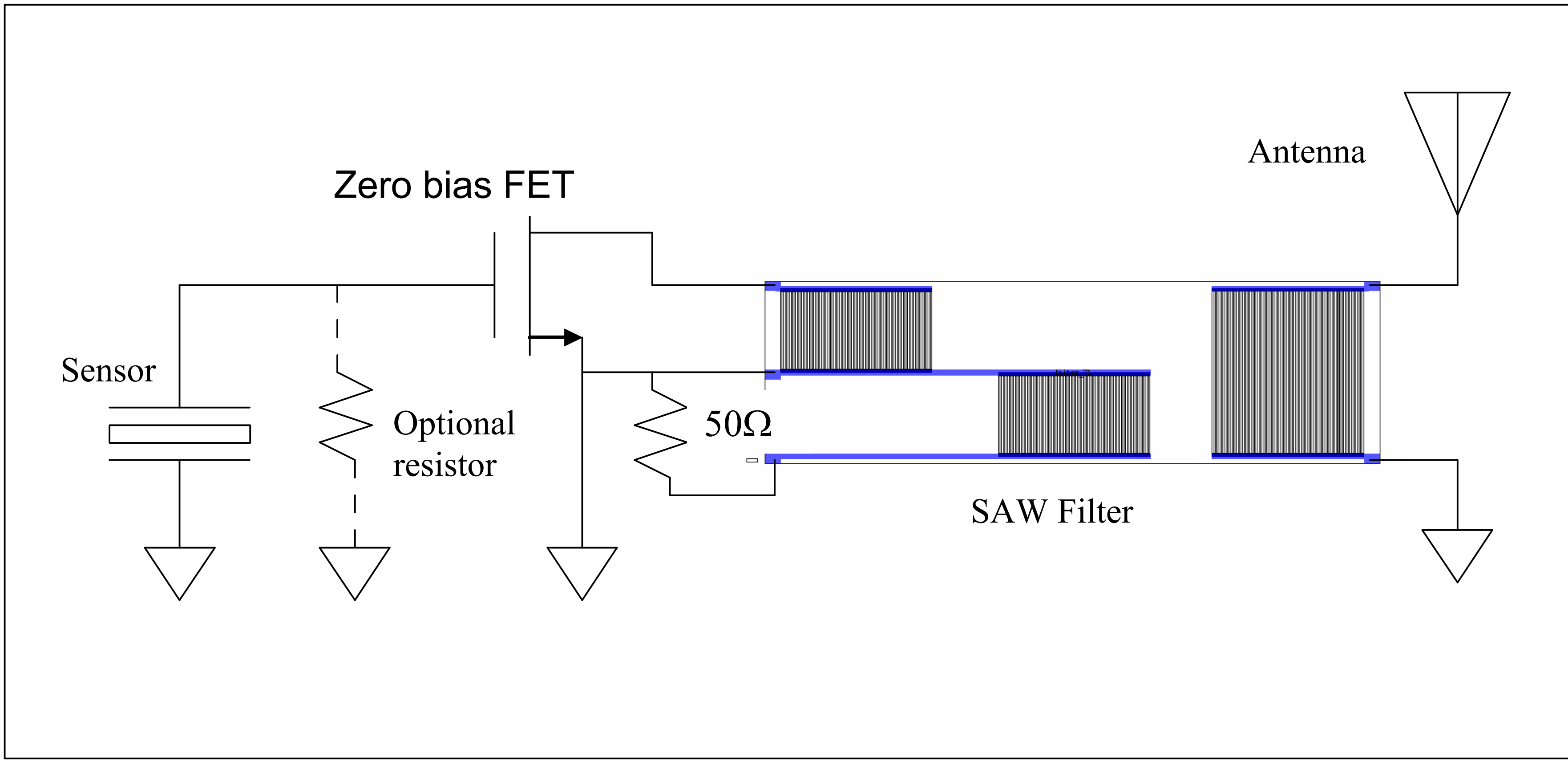
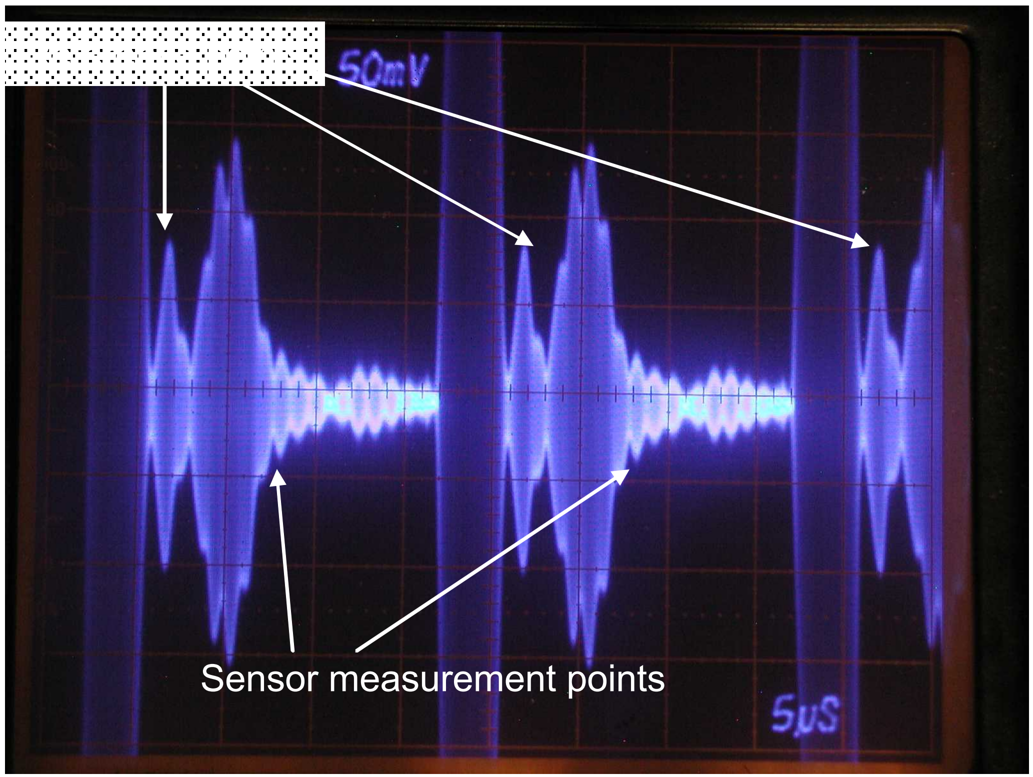


High Impedance Sensor



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.

Comparison with other passive RFID Technologies

- Silicon chip at 915 MHz
- Small, cheap, Info on side lobes ~90dB down
- Traditional SAWs
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- Acoustic/magnetic
- Very short range, yes-no ID