Tracking Technologies for Agri-Food

Marc Cohen

The Institute for Systems Research

UMD, College Park MD

Devastating Losses & Economic Cost

2006 E. coli   **2008 salmonella**   **2008/9 salmonella**

+ $6.9 billion in medical costs, lost productivity and premature deaths*
+ What's next?
+ How to mitigate the risk?

* USDA ERS report "Foodborne illnesses account for about 1 of every 100 U.S. hospitalizations and 1 of every 500 U.S. deaths"

Farm to Fork: What <u>should</u> technology do?

- PulseNet – *"passive"*
- FoodNet – *"proactive"*

} latency

- Automate
  - diagnostics/testing
  - locating/tracking
  - reporting/alerting
  - database updates
  - prognostics

2006 E. coli in spinach

- <u>Sept 14:</u> FDA warning - bags of fresh spinach
- <u>Sept 17:</u> FDA warning upgraded – fresh spinach & fresh-spinach containing products
- <u>Sept 18:</u> 111 people sick, one infant dies
- <u>Sept 20:</u> CDC announces genetic fingerprint, E. coli 0157
- <u>Sept 29:</u> FDA warning downgraded to specific brands of spinach

Agri-food Complex Lifecycle

Technology Overview

- Machine-Readable Codes
  - Barcodes & Sensor-Imbedded Barcodes
- Radio Frequency Identification (RFID) tags
  - Passive, Battery Assisted Passive & Active
  - Surface Acoustic Wave Tags (SAW)
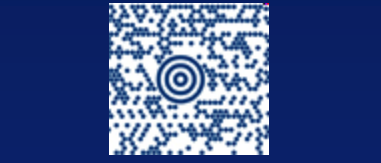- Real-Time Location Systems (RTLS)

Agri-food Lifecycle Monitoring

New Barcode Technologies

Machine-Readable Codes

Barcodes – simple, universal & low cost (½ cent)

|				
(UPC-A barcode: 0 21000 75896 8)	UPC-A	Numbers only: 11 + check digit	4 bits/symbol * 11 + 1 = 45 bits	Retail product marking in USA and Canada
(EAN-13 barcode: 9 780978 945619)	EAN-13	Numbers only: 13 + check digit	4 bits/symbol * 13 + 1 = 53 bits	Retail products worldwide
(Code 39 barcode: ABC123)	Code 39, LOGMARS	A-Z, 0-9; Space – . $ / + %. Extendable	6 bits/symbol * no. symbols (N) = 64 * N	Widely used. US Military. HIBC pharma
(Maxicode symbol)	Maxicode	All ASCII characters	7 bits/symbol * 93 symbols = 11904 bits	Developed by UPS. Includes error correction.
(PDF-417 symbol)	PDF-417	All ASCII characters. Extendable	7 bits/symbol * N = 128 * N bits	Widely used. US Military. Driver's licenses

Sensor-Imbedded Barcodes

Advantages:

- measure environmental factors
- record safe handling
- report product safety
- error-free conveyance to databases
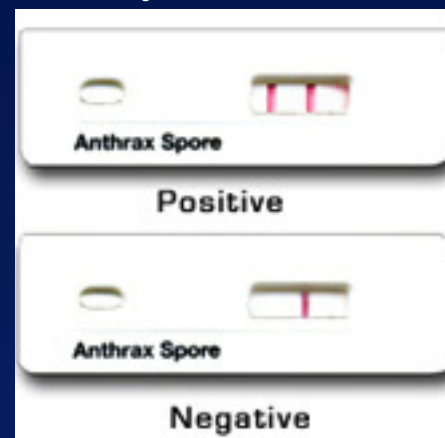- and more ….

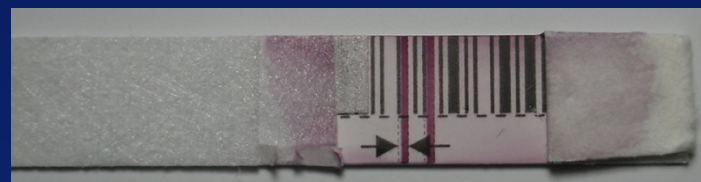Example:
Thermochromic Barcode
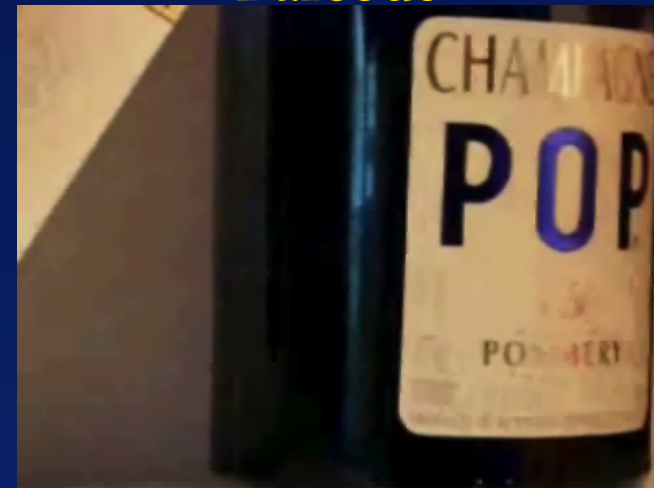
source: www.pop-technology.com

Assay-Imbedded Barcode

Traditional lateral flow assays
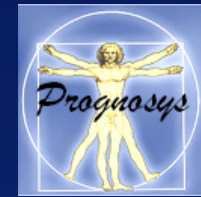

Assays Imbedded into Barcode Modules

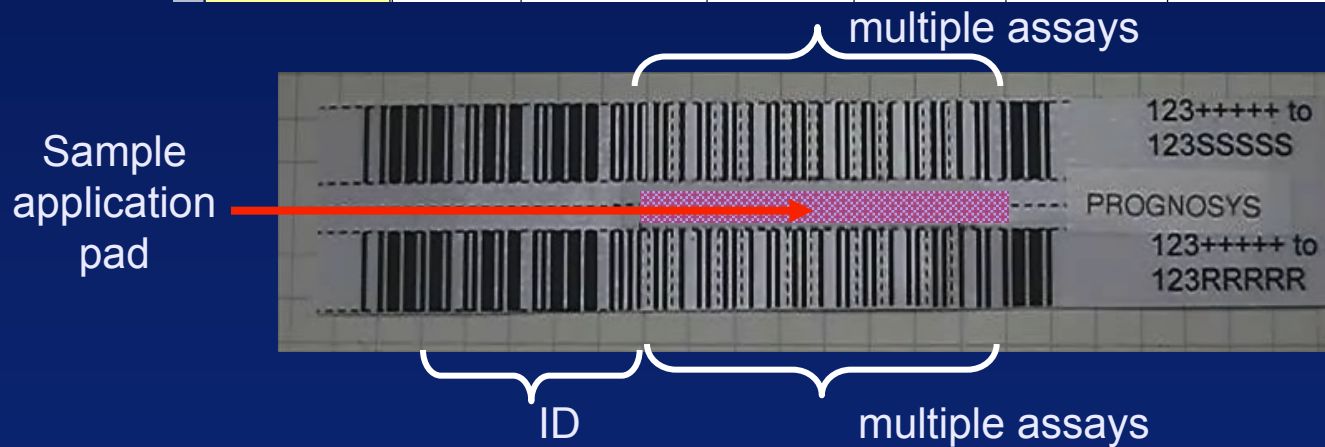**Can be read using a simple barcode reader**

Multiplexed Assay Array Imbedded Barcodes

Multiplexed Assay Array Portal

Barcode Reading	ID	Location	Date	Time	Test Types	Test Results
123SSSSS	123	Columbia, MD	5/4/09	12:59 PM	A,B,C,D,E	POS,POS,POS,POS,POS
123RRRRR	123	Columbia, MD	5/4/09	12:59 PM	F,G,H,I,J	POS,POS,POS,POS,POS

multiple assays

Sample application pad

123+++++ to
123SSSSS

PROGNOSYS
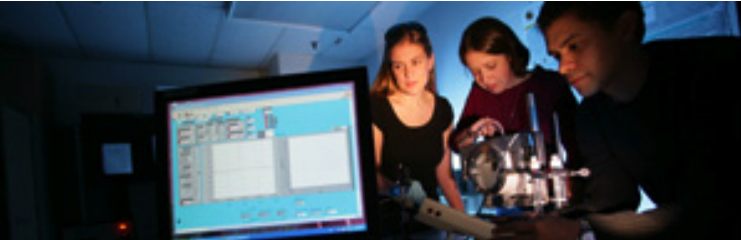
123+++++ to
123RRRRR
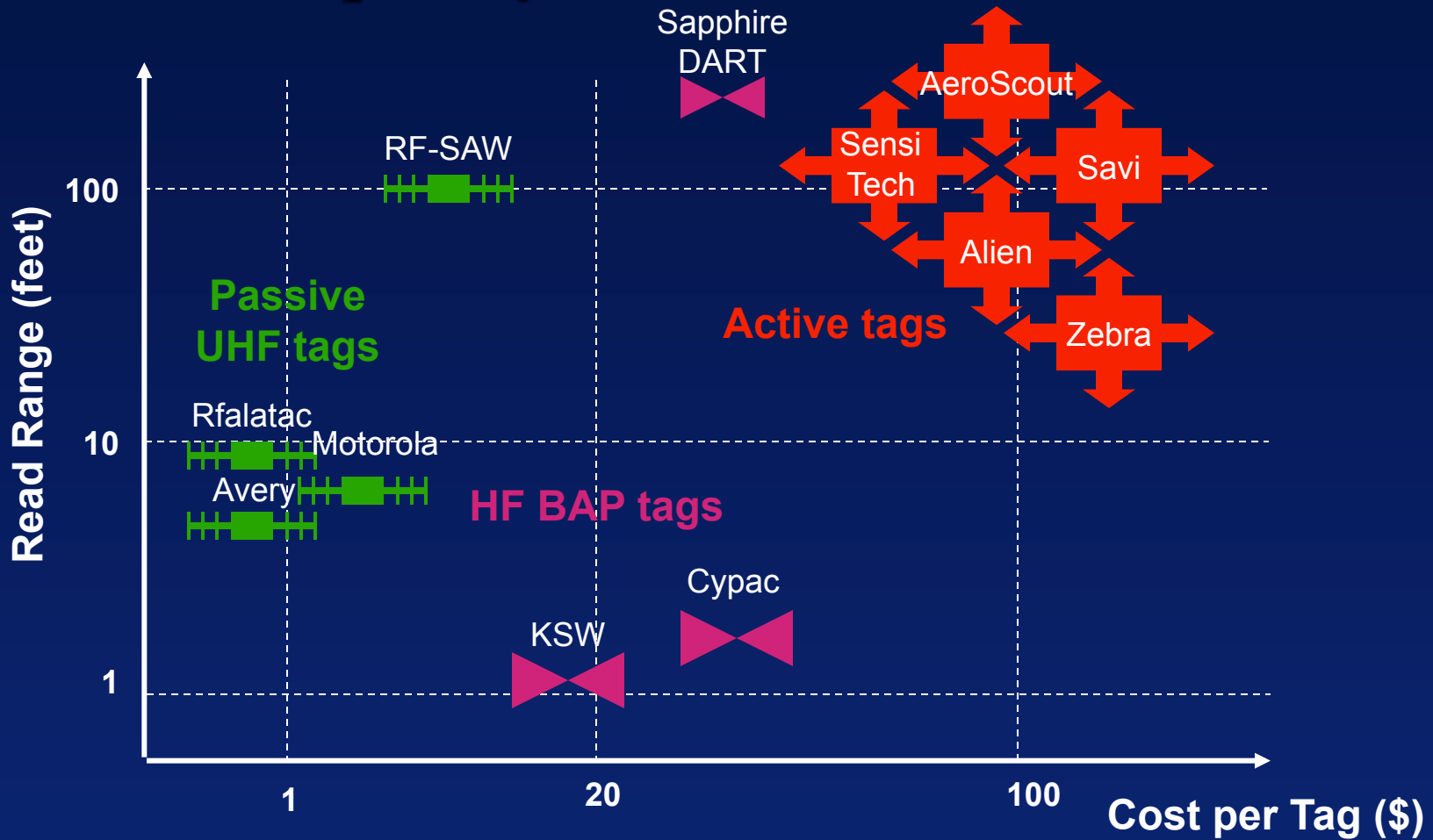
ID   multiple assays

Agri-food Lifecycle Monitoring

Passive RFID

Radio Frequency Identification: The Landscape
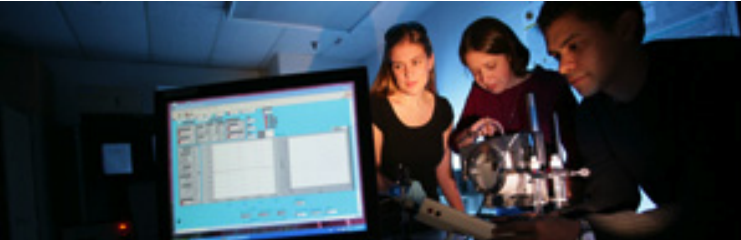
RFID

Injectable
LifeChip LF tag

Alien
"Squiggle"
passive tag
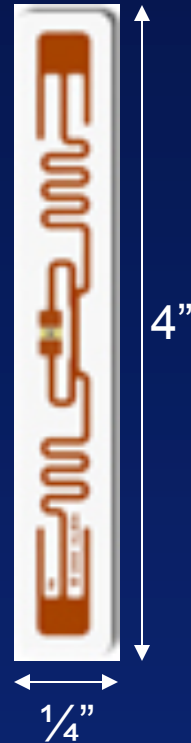
KSW Microtec
HF passive tag
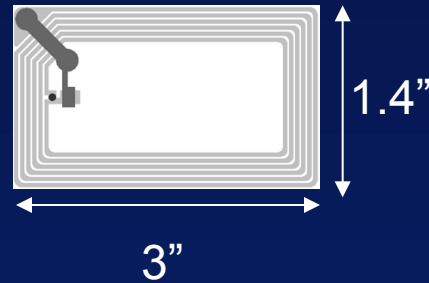
Savi active tag,
LF and UHF

1.4"

3"

1.2" diameter
LF e.Tag by
Destron Fearing

4"

¼"

Intelleflex
BAP tags

Passive RFID

Source: www.enigmatic-consulting.com

	Passive
cost	~10 cents
range	< 20 feet
memory	< 32 Kbytes
RTLS	complex
function	UID + manifest

RFID Frequency Bands

Band Frequency, Wavelength and Common Usage

Band	Unlicensed Frequency	Wavelength	Common Use
LF	125 – 134.2 KHz	7872 ft	Animal tagging and keyless entry
HF	13.56 MHz	72.6 ft	
UHF	850-950 MHz	1 ft	Smart cards, logistics, item management
ISM	2.4 GHz	0.4 ft	Item management

Examples of Dual Use Passive UHF Tags

Impinj Satellite™
.70 in. x 1.26 in/18mm x 32mm (inlay dimension)

Alien Mini-Squiggle™
.39 in. x 1.06 in./10mm x 27mm (inlay dimension)
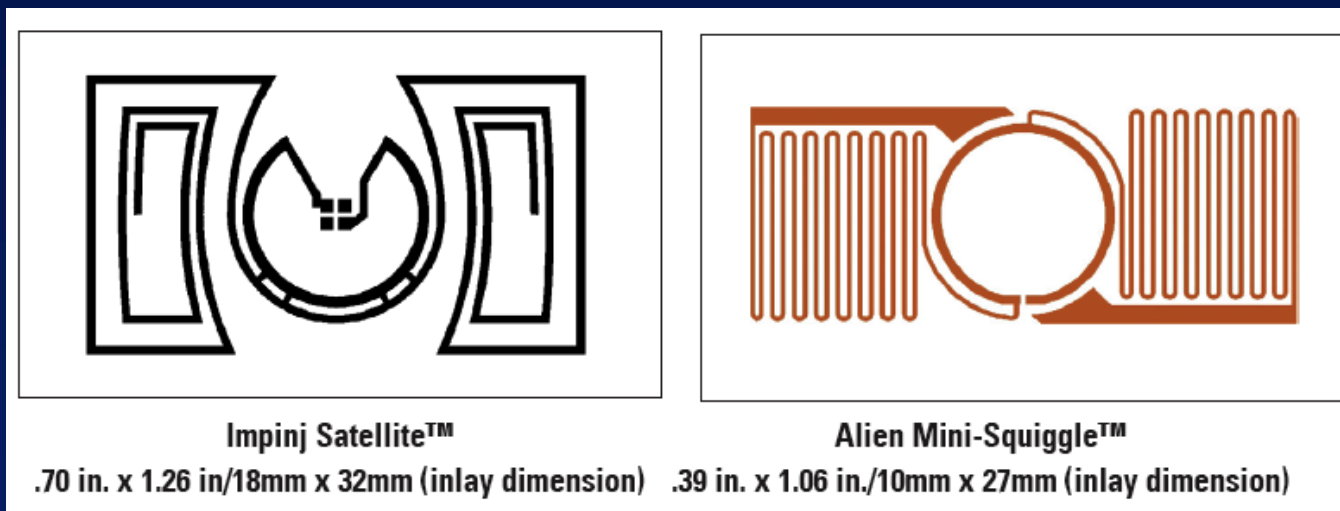
Tags with antenna designs that exploit both magnetic and electromagnetic field coupling, enabling both near and far field reads in a single tag

RFID EPC Classes

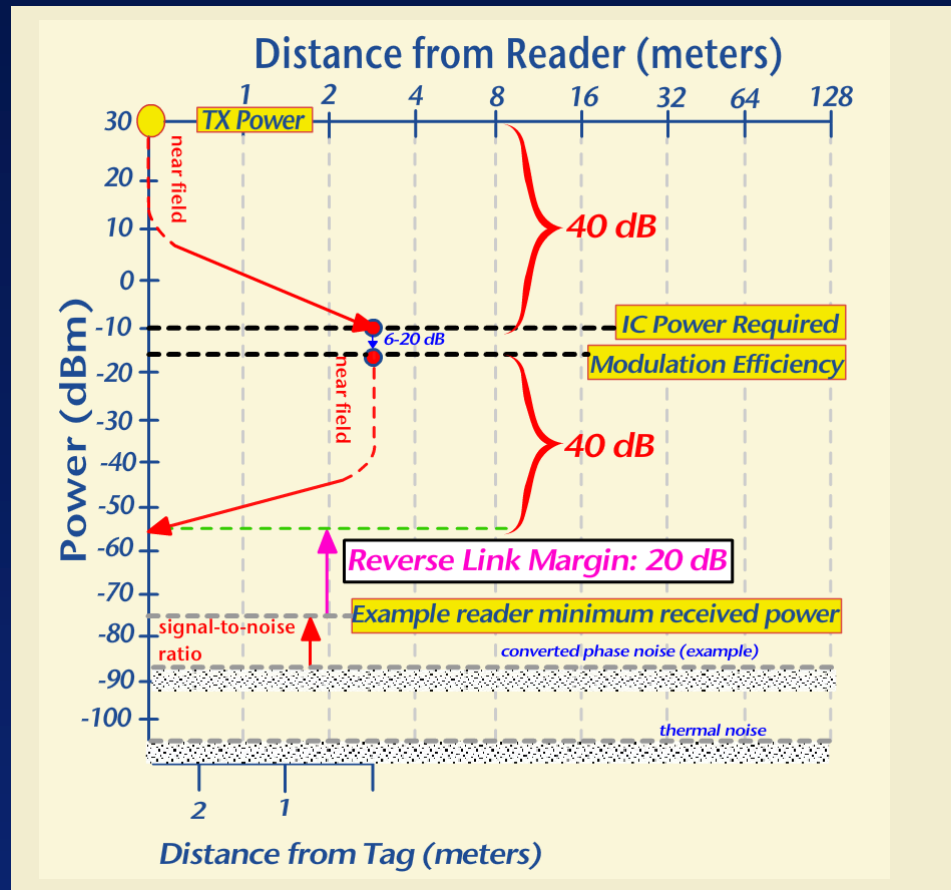| EPC Class	Definition	Programming
0	Passive, WORM	manufacturer
1	Passive, WORM	consumer
2	Passive, WMRM	reprogrammable
3	Semi-Passive, WMRM	
4	Active, WMRM	
5	Readers	

Ideal Passive RFID Read Range

✛ Pr = 1 watt, Maximum allowable power transmitted by reader

✛ Gr = 6 dBi, Reader's equivalent isotropic antenna gain

✛ Gt = 1 dBi, Tag's equivalent isotropic antenna gain

✛ λ = 0.32 m, Wavelength for 915 MHz

$$P_t = P_r \cdot G_r \cdot G_t \cdot \left(\frac{\lambda}{4\pi d} \right)^2 = 100 \mu W, \text{ Minimum power received by tag}$$

$$\therefore d_{max} = \frac{\lambda}{4\pi} \sqrt{\frac{P_r \cdot G_r \cdot G_t}{P_t}} = 5m \ (16.5 \text{ ft}), \text{ Maximum tag to reader distance}$$

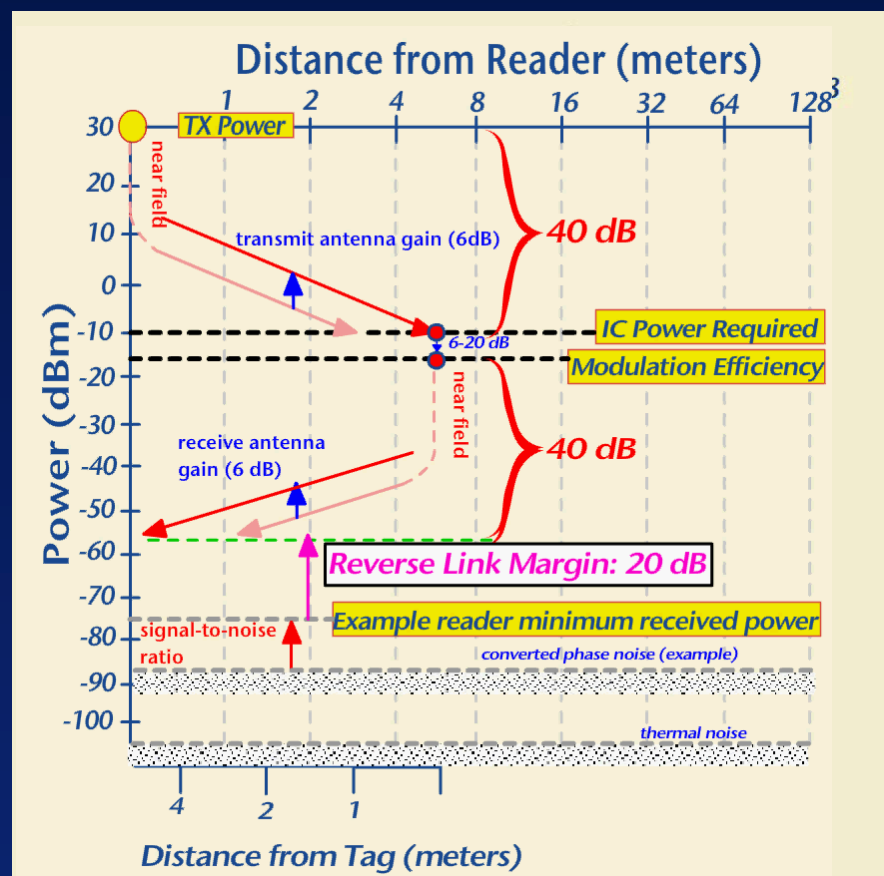# Passive RFID Read-Range

Marc Cohen

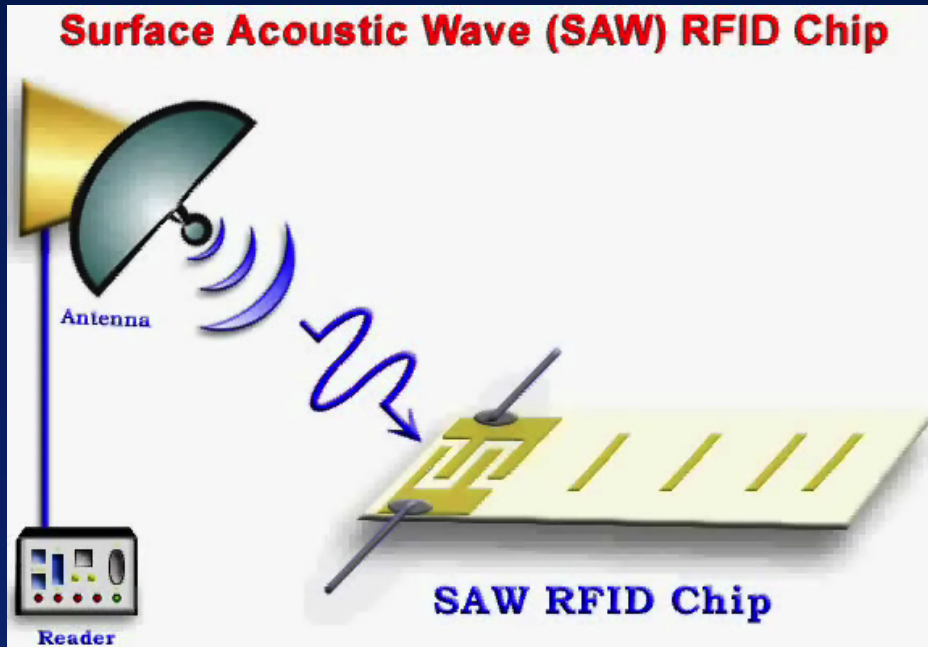Source: www.enigmatic-consulting.com

Antenna Effects

Surface Acoustic Wave RFID Tags

totally passive technology (2.4 GHz)

source: www.rfsaw.com

Features

Superior read range
(up to 30 meters unobstructed)
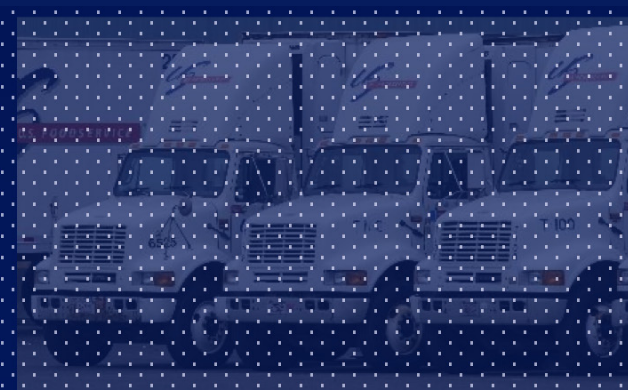
Tag location

Temperature measurements

Read–on–Metal/Liquid containers

Gamma Sterilization (>10 M RAD)

Agri-food Lifecycle Monitoring

▶◀ semi-passive RFID

Semi-Passive RFID

Source: www.enigmatic-consulting.com

|	Semi-Passive
cost	~$40
range	< 300 feet
memory	4 – 128 Kbyte
RTLS	yes
function	UID, manifest, sensing

Semi-Passive RFID Tags

- "On-board" battery (battery-assisted passive BAP)
  - Boosts read range to ~ 300 ft
  - Reads around challenging materials
  - Captures and stores (read/write) sensor readings
- Does not transmit data autonomously
  - Only when "pinged" by reader
- Captures and stores data autonomously
  - User defined pre-programmed time intervals
- Facilitates Real Time Location

Semi-Passive Time-Temperature Tags

source: www.infratab.com
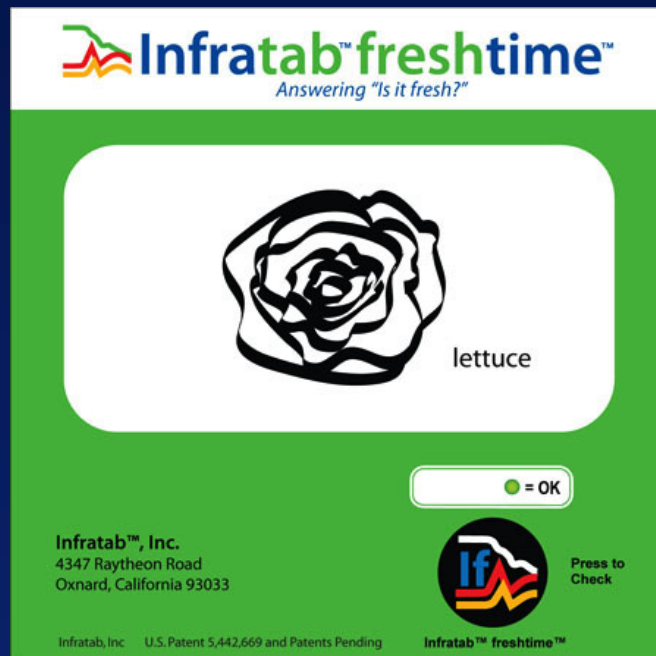
Specifications

Operating range: -25°C TO +70°C

Sensor accuracy: ± 0.5°C: -20°C to +50°C

Sensor resolution: 0.1°

Shelf life calculation: linear, exponential, other

Tag life: 1 day to 3+ years
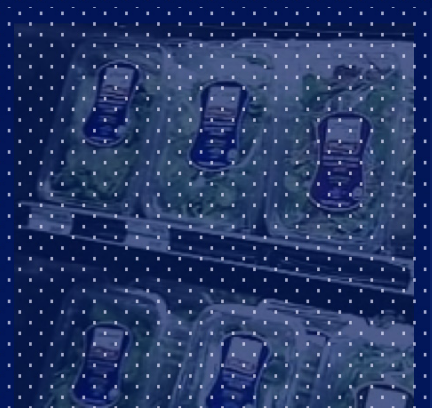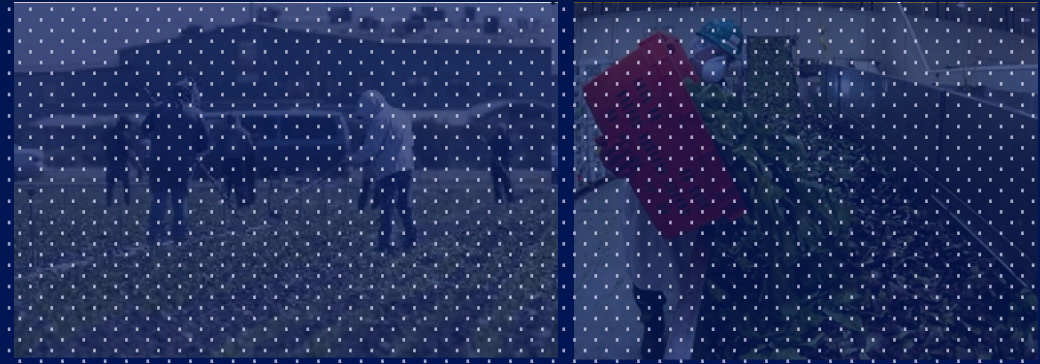
Alerts: shelf life, thresholds, elapsed time

History: start to either tag-stop or to "0" shelf life

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active RFID

Active RFID
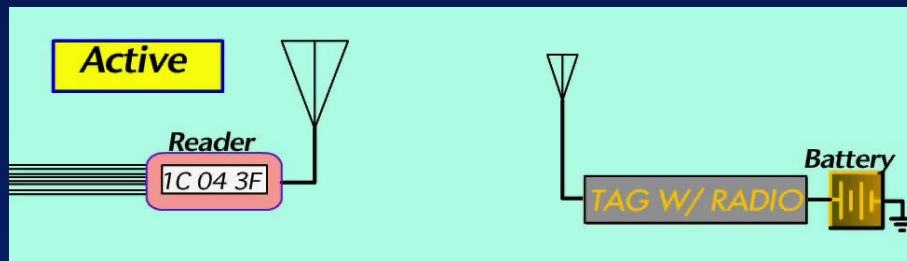
Source: www.enigmatic-consulting.com

	Active
cost	> $100
range	< 300 feet
memory	32 - 128 Kbyte
RTLS	yes
function	UID, manifest, sensing, RTLS

Active RFID

- Uses an on-board battery to autonomously:
    - Transmit ID and data to reader
    - Collect and store data from sensors
    - Report & store real-time location data
    - Boost read distance
    - Improve readability under difficult conditions
    - Alert under user-defined conditions

Agri-food Lifecycle Monitoring

→ Real-Time Location

Real-Time Location Systems

- Wireless Mesh Networks (WiFi, Bluetooth, Zigbee) **local**
  - Inertial, (Gyros, Accelerometers), Pressure, Signal Strength, Maps
  - Active RFID
  - Indoor – outdoor – **local**
- Global System for Mobile Comm. (GSM), General Packet Radio Service (GPRS)
  - Cell Phone networks
  - Outdoor – indoor – **long range**
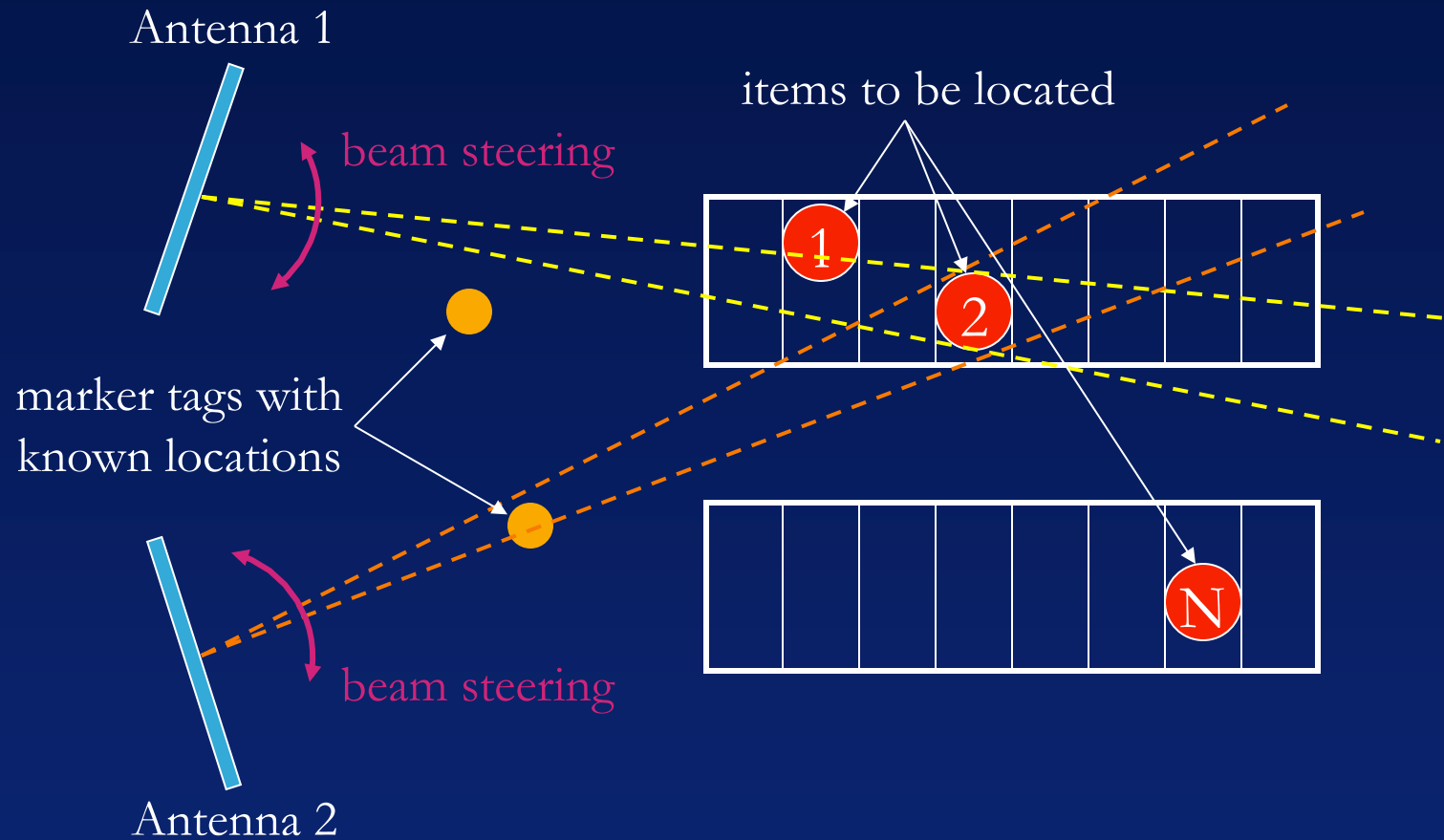- GPS, Satcomm, Inmarsat, …
  - Outdoor – **global range** **global**

RTLS: Common Methods

- Angle of Arrival (AoA)
- Line-of sight (LoS)
- Time of Arrival (TOA)
- Time Difference of Arrival (TDoA)
- Received Channel Power Indicator (RCPI)
- Received Signal Strength Indication (RSSI)
- Time of Flight (ToF)

RFID Real-Time Location

Antenna 1

beam steering

items to be located

marker tags with
known locations

1

2

N

beam steering

Antenna 2

TRX: Sentinel Tracking System

- Small sensor and data radio worn by each firefighter
- Monitors status, movement, location, and communicates in real time
- Tracks indoors and outdoors with display on a (networked) laptop
- Requires no pre-installed infrastructure
- Data replay for training purposes
- Mesh network formed by data radios

SEAMLESS outdoor to indoor

Outside

Inside
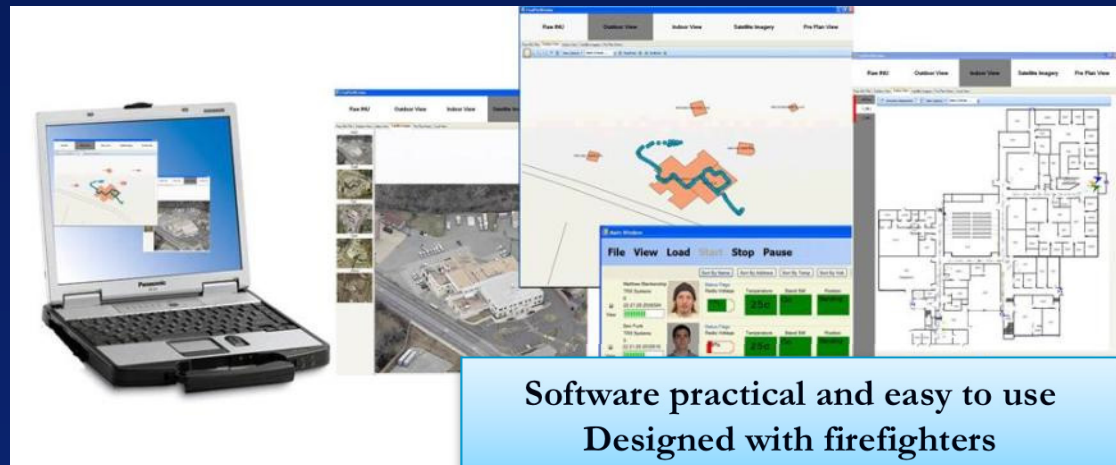
**Software practical and easy to use
Designed with firefighters**

Farm to Fork: What <u>can</u> technology do?

- In-field diagnostics
  - Multiplexed Assay Array Imbedded Barcodes
  - IT infrastructure
- Autonomous monitoring
  - Environment/Climate
  - Feed/Chemicals
  - Livestock

- Tracking and Tracing
  - Passive, BAP & Active RFID
  - RTLS inside and outside
- Secure Web Portals
  - Databases
  - Prognostics