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# Performance of EPC Gen 2 in the Real World

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Research Director

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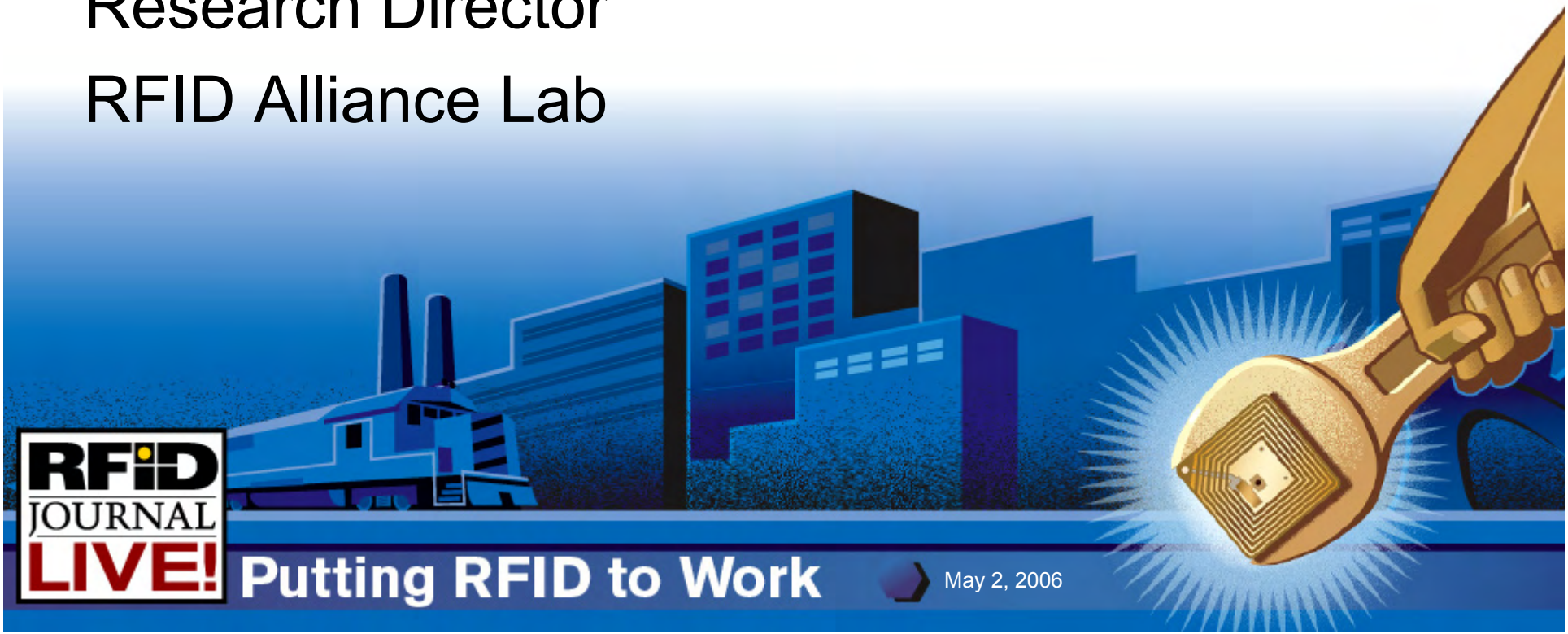

# RFID Alliance Lab: Deploying Gen 2

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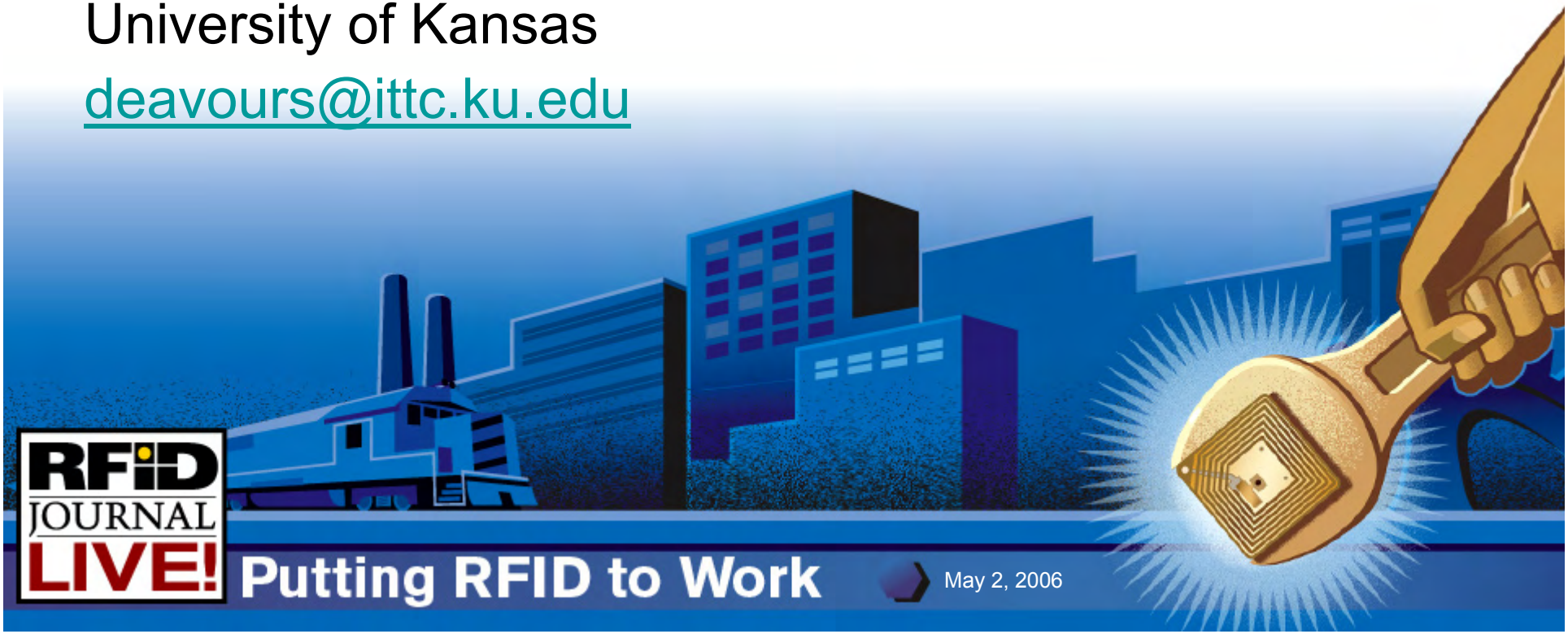


# Who We Are

- Evaluate RFID products in a *scientific* way
- Provide useful, timely, credible, and unbiased data to end users of RFID products
- Constituents
  - **University of Kansas / ITTC**: Primary research contributor
  - **RFID Journal**: Initial funding, distributor, advertisement
  - **Rush Tracking Systems**: Initiator, industry lesion
- Business model
  - Sell reports (~$1,000 / report) to finance future reports
  - Sponsorships
  - Research projects
- ITTC/KU Applied Research Labs
- Helping companies solve hard problems
  - Tagging small electronics devices
  - Seknion: direction of travel through portal
  - Tagging metal assets
- Adamas: high performance low profile metal tag
- Basic researchW
  - RFID privacy using CDMA
- We would like to talk with you about your hard problems

# Outline

- What factors affect RFID tag performance?
- Are all readers basically the same?

# Tagging Products: A Brief How-To

- Gen 2 tag performance depends on the antenna and its environment

1. Aperture
   - How “big” is the antenna?
2. Antenna Efficiency
   - How well is it living up to its potential?
3. Dielectric Loss
   - How much power is being lost to the environment?
4. Power Transfer
   - Is the power delivered to the RFID chip?
5. Chip efficiency
   - How little power needs to get to the RFID chip?

# 1. Aperture Size Matters

- 6.1” tag
  - 4× power of 3.75” tag
  - ≈ 2× distance
  - Does not fit on 6” label
- 3.75” tag
  - ≈ ½ distance of 6.1” tag
  - ≈10× power of item tag
  - Convenient form factor
- 1.2” tag
  - Short ~5 ft read distance
  - Highly orientation-dependent

- 6.1” Symbol tag

- 3.75” Raflatec tag

- 1.2” Raflatec item tag

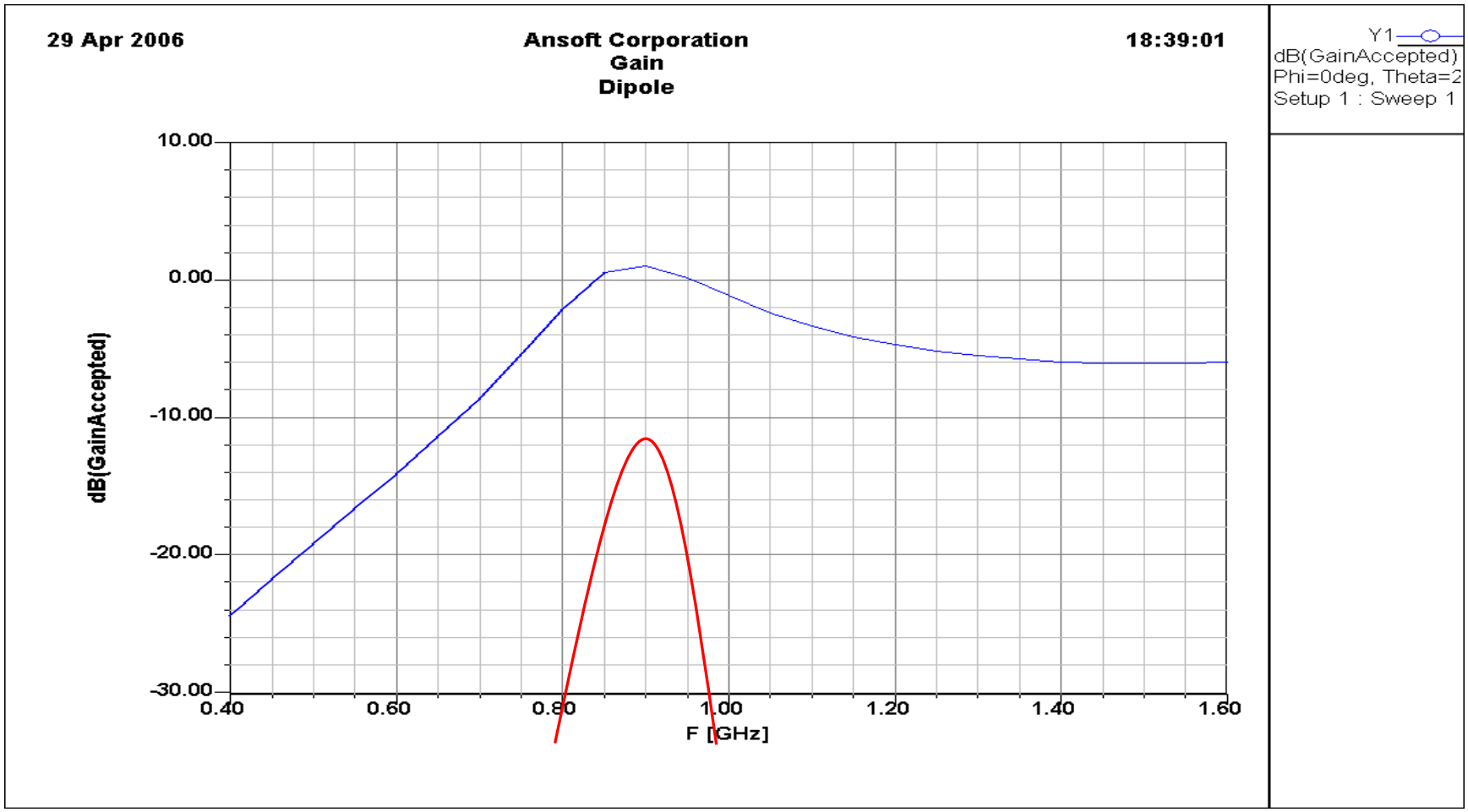
# 2. Antenna Efficiency Tuning Matters

- A tuning fork “resonates” well at a one frequency (plus harmonics)
- “Serpentine” dipoles meander so electrical length longer than physical length
- The speed (velocity) of light (or RF) is not a constant!
- Near-by materials affect tuning

| Material | Dielectric Constant | Resonant Frequency (MHz) |
|---|---|---|
| Air | 1.0 | 915 |
| Plastic (Polyethylene) | 2.25 | 768 |
| Plastic (PVC) | 3.4 | 676 |
| Glass | 5.5 | 570 |
| Water | 80 | 180 |

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

# Metal Increases “Q,” Decreases Bandwidth



# 3. Dielectric Loss
# Materials Can Absorb Power

- In optics: transparent, reflective, flat black
- RF fields develop around tag antenna
- Fields passing through opaque materials lose power to those materials
  - E.g., aerodynamic drag, or boat anchor
- The closer to the antenna, the worse the affects
- Water worst offender; liquids tend to be bad
- Not affect with metal

# 4. Power Transfer Between Antenna and Chip

- Sun reflecting off the water
  - Some goes into the water
  - Some gets reflected
- Power transfer between antenna and chip is critical

$$S_{11} = \frac{Z_L - Z_S}{Z_S + Z_L}$$

Swift Current Lake
Glacier National Park

# More on Power Transfer Efficiency

Power transfer efficiency is affected by

- Frequency, and therefore dielectric constant of close materials
  - Antenna impedance peaks at resonance
  - Phase positive below, negative above resonance
- Dielectric loss of close materials
  - Higher loss tends to decrease $Z_S$ overall
- Metal close to tag
  - Metal can *drastically* increase $Z_S$ especially at resonance

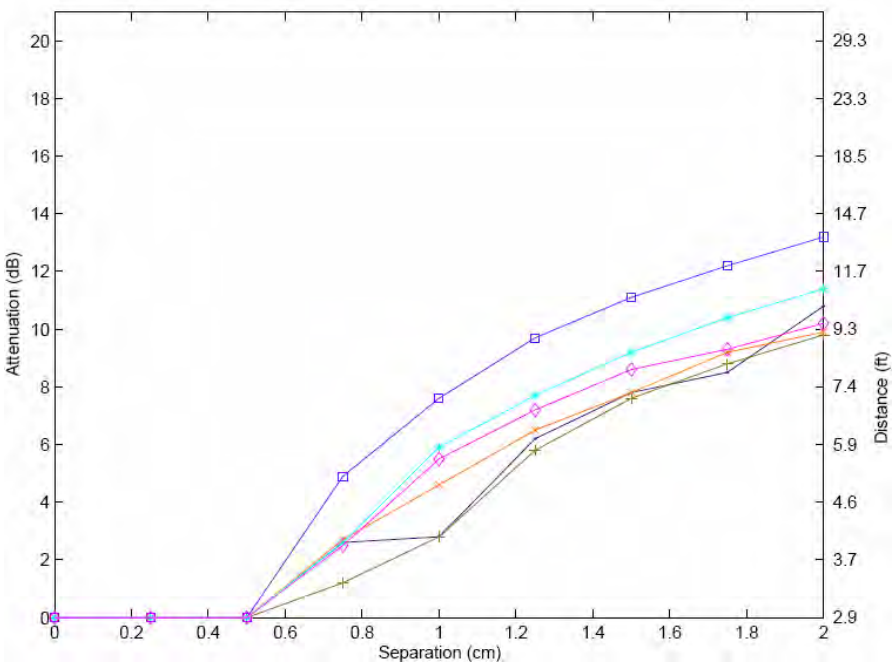
# 5. Chip Efficiency

- Chip performance depends on
  - Power consumed
  - Power reflected
- In the end, you get what you can get
- Impinj currently dominates the market
- **Many** new market entries this year and beyond

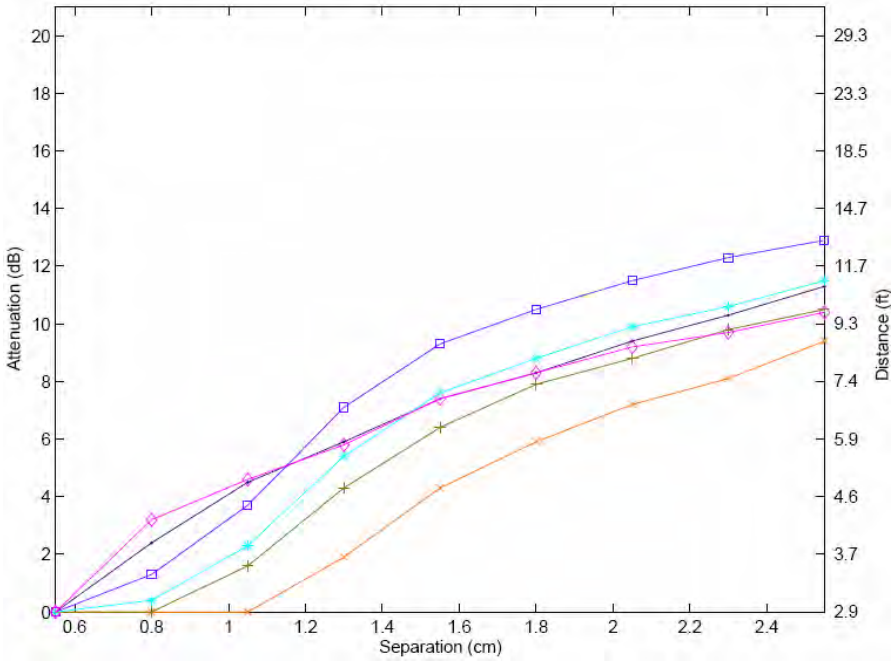
# Materials Impact Tag Performance: Approximate

| | Plastics | Ceramic | Metal | Water |
|---|---|---|---|---|
| Aperture | | | | |
| Antenna Efficiency | ◆ | ◆ ◆ | | ◆ ◆ ◆ ◆ |
| Dielectric Loss | ◆ | ◆ ◆ | | ◆ ◆ ◆ ◆ |
| Power Transfer | ◆ | ◆ ◆ | ◆ ◆ ◆ ◆ | ◆ ◆ ◆ |
| Chip Efficiency | | | | |

# Experimental Data:
# Tag Performance vs. Separation

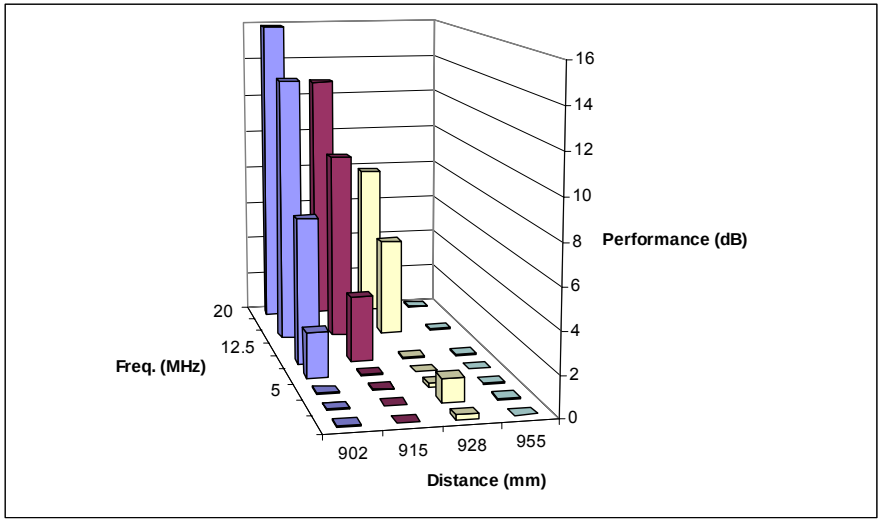



Separation from Metal

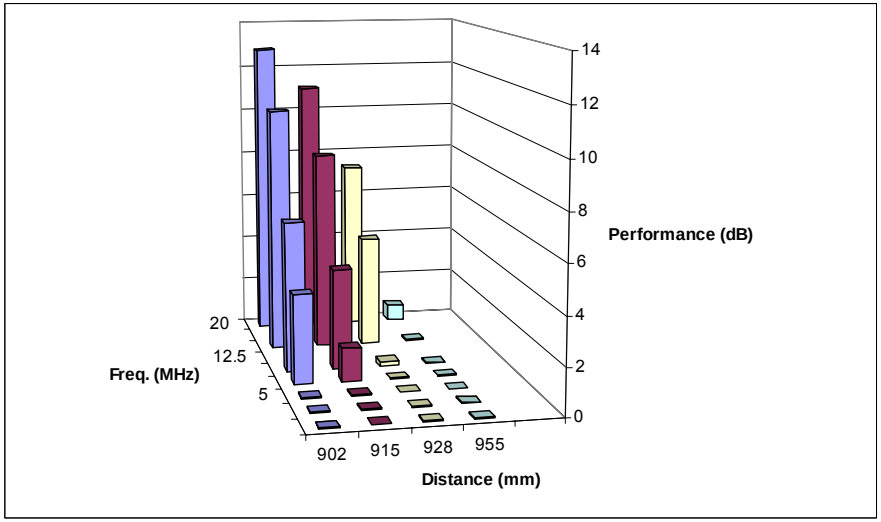



Separation from Water

# Experimental Data:
# Tag Performance vs. Separation




Separation from Metal




Separation from Water

# What To Do?

- Stay away from metal and water
  - Place antenna in natural air gaps
  - Create air gaps
- Use spacers
  - Foam best:  mostly air
  - Plastic poor
    - Makes narrowband
    - Changes resonant frequency
- Use specialty tags

# Metal Tag Market Solutions

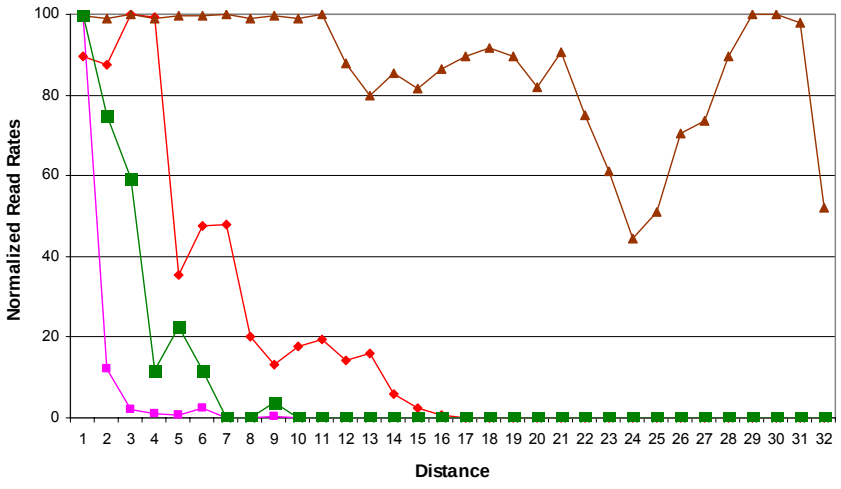
- Sticks
  - Dipoles with high dielectric material
  - Thick dipoles
- Stand-offs
  - Foam – absorbs moisture
  - Plastic – changes resonance
- Isolators
  - Change resonant frequency to ≈300 MHz
  - Add enough loss to counter affects of metal
  - Thin:  some around 0.05” or 1.2 mm
  - Modest performance

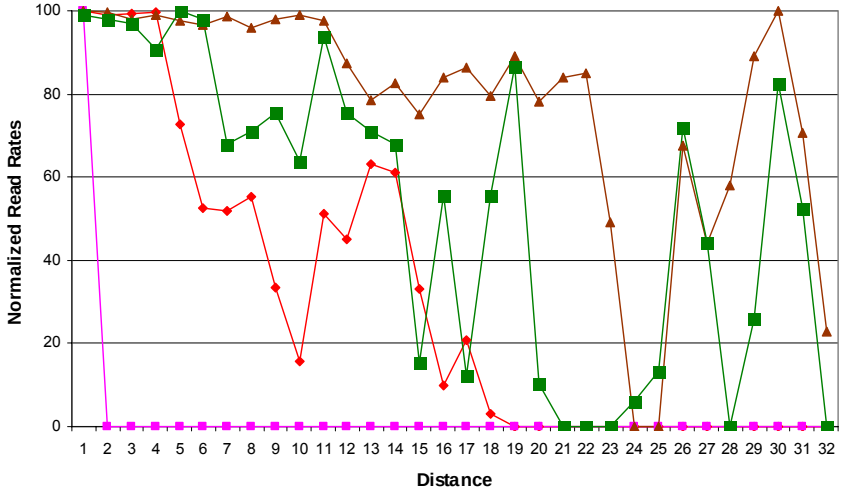
# Adamas-I Tag

- Thin microstrip “patch” antenna
  - 0.06” or 1.6mm
- Dual balanced feed
- Inexpensive materials
  - Polyethylene, Polypro
- Completely planar design
  - Via-free
- High performance
  - 30 ft+ reads on metal, water
- Bandwidth limitations being addressed
  - 26 MHz BW with > -4dBi

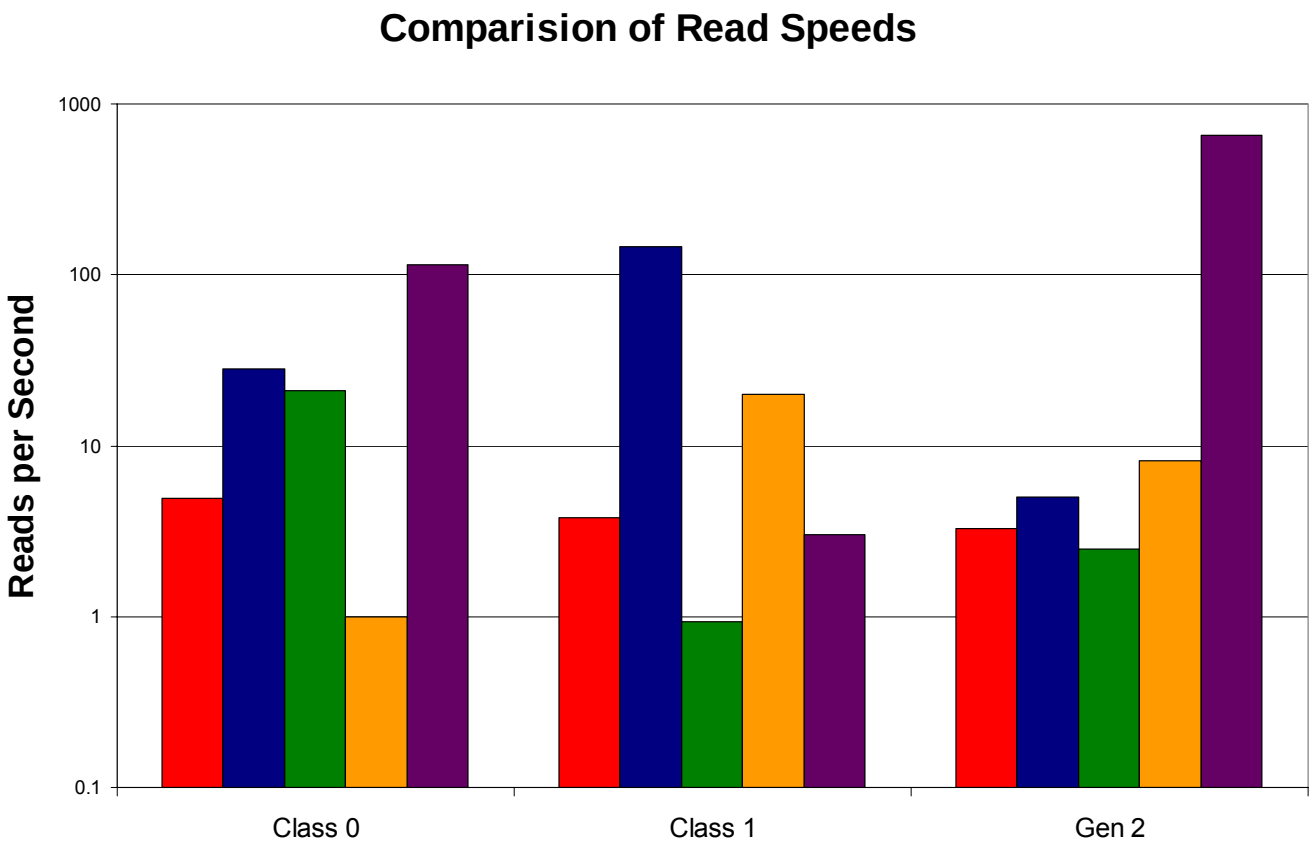
# Not All Readers are Alike

- Two Gen 2 tags
- Four Gen 2 certified interrogators
- Even different relative performance



# Speeds with Multi-Protocol Readers



# Conclusions

- For tag antennas, size matters
- Keep tags away from water, metal
  - Use a specialty tag for asset tracking

- Wide performance differences in readers
  - Read distances
  - Read speeds
  - Features