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Physics of RFID

Understanding the behavior of radio waves and how that affects RFID system performance

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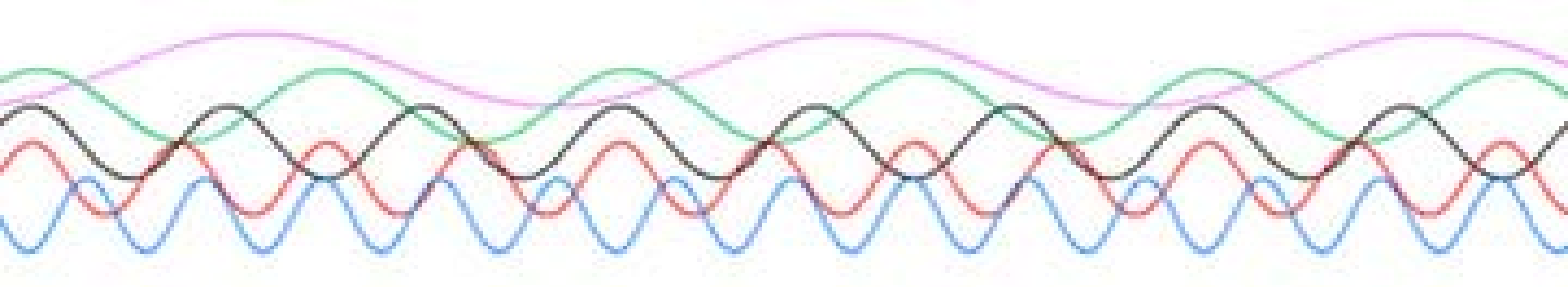
Agenda

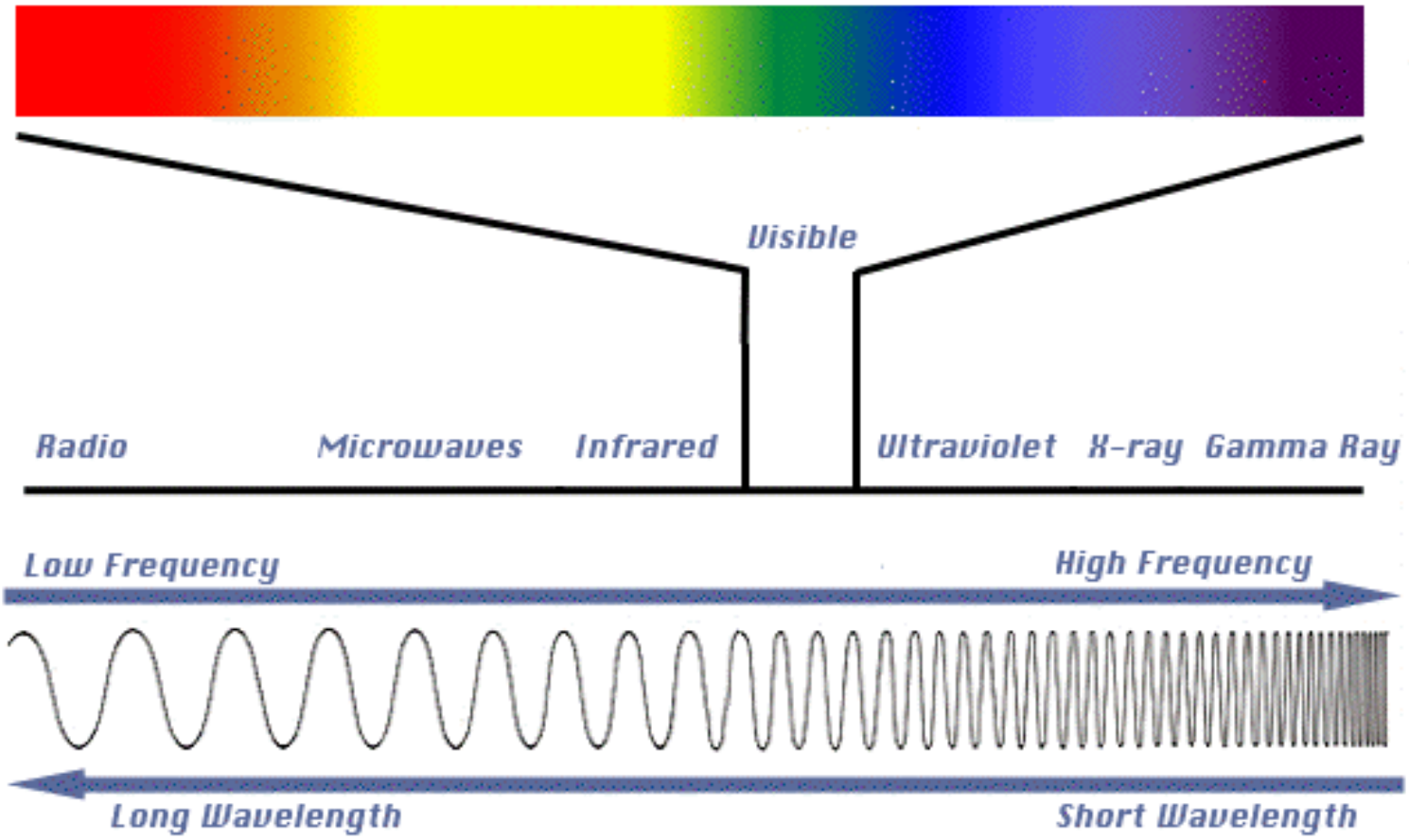
- Radio Waves
- Active vs. Passive
- Near Field vs. Far Field
- Behavior of HF Fields
- Behavior of UHF Fields
- Addressing UHF Physics Issues

Radio Waves

- What is Frequency?
  - Refers to the property of radio waves used to transmit data
  - Roughly speaking, it is the intensity of



Electromagnetic Spectrum



Radio Waves

- Frequency Allocations
  - RF waves are regulated by FCC. FCC and its associates specify the frequencies, communication means, amplitudes and uses that are permitted over the whole frequency spectrum through a spectrum licensing process

Radio Waves

- Frequency Allocations
  - Four primary frequency bands are being used for RFID applications:
    - Low Frequency (125/134KHz): Most commonly used for access control, animal tracking, asset tracking and most importantly when there is close proximity to water or non-conductive materials
    - High-Frequency (13.56 MHz): Used where medium data rate and read ranges are acceptable. It has the advantage of not being susceptible to interference from water or metals.
    - Ultra High-Frequency (850 MHz to 950 MHz): It offers the long read ranges and high reading speeds.
    - Microwave Frequency (2.4 GHz): Highest penetration in metals and lowest in water surroundings

Radio Waves

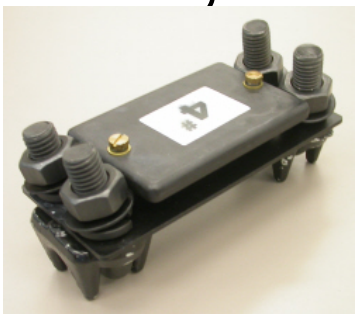
- Range & Power Levels
  - The range that can be achieved in an RFID system is determined by
    - The power available at the reader
    - The power available within the tag
    - The environmental conditions and structures
    - More important at higher frequencies than at lower frequencies

Radio Waves

Material Composition	Its Effect on RF Signal
Corrugated Cardboard	Absorption from moisture
Conductive Liquids	Absorption
Glass	Attenuation
Groups of Cans	Multiple propagation effects; reflection
Humans/Animals	Absorption; detuning; reflection
Metals	Reflection
Plastics	Detuning (dielectric effect)

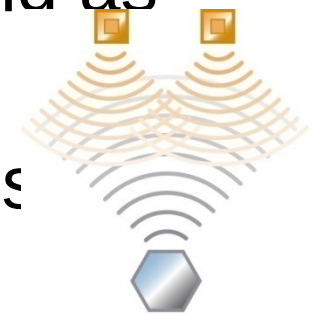
Active Tags

- Broadcast a signal
- Performance not usually an issue
  - Think of your cell phone
- With some lower-frequency systems, rain might affect performance

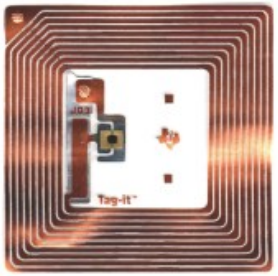


Passive Tags

- Use energy from the reader
- Radio waves from the reader are on the same frequency as waves being reflected by the tag
  - Reader emissions 1,000 times as strong as the tag reflecting back
  - Depending on environmental conditions reading tags can be difficult

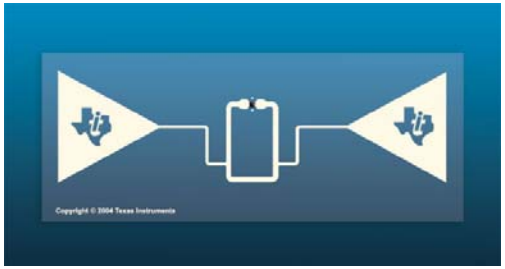


Passive Tags



HF tag

LF tags



UHF tag

UHF item tag

Reusable UHF tag

Metal mount tag

Cattle tag

Button tag

Passive Tags

- Key is to get enough energy to the tag
- Metal reflects radio waves
- Water absorbs UHF radio waves
- Other materials have varying effects on radio waves

RF Behavior

- Behavior of RF depends on Frequency
  - Low frequency is like your FM radio
    - Waves pass through walls easily
  - UHF and microwave frequencies behave more like light
    - Light bounces off objects, doesn't penetrate
    - Light travels quickly
    - Light can carry more information
      - Think fiber optic cable

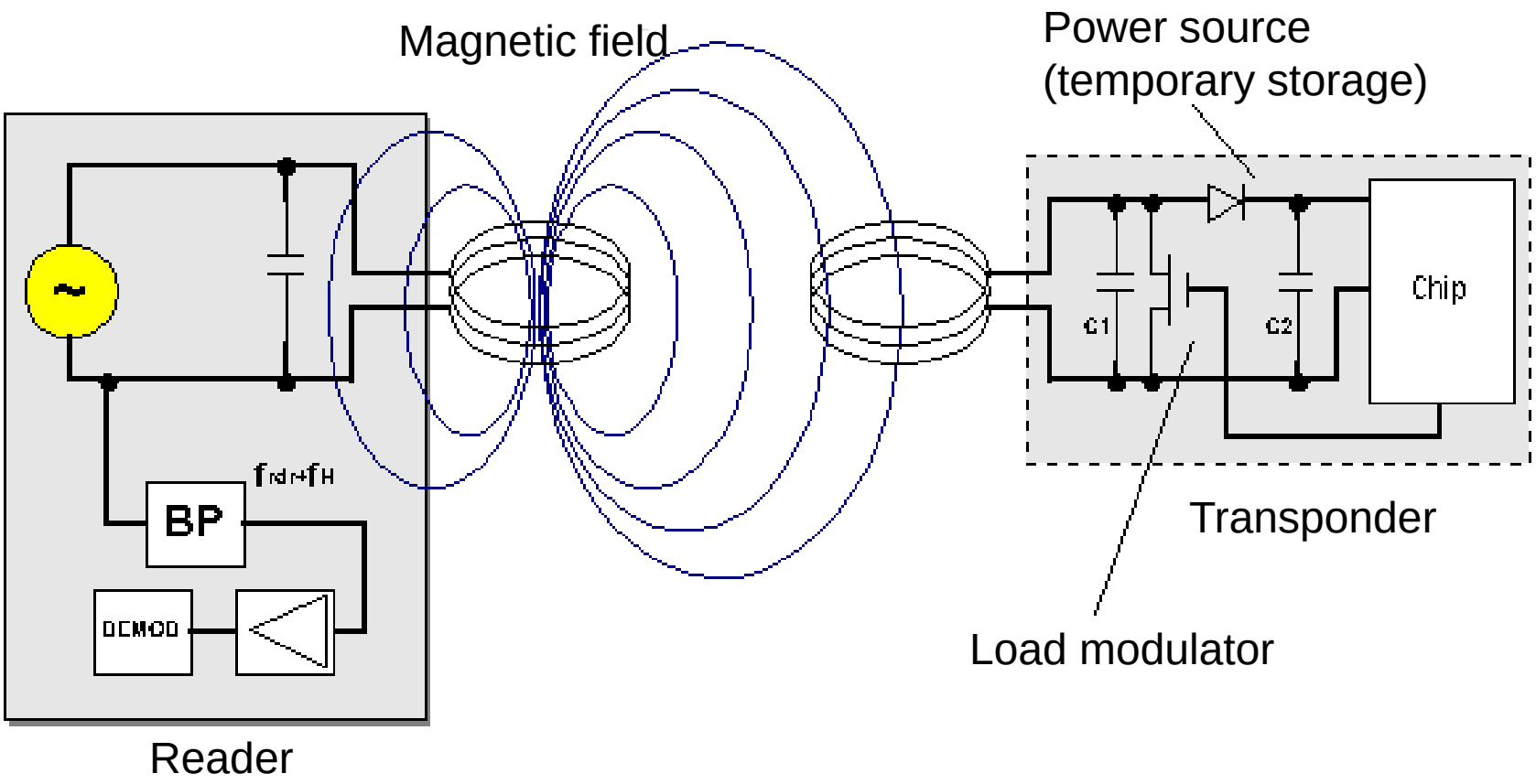
Near Field vs. Far Field

- Near field is within one wave length
- Far field is beyond one wave length
- These are very different types of communication
- Near field is magnetic
- Far field is electromagnetic

Near Field Communication

- LF and HF systems work with near-field communication
- A coil in the reader emits energy that creates a magnetic field with the coil in the tag
- The tag modulates and demodulates its antenna, changing the field
- The reader picks up changes in the field and turns them into binary data

Near Field Communication



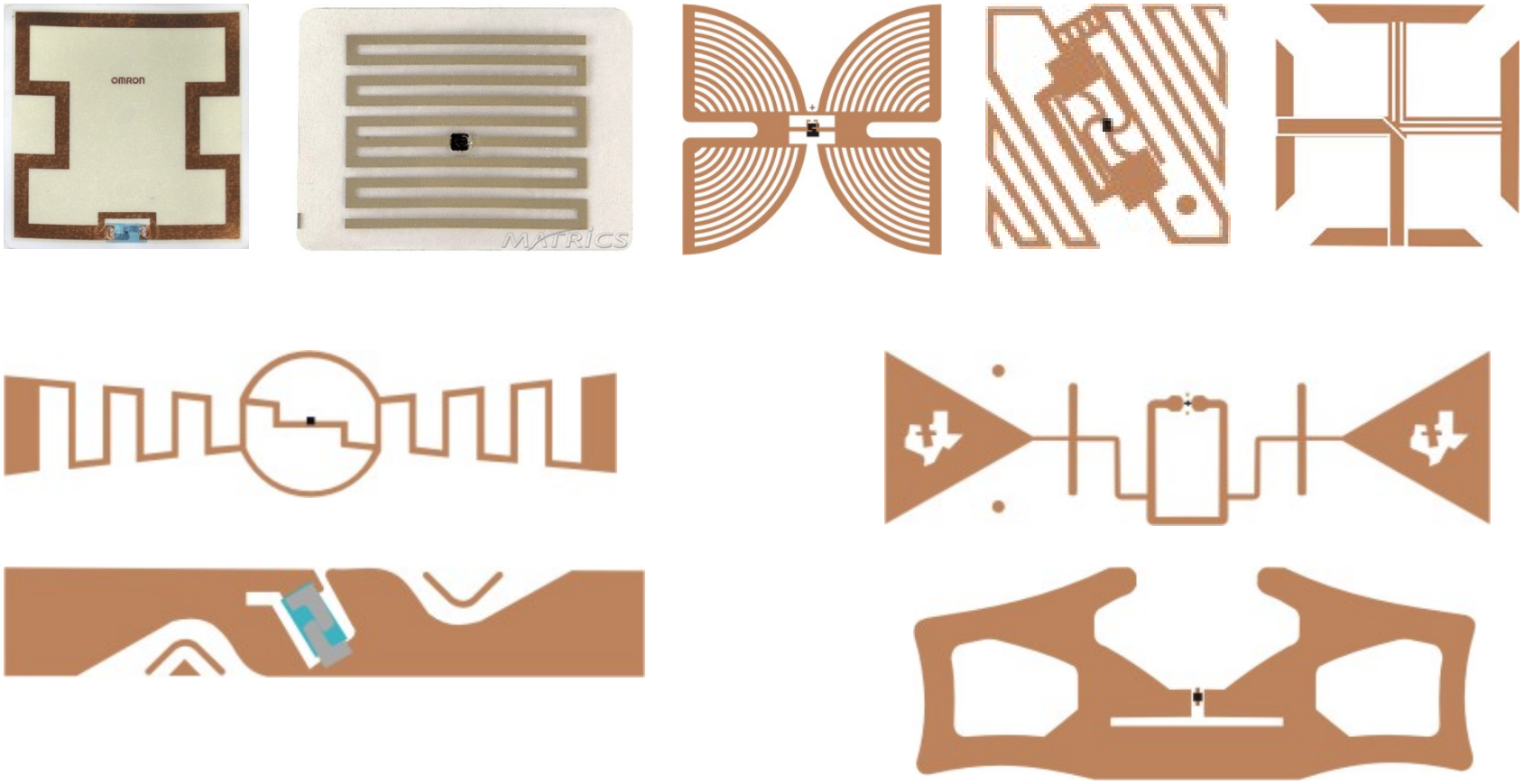
Near Field Communications

- Characteristics of near-field RFID systems
  - Short read range
  - Well-defined read zone
  - Consistent reads
  - Good penetration through materials
  - Not highly affected by water

Far Field Communications

- UHF systems work with far-field communication
- A plate or patch antenna radiates energy
- An antenna attached to the chip receives the radio waves and converts them to energy to power the chip
- UHF tags usually have large antennas

UHF Tag Examples



Behavior of UHF Tags

- The tag converts energy from the reader into energy to run the chip
- Antenna is designed to capture most energy
- The reader antenna can be circular-polarized
  - Energy emitted in a circular pattern to reduce orientation sensitivity
- The reader antenna can be linear-polarized
  - Energy is channeled into a narrow band to increase read range

Behavior of UHF Tags

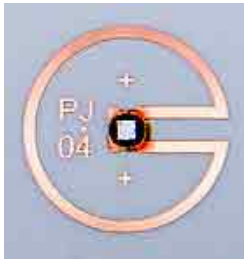
- The chip uses energy from the reader antenna to modulate and demodulate the antenna, changing the wave reflected back
- There are different ways to modulate the antenna
  - Frequency modulation (FM)
  - Amplitude modulation (AM)
  - Frequency shift-keying (FSK)
  - Phase shift-keying (PSK)

Coding & Modulation

- Signal Coding:
  - It takes the message to transmitted and codes it in a way that will be optimal for the transmission channel
  - It provide protection against interference or/and collisions
  - Examples: NRZ code, RZ code, Differential coding, pulse-pause coding, ..etc
- Modulation
  - It is the process of altering the signal parameters of a high frequency carrier in relation to the signal to be transmitted (the data)
  - Examples: ASK, FSK & 2 PSK

UHF Near Field Tags

- Some companies are developing UHF tags that work in the near field
  - Short read range
  - More defined read zone
  - More consistent reads
  - Good penetration through materials
  - Less affected by water



Conclusion

- LF, HF and UHF perform differently because of the physics of different radio waves
- Companies must choose the RFID system that works best for their application(s)
- Companies must overcome the limitations of UHF tags to achieve consistent reads

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Real World Considerations

Understanding the factors that will affect RFID deployments

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Factors

- Cost, cost, cost
- Deployment issues
- System performance
  - Materials tagged
  - Quality of tags/readers
  - Noise/interference
- Privacy/social issues

Costs

Cost of Tags

- Tags
  - ~5 cents for UHF inlays
  - ~10 cents and up for UHF
  - ~20 cents and up for UHF smart labels
  - ~50 cents and up for HF smart labels
  - ~Semi-active tags are $10 and up
  - ~Active tags $15 and up

Bringing down cost of Tags

- Research and development focused on
  - More efficient ways to assemble tags
  - Conductive inks for printing antennas
  - Improved converting processes for labels
  - Recyclable tags
  - Embedding techniques

Cost of Readers

- A typical UHF standalone reader: $1,000 to $3,000
- Handheld readers:
- Small UHF readers: $200 and up
- HF readers: $200 and up
- Label printers: $3,000 and up
- Active RFID Readers: Depends on type of system!

Bringing down cost of Readers

- Research and development is being done on a system and component level
- Goal is to shrink the components on a reader's printed circuit board down to a few chips
- UHF readers could come down to less than $100
- Investments won't be made until volumes increase

Middleware, Apps, Installation

- Cost depends on your project size
- World Kitchen spent $400,000 to become Wal-Mart-compliant
- That includes
  - Readers
  - Initial lot of tags
  - SAP's AII middleware
  - Integration with SAP back-end systems
  - Installation

Deployment Issues

- Limited number of people/systems integrators with RFID experience
- Readers aren't plug-and-play
  - Antennas need to be properly positioned and tuned
  - Appropriate technology needs to be used
- Limited number of reader form factors
- Limited testing and deployment tools
- Not many best practices

Systems Performance Issues

- Materials can be “RF friendly” or “RF unfriendly”
- Water is unfriendly (absorbs UHF energy)
- Metal reflects radio waves
- Different types of materials detune tag antennas
- Anti-static containers absorb RF
- Behavior of RF is unpredictable

Deployment Issues

- Limited number of people/systems integrators with RFID experience
- Readers aren't plug-and-play
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- Limited number of reader form factors
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- Not many best practices

Tagging Liquid Products

- Look for air gaps in packaging to keep tag away from water-based products
- Use a tag with a foam spacer to keep tags off water products
- Use tags designed to work well around water

Tagging Metal Products

- Use metal-mount tags that have spacers to keep tags away from the metal
- Use tags designed to couple with the metal product
- Find air gap in packaging that keeps tag away from the metal

Quality of Tags

- Few companies deliver 100% readable tags
- Tag yields continue to improve
- 2% failure is not uncommon

Quality of Readers

- Reader performance does vary
- Generally, readers work well
- Read scenarios in your application will determine appropriate reader format to choose
- Interoperability will improve over time

Challenging RF Environments

- Electromagnetic energy will affect your ability to read tags consistently
- Any device operating in the UHF spectrum can interfere with UHF RFID systems:
  - Cordless phones
  - Older wireless networks
  - Some alarm systems

Challenging RF Environments

- Other devices give off electromagnetic energy:
  - Electric motors
  - Forklift trucks
  - Some conveyors
  - Florescent lights

Work-arounds for RF issues

- Have a site survey done to see where problems might occur
- Shield electric motors
- Upgrade older wireless LANs
- Deploy in areas with less metal, if possible
- Attenuate reader signal to avoid false reads
- Get antennas as close to tags as possible

Privacy Issues

- Tagging individual items or cases consumers might buy could raise problems:
  - Bad press
  - Angry customers
- Take concerns seriously
- Be open with customers:
  - What data you are collecting
  - Where RFID is used
- Use “RFID inside” labels

Environmental Issues

- Metal antennas can’t be recycled
- Metallic ink antennas can’t be put in some landfills
- New readers will need to comply with recycling laws for electronic components

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Building an RFID Business Case

Understanding how RFID can deliver a return on investment

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Open Loop vs Closed Loop

- Open Loop Solutions
  - Applications span multiple organizations and or locations
  - Information shared to benefit all trading partners
- Closed Loop Solutions
  - Applications span single organizations
  - Information retained within organization

Closed Loop Solutions

- Closed Loop solutions solve a specific problem
  - Lost, stolen, misplaced assets
  - Manufacturing errors
  - Slow warehousing throughput
  - Time wasted searching for documents

Business Case – Closed Loop

- Business Case easier to develop
- Identify pain points within the organization
- Quantify loss (assets, productivity)
- Evaluate potential benefits
- Organization paying for deployment experiences the benefits!

P&G Facility finds ROI in floor

- A P&G facility in Spain needed to increase throughput
- Warehouse was a bottle neck
- Needed to go to direct loading, no staging on the dock
- Needed a system that was 100% accurate
- RFID was the answer

P&G Facility finds ROI in floor

- Installed tags in floor, readers under the forklift
- Associated the pallet with the location
- System cost ~$150,000
- Benefits
  - Increased throughput
  - Improved order accuracy
  - Reduced forklift drivers by one per shift
- ROI achieved within one year

Open Loop Solutions

- Open loop solutions tend to benefit multiple organizations
  - Item Tracking in Retail
  - Pharmaceutical Tracking
  - Traceability initiatives

Business Case – Open Loop

- Business Case complex to develop
- Identify pain points within the entire supply chain
- Quantify value of information at various points and for various stakeholders
- Evaluate potential benefits
- Determine an appropriate mechanism for sharing deployment costs!

RFID as Infrastructure

- Multiple applications can be supported using same infrastructure
- Initial investment justified for one application can provide additional benefits for a fraction of investment
- Support costs shared over multiple applications
- Ex. Premise access solution deployed to identify vehicles can be used to enable better records keeping for vehicle maintenance

Building a Business Case for RFID as Infrastructure

- Identify the pain points
- Examine how internal benefits can be achieved within multiple functional areas
  - Leverage the same tags
  - Leverage the same reader infrastructure
- Bring in stakeholders from a variety of areas of the business: operations, finance, IT, security

Business Case Challenges for RFID as Infrastructure

- No one application delivers complete ROI
- Infrastructure costs are high
- Infrastructure depends on how it's used
- New funding models need to be explored
- However: *Long-term benefits can be great*

Building Business Case

- Pay attention to business processes
- Draft a clear understanding of the business requirements
- Identify appropriate technologies that will help address identified requirements
- Deploy pilot project
  - Observe performance of selected technologies
  - Uncover challenges that might have been unaccounted during initial planning stages

Building Business Case

- Communicate, communicate, communicate…
- Revisit initial assumptions and update based on current information
- Spend time and effort on data management

Proactively acting on real time information will enable operational benefits

Evaluate & Prioritize

- What are the quantifiable costs/benefits?
- Will the initiative be critical in enabling bottom-line benefits?
- Will the initiative create a strategic point of difference or enable better quality of service?

Evaluate Potential Challenges

- What processes will be impacted in one or multiple businesses and/or functions?
- Are new processes being created, and/or current processes being significantly retooled?
- How many people are affected?
- Are reporting relationships and performance measures affected?
- Are there dependencies on long-term integrated solutions and/or significant data conversions?

Analyze Current Processes

- Break down the way you are doing things today
- Analyze gaps or weaknesses in those processes
- Examine how they might be addressed, given the ability to gather RFID data at key points in those processes

Pilot Phase

- Limit the scope
- Run the pilot—then run it again
- Examine assumptions
- Examine other changes going on to confirm benefits came from RFID and not other factors
- Determine the return on investment

Pilot Phase

- Confirm the benefits can be achieved
- Make sure the hardware and software perform the way they did in the field test
- Make sure people are trained properly
- Prepare for the roll out

ROI Models

- Measurable enhancements should be determined based on functional area:
  - Operational enhancements
    - Cost savings due to more efficient processes
  - Security enhancements
    - Increased Security; Cost savings might not be an objective
- Need flexible ROI models based on maturity of project

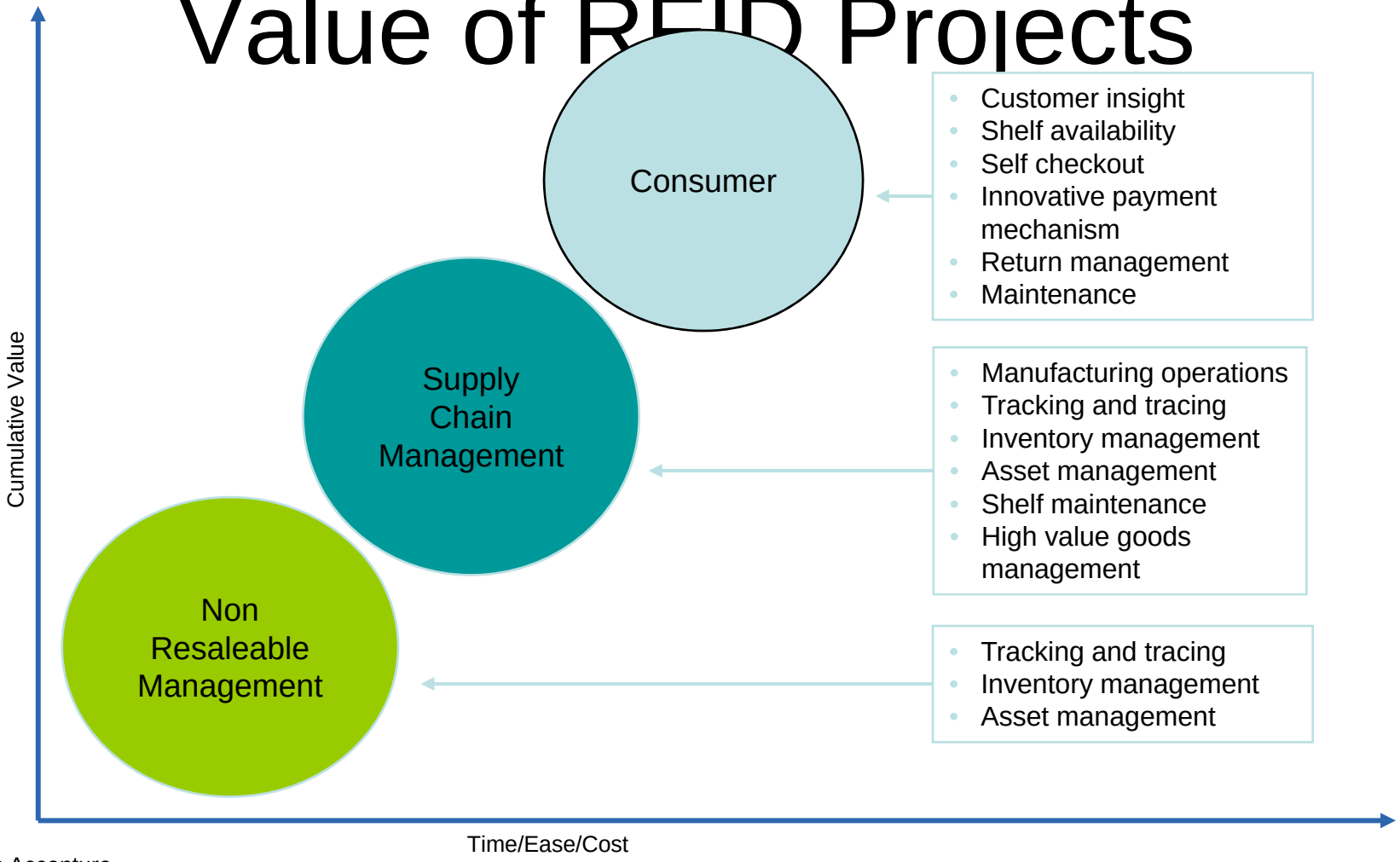
ROI Models – Innovative Projects

- Realistic cost savings might be hard to predict
- Lack of experiential knowledge; *Lots of assumptions to build initial ROI*
- Track project success based on defined deliverables
  - Freeze requirements to avoid scope creep
  - Tangible deliverables based on requirements

ROI Models – Mature Projects

- Ability to predict cost savings based on experiential knowledge
- Well defined requirements & deliverables
- Project success measured based on initial calculations
- ROI = (Earnings or Cost Savings)/Cost

Value of RFID Projects



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