Agenda

- Introduction to RFID
- Standards
- The Building Blocks of an RFID System
- Selecting and Implementing Tags and Readers
- Existing Applications
- Viable Applications
How RFID Works

- Asset Contains an RF Tag/Label Instead of (or in conjunction with) a Bar Code Label
- Interrogator “Scans” the Tag for Information Using RFID.

The Differences:

- a) Interrogator May Read any field or memory location
- b) May select a group of tags based on field values
- c) Write New or Additional Information to Tag (depending on privileges or process requirements)
Theory of Operation

Antenna

Reader / Interrogator

Tag

Existing Data Collection System

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Standards
Standards

Technology Standards

- ISO/IEC 18000 Part 6
  RFID Air Interface standard for item management at UHF
- ISO/IEC 15961 & 15962
  Information interface for object orientated use of RFID in item management
- ANS INCITS 256:2001
  American RFID standard for item management
- ISO 18185
  RFID for electronic seal tags
- ISO 23389
  Freight containers – read/write radio-frequency identifications

Products

Application Standards

- EAN.UCC GTAG™
  Application standard for the use of RFID in the macro-supply chain
- ANS MH10.8.4
  ANSI application standard for RFID on reusable plastic containers
- AIAG B-11
  Application standard for tire and wheel identification
Competing UHF RFID Standards

- ISO 18000-6
  - Global
  - Consortium developed
  - a and b versions

- EPC (Auto-ID Center at MIT)
  - Initial draft specifications not finalized
  - First versions US only
  - Initially only available from VC funded companies
# Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gen 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read Rate</td>
<td>US: 1700 tags/sec</td>
</tr>
<tr>
<td></td>
<td>EU: 600 tags/sec</td>
</tr>
<tr>
<td>Rewriteability</td>
<td>Fully Rewritable</td>
</tr>
<tr>
<td>Privacy</td>
<td>-- 32-bit Password</td>
</tr>
<tr>
<td></td>
<td>-- Concealed Mode</td>
</tr>
<tr>
<td>Security</td>
<td>-- Reader does not transmit OID</td>
</tr>
<tr>
<td></td>
<td>-- Has authentication and encryption</td>
</tr>
<tr>
<td>Regulatory Compliance</td>
<td>Worldwide</td>
</tr>
<tr>
<td>Multi-Reader Environment</td>
<td>-- Reader transmissions are spectrally separated from tag backscatter</td>
</tr>
<tr>
<td></td>
<td>-- Guardbands prevent reader-on-tag collisions</td>
</tr>
</tbody>
</table>
Next Steps

- Increase Vendors
- Ramp Up Production
- Create ISO 18000-6C
The Building Blocks of an RFID System
Not All Tags Are The Same

Three Basic Types:

- **Active Tags**
  - Battery powered memory, radio & circuitry
  - High Read Range (300 feet)
  - $$$

- **Active Backscatter**
  - Reader activates tag, but battery powers memory and circuitry
  - Medium Read Range (10 - 50 feet)
  - $$

- **Passive Backscatter**
  - Reader powered
  - Shorter Read Range (4 inches - 18 feet)
  - $
Active Tags Have Their Place

Advantages:

- Long Range Monitoring (15 – 300 ft.)
- Can afford
  - $25 - $50 per tag
  - reusable / life of asset
- Need to monitor events (temp, shock, etc.)
- Desire instant inventory
- Desire location look-up capability
Active Tags - Disadvantages

- Power Management of Tag Battery
  - Blink Rate vs. Battery Life
- Only some assets can afford to be tagged
  - Tag Size is an issue
  - Tag Cost is an issue
  - The Operational Environment is an issue (heat, cold)
- Proprietary Air Interfaces and Data Structures
- Lack of International Regulatory Acceptance
Passive Backscatter – Our Focus

- Low Cost
- Good Read Range
- Good Read Rate
- Standards
Frequencies

Best bet…
Concentrate on your business requirements
Let requirements dictate frequency
Wavelength

- Inverse of Frequency
- Affects Antennas and Coupling
- Near-field (< 1 wavelength)
- Far-field (= 1 wavelength)

- 129 KHz = 2.3 Km (1.4 miles)
- 13.56 MHz = 22 m (72.4 ft.)
- 900 MHz = 33 cm (1.09 ft.)
- 2.45 GHz = 12 cm (4.8 in.)
RFID Communications Methods

RFID Frequencies
125 KHz - 13.56 MHz

- Electromagnetic or Inductive Coupling
- Close Proximity
- Slower Data Rates
- Ferrous Metal Affects Inductive Coupling

RFID Frequencies
400 MHz – 6800 MHz

- Propagating Electromagnetic Waves
- Longer Range
- High Data Rate
- Absorption Affects Propagation

Inductive Coupling

Propagation Coupling
125 – 134 kHz RFID

Lower Frequency Tags are typically identified by their larger sized or long looping antennas. This increases tag thickness and cost.
125 – 134 kHz RFID

Advantages

- Uses normal CMOS processing — basic and ubiquitous
- Relative freedom from regulatory limitations
- Well suited for applications requiring reading small amounts of data at slow speeds and minimal distances
- Penetrates materials well (water, tissue, wood, aluminum)
125 – 134 kHz RFID

Disadvantages:
- Does not penetrate or transmit around metals (iron, steel)
- Handles only small amounts of data
- Slow read speeds
- Larger Antennas -- compared to higher frequencies
- Minimal Range
- Tag construction is:
  - thicker (than 13.56 MHz)
  - more expensive (than 13.56 MHz)
  - more complex
  (requires more turns of the induction coil)
13.56 MHz RFID
13.56 MHz Tags
13.56 MHz RFID

Advantages

- Uses normal CMOS processing—basic and ubiquitous
- Well suited for applications requiring reading small amounts of data and minimal distances
- Penetrates water/tissue well
- Simpler antenna design (fewer turns of the coil); lower costs to build
- Higher data rate (than 125 kHz—but slower than higher MHz systems)
- Thinner tag construction (than 125 kHz)
- Popular Smart Card frequency
13.56 MHz RFID

Disadvantages

- Government regulated frequency
  (U.S. versus Europe)
- Does not penetrate or transmit around metals
  (unless very thick)
- Large Antennas (compared to higher frequencies)
- Larger tag size than higher frequencies
- Tag construction: requires more than one surface to complete a circuit
- Reading Range of ~ 0.7 m
865-928 MHz UHF RFID

4” x 4”
865-928 MHz UHF RFID

Advantages

- Effective around metals
- Best available frequency for distances of >1m
- Tag size smaller than 13.56 MHz
- Smaller antennas
- Range: licensed to 20-40' with reasonable sized tag (stamp to eraser size)
- Good non-line-of-sight communication (except for "lossy" materials)
- High data rate; Large amounts of Data
- Controlled read zone (through antenna directionality)
865-928 MHz UHF RFID

Disadvantages

- Does not penetrate water/tissue
- Regulatory issues (differences in frequency, channels, power, and duty cycle)
  - Radio Region 1 Europe - 869 MHz, 250 KHz Bandwidth, 0.5W ERP, 10% Duty Cycle
  - Radio Region 2 – Americas – (902-928 MHz, 4W EIRP, 100% Duty Cycle
  - Radio Region 3 – Asia – Emerging Standards
- Summary – Requires Frequency Agile Chip Capable of Operating 0.5 W to 4 W - Varying Duty Cycles and Output Power
2.45 GHz Tags
2.45 GHz

Advantages

- Tag size smaller than inductive or UHF (1" x 1/4")
- Range: greater range than inductive w/o battery
- More bandwidth than UHF (more frequencies to hop)
- Smaller antennas than UHF or inductive
- High data rate
2.45 GHz

Advantages

- Good non-line-of-sight communication (except for "lossy" materials)
- Can store large amounts of Data
- Controlled read zone (through antenna directionality)
- Effective around metals with tuning/design adaptations
2.45 GHz

Disadvantages

- More susceptible to electronic noise than UHF
- Shared spectrum with other technologies—microwave ovens, RLANS, TV devices, etc.
- Requires non-interfering, "good neighbor" tactics like FHSS
- Competitive requirement: single chip—highly technical; limited number of vendors
- Regulatory approvals still "in process"
Are All Tags The Same?

- **Memory**
  - Read-Only
    - Infrastructure requirements
    - Like pre-printed barcodes
  - OTP (One Time Programmable)
    - Like current barcodes
  - Read/Write
    - Flexibility
  - Capacity
    - Offset data use with speed
Tag Designs

- Different Shaped Antennas for Different Applications
- Different Housings for Different Applications
- How to Choose the Right Tag for the Right Application (Frequency, Antenna Shape, Housing, Memory)
RFID Chips/Inserts/Tags/Labels

- Chip
- Insert with Antenna
- Tag or Label

One
Small number
Application specific

Multiple Tag Antenna Shapes and Encapsulations Cover Several Frequencies and Application Environments
Tag Considerations

- Frequency
  - Materials and Mounting Surface
  - Range
  - Size
- Antenna Shape
  - Range
  - Size
  - Mounting Surface
- Housing
  - Size
  - Environment
- Memory
  - Application Requirements
Tag & Reader Communication

- Basic mode
  - Allows for faster read rates
- Error checking
- Collision avoidance algorithms
- Tag selection
  - Provides faster read capability
- Password Protection
  - Write Protect
  - Hiding
Read Rates

- Basically, 100 tags / second or more
- Protocol
- Amount of data
- Environment
- Tag density
Common Commands

- Read / Write
- Error handling
- Filters
- Triggers
- Attributes
  - Attempts
Interoperability

- Standards
- Basic plus enhancements
Reader Overview
RFID System Components

Reader
- An integrated package containing both the reader and RF module.
- May include an antenna, or the RF module will be a discrete system component.
- These pieces combine to perform the necessary functions such as
  - encoding/decoding
  - communications interface control
  - I/O sensing and control
  - Generation, transmission, and reception processing of RF signals
Antenna Analysis

- **Directivity**: The property of radiating more strongly in some directions than in others
- **Gain**: The overall gain in power density when compared to an isotropic antenna
- **Polarization**: The direction of the antenna’s electric field with respect to earth.
**Field Pattern - “Read Zone”**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Considerations</th>
</tr>
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<tbody>
<tr>
<td>Asset Rate and Density</td>
<td>Asset Speed and Path Through Field</td>
</tr>
<tr>
<td></td>
<td>Singulated – Minimum Distance Between Assets</td>
</tr>
<tr>
<td></td>
<td>Batch – Max. Number of Assets Simultaneously In Read Zone</td>
</tr>
<tr>
<td>Antenna Diversity</td>
<td>Asset Properties (Physical Orientation, Motion, Tag Placement &amp; Attachment)</td>
</tr>
<tr>
<td></td>
<td>Asset Rate and Density (singulated or batch)</td>
</tr>
<tr>
<td>Asset Properties</td>
<td>Physical Size, Orientation, Motion, Tag Placement &amp; Attachment</td>
</tr>
<tr>
<td>Transactions</td>
<td>The amount of information to be written to or read from the tag.</td>
</tr>
</tbody>
</table>
Multiplexing

- Multiple antennas
  - Greater coverage
- Multiple readers at one location
  - Greater throughput
- Multiple readers across multiple locations
  - Enterprise applications
Regulations

US and Canada: 902 – 928 MHz

Europe: 862 – 870 MHz
(869 MHz)

Middle East: Potential for 862 – 870 MHz

China: Permissive 915 MHz

Japan: 862 - 928 MHz allocated to mobile telecommunications

Pacific Rim: Singapore 862 – 870 MHz, Taiwan 915MHz

Mexico: Typically 915MHz, Case by case basis

Northern Africa: 862 – 870 MHz
(869 MHz)

Southern Africa: 915MHz Typically permit FCC approved devices

Australia: 915MHz Typically permit FCC approved devices

New Zealand: 862 - 928 MHz with FCC power levels

South America: Undefined but 915 is typically accepted

Northern Africa: 862 – 870 MHz
(869 MHz)
# Varying Power Regulations

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Region</th>
<th>Available Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>869.4 - 869.65 MHz (UHF)</td>
<td>Europe ¹)</td>
<td>0.5 W ERP</td>
</tr>
<tr>
<td>865.5 - 867.6 MHz (UHF)</td>
<td>Europe ²)</td>
<td>2.0 W ERP</td>
</tr>
<tr>
<td>902.0 - 928.0 MHz (UHF)</td>
<td>America ³)</td>
<td>4.0 W EIRP</td>
</tr>
<tr>
<td>860.0 - 930.0 MHz (UHF)</td>
<td>Others ⁴)</td>
<td></td>
</tr>
<tr>
<td>2.400 GHz - 2.4835 GHz</td>
<td>Europe ⁵)</td>
<td>0.5 W EIRP</td>
</tr>
<tr>
<td>2.400 GHz - 2.4835 GHz</td>
<td>Europe ⁵)</td>
<td>4.0 W EIRP</td>
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<tr>
<td>2.400 GHz - 2.4835 GHz</td>
<td>Others ⁷)</td>
<td></td>
</tr>
</tbody>
</table>
RFID Regulatory Differences

- Usage of channel
  - Primary service
  - Secondary service
    - Cannot interfere with primary service
    - Cannot claim protection of interference from primary service
    - Can claim protection of interference from other secondary users
- Industrial, Scientific, & Medical (ISM) Bands
- Narrowband or Spread Spectrum
- Power level
- Duty cycle
Reader Inputs

- Getting the Reader Started
  - Motion Sensors
  - Presence Detectors
Reader Outputs

- Exception Handling
  - Message boards
  - Alarms
  - Status lights
- Decision Tools
  - Lift gates
  - Door locks
  - Diverters
Interference Issues

- Reader Collision
  - Isolation
  - Frequency hopping
  - Band separation
- Tag collision
  - Random back-off
  - Addressing (polling)
- Other RF devices
  - Same as readers
- Electromagnetic interference from robots and conveyors
  - isolation
Tag and Reader Performance Issues

- Signal attenuation
  - Absorptive materials (liquids)
  - Create space
- Signal reflections
  - Ferrous materials
  - Use to advantage
- Null spots
  - Signal cancellation
  - Movement (reader or tag)
Dealing with Metal

If properly tuned to the environment, a reflective metal ground plane can increase the tag’s read range.
Implementation

- Qualification
  - Block Diagram
    - Reader locations
    - Read range, orientation, speed
    - Peripheral devices
  - Tagged Items
    - Environmental constraints (water, metal)
    - Tag memory layout
Implementation

- Preliminary Site Visit
  - Spectrum Analysis
  - Mounting Requirements
  - Power and Network Connections
  - Tag Attachment
  - Interface Requirements
Implementation

- System Engineering and Design
  - Hardware List
  - Power and Network Connection Instructions
  - Tag Attachment Instructions
- Installation
  - Mount Readers
  - Mount Antennas
  - Attach Tags
  - Installation and Configuration of Additional Networking
Beyond Tags and Readers

- Exception handling
  - Barcodes
  - Handheld readers
- Configuration flexibility
  - Shipping and receiving through same door
- Reader mobility
  - Handhelds
  - Battery operation
  - WLAN connectivity
Applications in Use
Logistics / Transportation

- Raxel
  - Biohazardous waste tracking / disposal
  - Governmental compliance
- JM Family Toyota
  - Automotive inventory control
  - Barcode and RFID
- Paramount Farms
  - Nut harvesting
  - Truck / trailer tracking
- Cargill
  - Sugar cane harvesting
  - Truck / trailer tracking
Consumer Products

- Excel Beef
  - Beef tracking
  - Governmental compliance
- Georgia-Pacific
  - Pilot
  - Reusable plastic containers
Retail and Retail Supply Chain

- Metro AG
  - Case and pallet level tracking
  - ISO 18000
  - GTIN plus serial number
  - Future store initiative
  - Vendor mandate
    - Installing multiple DCs now
Industrial Products

- Major Automotive OEM
  - WIP tracking and process control
  - Engines, transmissions, chassis
- Two Major Heavy Duty Truck Makers
  - WIP “traveler” and process control
  - Avoid assembly line shutdowns
- Major Personal Watercraft Maker
  - Final assembly
  - WIP “traveler” and process control
- Major Automotive OEM
  - In-plant metal rack tracking
  - Forklift readers
  - Handhelds
Homeland Security

- US Army FORSCOM (Ft. McPherson)
  - Access control during low level security threats
  - Real-time descriptions of authorized vehicles and personnel
  - Windshield decals

- INS
  - Border crossing security
  - Plastic ID cards with RFID
Miscellaneous

- Sharp – major appliances
- Sheetz – computer asset tracking
- Boise Cascade – QA location inspection
- Trane – air conditioners
- Johnson Space Center – gas cylinder
- Delphi – plastic part containers
- MTD – engines for mowers & snow blowers
- Woodbridge – metal racks
RFID Pilots

- Tire Tagging
- Medical Instruments
- Tobacco Pallets
- Metro AG – cases & pallets
- Cases of Meat – retail stores
- Carpet & flooring material tracking
- FEMA – asset tracking
- American Woodmark – pallets of cabinets
- Lockheed Martin – Navy ship components
Viable Applications
Your Manufacturing Floor

- Receiving
- Product Labeling & Tracking
- WIP Replenishment
- Tool Crib
- Work-in-Process
- Shipping
- Inventory Management
- Quality Assurance
- Asset Tracking
- Secure Access
- Labor Tracking
- Time & Attendance
Manufacturing Product Solutions

Bar Code Printers including RFID

Fixed Mounted RFID Tag Reader/Writers

Windows Based Fixed/Vehicle Mounted Computers & RFID

Scanners

Hand-held Computers & RFID Interrogators

Hand-held Computers With WWAN and GPS Solutions & RFID

Access Points For Indoor and Outdoor Coverage

Pallet Tags

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Your Warehouse/Distribution

- Receiving
- Cross-Docking
- Picking
- Putaway
- Inventory Management
- Order Consolidation
- Shipping
- Forward Pick
- Replenishment
- Document Management

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Warehouse Product Solutions

- PocketPC Based Hand-held Computers & RFID
- Windows Based Fixed/Vehicle Mounted Computers & RFID
- Key-based Hand-held Computers & RFID Interrogators
- Bar Code Printers including RFID
- RFID Pallet Tags
- RFID Portal Tag Reader/Writers
- Access Points For Indoor and Outdoor Coverage
- RFID Portal Tag Reader/Writers
- PocketPC Based Hand-held Computers & RFID
- Access Points For Indoor and Outdoor Coverage
- Bar Code Printers including RFID
Product Genealogy

Mechanics
- RFID tag affixed to part, assembly or box
- Tag can contain part number, location produced, production line, worker, date and other types of information
- Product genealogy can travel with the part through out its useful life or requirement of the process
- Portals, VMU or hand-held units can interrogate and update the RFID tag anywhere, any time to get a complete history of the item

Benefits
- Eliminates wasted time
- Improves regulatory compliance
- Minimize warranty risk
- Optimize efficiency and customer satisfaction
- Increases recall efficiency
Putaway & Picking

Mechanics
- Place RFID tag at each location
  - Recommended for A and B level items
- RFID pallet tag or over-pack label on each load
- VMU interrogator automatically reads and writes tags
- Any scanning required by a WMS for location and pallet ID
- Hand-held unit can be used

Benefits
- Swifter identification and location
- Alerts incorrect action
- Item and location matching eliminates wasted time and costs
- Validated without error
Putaway/Picking

RFID Reader on Forklift

RFID Tags on pallets and at locations
Putaway/Picking

- Tags at Locations & Pallets
- RFID Reader on Forklift

1. Go To A2 
   Verify
2. Incorrect 
   Go To A2
3. Putaway 
   Go to A4
4. Pick 
   Go to S3
Putaway/Picking

Tags at Locations & Pallets

RFID Reader on Forklift

Pick
Go to S3

Return to Receiving

1 2 3 4

A B C
Kanban Signaling - Replenishment

Mechanics
- RFID tag can contain exact part number and production line destination
- When parts are gone, container can be placed or pushed into range of RFID reader. Or tag can be exposed by missing part.
- Forklift driver is directed to pick the part and deliver it to the proper work location
- Location tag at the work cell can be read by the VMU interrogator or handheld unit to verify proper match
- ERP and WMS are updated

Benefits
- Ensures accurate replenishment
- Decreases or eliminates down time
- Reduces error correction expenses
- Kanban directly communicated
- Improves workcell efficiency
- Increases on-time delivery
Kanban Signaling - Replenishment

Replenish WC27
P/N B6579C
Kanban Signaling - Replenishment

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Allows tracking between suppliers and customers
Labor Tracking & Security

Worker badges contain RFID tag
- Tag contains worker ID and other authorizing data
- **Security** - Workers can use their RFID badge to open portals, secure doors, cages, etc.
- **WIP** – labor value added by specific individuals can be captured
- **Asset Utilization** - Attempts to utilize assets, such as forklifts, can be verified against training

**Benefits**
- Increases facility security
- Decreases risk
- Efficiently captures labor costs
- Optimizes warranty
Plant Maintenance & Field Service

Mechanics
- Plant or field equipment carries an RFID tag
- Tag can contain information such as last maintenance date, technician ID, parts upgraded, actions taken and next maintenance date
- Technicians read tag to verify equipment and location, perform maintenance or repair, and update RFID tag with newest data

Benefits
- Ensures proper location and equipment
- Allows quick reference
- Immediate updates
- Eliminates wasted time and procedure errors
Yard Management

Mechanics

- Incoming trucks logged-in
- Bill-of-Lading/Manifest matched to P.O.
- Temporary RFID tag attached to the trailer
- Scanning tag with handheld unit or as truck goes through a portal, writes manifest number to RFID tag
- If location tags are use, location is matched when trailer is dropped by driver
- If random location is used, RFID tag allows swift trailer location & content identification

Benefits

- Reduces lost shipments
- Increases productivity
- Eliminates costs
- Reduces excess inventory
- Increases customer satisfaction
Yard Management

Lot A

Park in Slot 3

Lot B

No
Not
Truck #5

This is Truck #5

Yes

1 4 3 2

5 8 7 6

9 1 2 1 1 0 1 3 1 6 1 5 1 4

14 1 3 1 5 1 6
Thank You! Questions?

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