Integrating RFID with Plastic Products and Packaging

NPE 2006 Education Program

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UPM Raflatac

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RFID Tagging of Plastics

**Agenda**

- RFID Basics for HF and UHF Tags
- RFID Players, Standards and Acronyms
- Activity in Pharma and Supply Chain
- RFID Integration into Plastic Parts and Packaging
- Environmental Consideration with Integral RFID Tagging
## Comparison of Product Identification Technologies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Barcode</th>
<th>Passive RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data quantity and density</td>
<td>1-100 bytes (8i). Static data</td>
<td>1 - 32 k. Configurable (R/W)</td>
</tr>
<tr>
<td>Machine readability</td>
<td>Good, line-of-sight needed</td>
<td>Good, no line-of-sight</td>
</tr>
<tr>
<td>Human readability</td>
<td>Limited</td>
<td>Impossible</td>
</tr>
<tr>
<td>Influence of optical covering</td>
<td>High. Impossible to read</td>
<td>Low/non-exiting unless communication is prevented</td>
</tr>
<tr>
<td>Influence of materials</td>
<td>No influence</td>
<td>High. Can cause functional failure</td>
</tr>
<tr>
<td>Influence of position/direction</td>
<td>Noticeable as function of distance</td>
<td>Very limited. Dependant on the dipoles orientation</td>
</tr>
<tr>
<td>Investment and operational costs</td>
<td>Low investment costs. Multiple sourcing</td>
<td>still limited sources for components</td>
</tr>
<tr>
<td>Unauthorised copying/modification</td>
<td>Relatively easy</td>
<td>Impossible</td>
</tr>
<tr>
<td>Reading speed</td>
<td>Low, single read cycles</td>
<td>High, 'multiple read' cycle</td>
</tr>
<tr>
<td>Maximum communication distance</td>
<td>0-50cm</td>
<td>0-500 cm (regional differences)</td>
</tr>
</tbody>
</table>
RFID Tagging of Plastics

Passive RFID Read/Write
RFID Tagging of Plastics

How RFID Systems work

- RFID tag gets into reading device's electromagnetic field
- Tag receives the signal which energizes the passive tag
- Tag transmits the data stored in the IC in return
- Reader passes the information to the host system
- Host system can be connected into the Internet or company's ERP system
- Reader can also pass information to the tag which can be re-written or deactivated
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Passive RFID tags

- No internal power source
- IC (integrated circuit) - provides the memory and stores data
- Antenna – harvests power & communicates with the reader
- Inlay/inlet – IC and antenna assembled together for insertion
- RFID tag – an inlet converted in a way that it can be applied to an object
RFID Tagging of Plastics

RFID Frequencies

- 125-134 KHz  LF: Low Frequency
- 13.56 MHz  HF: High Frequency
- 862-950 MHz  UHF: Ultra High Frequency
- 2.45 GHz  Microwave
- 5.8 GHz  Microwave
Construction of Passive RFID Transponders

13,56MHz Ultra High Frequency 867-950MHz

IC+conductive adhesive

Printed insulator and bridge

Dipole antenna

IC+ACP

Floor plan of passive RFID IC

- Size approximately 0.6 x 0.6 to 1 x 1 mm.
- Assembly tolerances appx. +/- 50um
- About 40 000 pcs per wafer (8’’)
Overview of Technical Principles of Passive RFID

HF (13.56MHz)
- coupled system where the reader transmitter is sending commands via magnetic coupling between the reader antenna and the transponder “antenna” (magnetic dipole)

- The power transfer efficiency between the reader and the transponder is proportional to the resonance frequency, number of windings in the coil, the area of the coil, the angle and the distance between the reader and tag coils
- Reader receiver senses the change in the 'transformer' load and converts the analogue signal changes to digital for
Overview of Technical Principles of Passive RFID

ELECTROMAGNETIC WAVES AND RADIATION PRINCIPLES
- In Ultra High Frequencies, the commonly used radiator element in RFID is a dipole antenna
- dipole has a specific electrical length to corresponding frequency being used
- the field strength follows approximately the relationship $1/d^3$ in near field and $1/d$ in far field. The limit is not exactly measurable but a estimate of Wavelength / $2 \times \pi$ is often used
- The dipole has polarisation and gain characteristics which are important to take into consideration in RFID communications systems

EIRP (effective isotropic radiated power)
$$P_{\text{EIRP}} = P \times G$$

ERP (effective radiated power)
$$P_{\text{ERP}} = P \times 1.64$$

This means that the 4W EIRP in USA and 3.2W EIRP (2W ERP x 1.64) in Europe are almost the same
Electronic Product Code (EPC)

**EPC Network**

RFID label is scanned by -> Reader that sends the EPC code to a Savant Server that - > Queries the ONS database which - > maps the EPC code to URL that has the object information which - > is managed by PML server that has all product data e.g. manufacturing and shipping information
## Comparison of Passive RFID Technologies

<table>
<thead>
<tr>
<th></th>
<th><strong>HIGH FREQUENCY</strong></th>
<th><strong>ULTRA HIGH FREQUENCY</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FREQUENCY RANGE</strong></td>
<td>13,56 MHZ globally available frequency</td>
<td>ranging from 865 to 956MHZ (2.45GHz)</td>
</tr>
<tr>
<td><strong>STANDARDS</strong></td>
<td>e.g. ISO15693, ISO14443A/B</td>
<td>ISO18000-6B, ePC Class 1 G1 and G2</td>
</tr>
<tr>
<td><strong>OPERATING METHOD</strong></td>
<td>Magnetic coupling (&quot;inductive&quot;)</td>
<td>Electric radiation (&quot;capacitive&quot;)</td>
</tr>
<tr>
<td><strong>CONDUCTOR MATERIAL</strong></td>
<td>Conductor thickness affects resistance. High conductivity in vicinity applications</td>
<td>Thinner conductors feasible</td>
</tr>
<tr>
<td><strong>MANUFACTURING COMPLEXITY</strong></td>
<td>Tolerates assembly variances. Low paracitic Cp effect</td>
<td>Tight assembly window required. High paracitic Cp effect</td>
</tr>
<tr>
<td><strong>ESD TOLERANCE</strong></td>
<td>High. Usually 2-8 kV (HBM)</td>
<td>Low. Can be &lt;500 V (HBM)</td>
</tr>
<tr>
<td><strong>PERFORMANCE RANGE</strong></td>
<td>Typically 1 - 250 cm</td>
<td>Typically 50 - 500 cm</td>
</tr>
<tr>
<td><strong>PERFORMANCE RATE</strong></td>
<td>100 - 500 tags/s</td>
<td>100 - 1000 tags/s</td>
</tr>
<tr>
<td><strong>FIELD UNIFORMITY</strong></td>
<td>Defined.</td>
<td>Undefinable.</td>
</tr>
<tr>
<td></td>
<td>Relative field strength falls quickly as a function of distance</td>
<td>Field strength ratio smaller than in HF but does not decrease as rapidly (propagating wave)</td>
</tr>
</tbody>
</table>
Factors of Transponder Readability

- Transponder
- Local Regulations
- Reader
- Protocol
- Portal Configuration
- Reader Antenna
- Environment
- End Use Product
- Readability

Diagram illustrating the factors affecting transponder readability.
RFID Tagging of Plastics

RF Tagging Solutions – Visibility
- HF (13.56MHz) Inductively Coupled (X-Former)
  - Range Limited (6 x Size of Tag)
  - Very Robust in Range
  - Water/Metal Tolerances
  - Data Speed Limited by Carrier
  - Global Frequency Standard
- UHF (860-950MHz) Modulated Backscatter (Mirrors)
  - Longest Read Range >> 6” Dipole antenna
  - Higher Carrier Frequency >> Higher Data Rate
  - Limited by Reflections, Standing Waves, and Shadows
  - Water/Metal Intolerant
  - Multiple Carrier Frequencies Around the World
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UHF Frequencies

Europe: 868 MHz
USA: 915 MHz
Korea: 908.5–914 MHz
Singapore: 866-869 & 923-925 MHz
Japan: 950 MHz (pending)
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Prevalent RFID Protocols

UHF Tags – 860 to 960 MHz

- EPC Class 0/0+
- EPC Class 1 Gen 1
- EPC Class 1 Gen 2
- ISO 18000-6a,b,c
- U-Code 1.19

HF Tags – 13.56 MHz

- ISO 15693
- ISO 14443 A
- ISO 14443 B
- ISO 18000 P3
- EPC HF
RFID Tagging of Plastics

The ISO organization devotes itself to definition and promotion of worldwide-recognized standards in the contactless area. 3 standards for objects operating in the 13.56MHz frequency range have already been approved (ISO SC17 on identification cards and related devices):
- ISO10536 identification cards and contactless integrated circuits cards – Close-coupling cards (reading range below 2 cm).
- ISO 14443 identification cards and contactless integrated circuits cards – Proximity cards (reading range up to 20 cm). Data rates up to 424kbit/s.
- ISO 15693 identification cards and contactless integrated circuits cards – Vicinity cards (reading range up to 1-1.5 m).

<table>
<thead>
<tr>
<th>ISO14443-A/B</th>
<th>Frequency</th>
<th>Data rate</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.56MHz</td>
<td>106kb/s</td>
<td>Proximity Personal identification</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ISO15693</th>
<th>Frequency</th>
<th>Data rate</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.56MHz</td>
<td>1.6kb/s-26.69kb/s</td>
<td>Vicinity Personal identification</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ISO18000-3 mode1 mode2</th>
<th>Frequency</th>
<th>Data rate</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.56MHz</td>
<td>1.6kb/s-26.69kb/s</td>
<td>106kb/s-423.75kb/s</td>
<td>vicinity Item management</td>
</tr>
</tbody>
</table>
## RFID Tagging of Plastics

### Dry Inlay, 2 layer (90um):

<table>
<thead>
<tr>
<th>PET12</th>
<th>Adhesive</th>
<th>Antenna</th>
</tr>
</thead>
</table>

### Tag, 3 layer (180um):

<table>
<thead>
<tr>
<th>Face paper</th>
<th>Adhesive</th>
<th>Antenna</th>
<th>Adhesive</th>
<th>Backing paper</th>
</tr>
</thead>
</table>

Continuous web

Die-cut
# Terms and Acronyms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID</td>
<td>General term for all wireless identification systems, including active systems like remote controllers and passive systems like RFID tags without internal power source</td>
</tr>
<tr>
<td>Reader/Writer</td>
<td>Device for communicating with RFID tags and inlays. Usually capable of communicating with several protocols at same frequency</td>
</tr>
<tr>
<td>HF/UHF</td>
<td>High Frequency/ Ultra High Frequency</td>
</tr>
<tr>
<td>Coil</td>
<td>Coupling element in HF (13.56MHz) systems. The electrical length of a HF coil is much shorter than the wavelength so it acts as a poor radiating element</td>
</tr>
<tr>
<td>Antenna</td>
<td>Radiation element in the UHF (850-950MHz) systems. The electrical length of a UHF antenna is a calculated portion wavelength so it acts as a good radiating element</td>
</tr>
<tr>
<td>Transponder</td>
<td>Communicating device comprising an coupler/ antenna and IC. A product which is usually either laminated to adhesive label or capsulated to hard tag</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit. In tags/inlays the IC has the circuitry divided to analog and digital part</td>
</tr>
</tbody>
</table>
## Terms and Acronyms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backscatter</strong></td>
<td>Communication method used in passive UHF RFID</td>
</tr>
<tr>
<td></td>
<td>The received energy is modified by load circuitry the ICs and the reader senses the changes in its receiver</td>
</tr>
<tr>
<td><strong>Inductively Coupled</strong></td>
<td>Communication method used in passive HF RFID</td>
</tr>
<tr>
<td></td>
<td>The received energy is harvested power from the magnetic field to power the IC which in turns modulates its current creating a receivable magnetic field at the reader antenna. The antenna must be a closed loop</td>
</tr>
<tr>
<td><strong>Near Field UHF</strong></td>
<td>Communication method used in inductively coupled UHF</td>
</tr>
<tr>
<td></td>
<td>A closed loop is attached to the IC. Re-emerging technology that overcomes UHF limitations at very close range.</td>
</tr>
<tr>
<td><strong>Passive</strong></td>
<td>Tag must harvest power from rf field created by reader</td>
</tr>
<tr>
<td><strong>Active</strong></td>
<td>Tag has a battery and may independently send data</td>
</tr>
<tr>
<td><strong>Semi-active</strong></td>
<td>Tag has on board battery to capture in route data. Must be queried for memory contents; on board battery extends range</td>
</tr>
</tbody>
</table>
RFID Tagging of Plastics

Players

Mandaters:
Walmart, Target, Albertson, Best Buy, DoD, State Pharmacy Boards, 
FDA, Metro, Tesco, Ahold, Boeing/Airbus

Standard Organizations and Trade Associations:
EPC Global, a subsidiary of GS1, formerly UCC and EAN; International 
Standard Organization (ISO); Association for Information and Mobility 
(AIM); Health Distribution Management Association (HDMA); National 
Association of Chain Drug Stores (NACDS); Automotive Industry Action 
Group (AIAG); International Air Transport Association (IATA)
RFID Tagging of Plastics

Players

Vendors:

IC's:
Philips, TI, Infineon, STMicroelectronics

Tags:
UPM Raflatac, Avery Dennison, Alien, RFidentics, KSW

Readers:
Intermec, Symbol, Tyco, Alien, AWID

RF Writing Printers:
Zebra, Sato, Printronix, Avery Dennison, Monarch

Middleware:
Globe Ranger, Supply Scape,

Enterprise Integrators:
IBM, Accenture, Cap Gemini,
RFID Tagging of Plastics

Mandate Status

Walmart – (UHF) 150 stores, adding 10K readers, 300Mil tags shipped with 13Mil read, adding 300 suppliers to present 300

Albertson - (UHF) rumored to be buying 10K readers, also for sale

Target – (UHF) low key, tending toward fast follower of Walmart

DoD - (UHF/Active) Great Active Tag program, 2 Distribution Centers started up passive, passive tag volume very low

Best Buy – (LF) still piloting
**Mandate Status**

**Tesco** - (UHF) scaling back due to ETSI limitations, focus on roll cages

**Metro** - (UHF/HF) Metro Future Store for display and development

**Ahold** – (UHF/HF) Roll cages in Europe, Pharma pilots

**FDA** – (??) Guidelines Issued 31 May 06

**Florida Pedigree** – (Paper or Electronic) Set for 1 July 06 Startup

**California, Nevada, Indiana Pedigree (Electronic) 2007**
RFID Tagging of Plastics

Mandate Status

Pfizer Pilot – 3Mil Icode1 tags on Viagra

GSK Pilot – 200K Icode1 tags on HIV drug

Purdue Pharma – 1Mil Class 0+ on Oxycontinum
RFID Tagging of Plastics

PE IMT and PP IMT
- adheres to PE (LDPE, HDPE) and PP (H-PP, Co-PP)
- tolerates normal PE and PP injection molding process temperatures
- not marketed as printable, but can be TTR printed with suitable ribbons
- good thermal and chemical resistance
RFID Tagging of Plastics

**IMT Application Guidelines**

**PE Melt Temperature**

**PP Melt Temperature**

**Electronic Adhesive Max Temp**

Place IMT on Flat, Cool Mold Face with Normal Resin Flow

Hold with Vacuum if Possible at near Vent

Greater than 25KV ESD will kill the IC
RFID Tagging of Plastics

Typical In-Molding Operating Points:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mold Temp. at IMT Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall Thickness behind IMT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What is the Short Term Impact on Plastics
- Case-like Plastic Containers will be Tagged
- Returnable Plastic Assets will be In-Mold Tagged
- Plastics Housings for Expensive Components will be In-Mold Tagged
- Existing Returnable Assets will need Tagging
- Pallet Shrink Wrap Trash will have Tags
RFID Tagging of Plastics

What is the Long Term Impact on Plastics

- Molders will be asked to In-Mold tag All Containers
- RPC will have a permanent GRAI and password changeable SSCC
- RFID Tag Cost will Approach Bottle Cost
- In-moldLabels will have RF Tags Embedded
- Everywhere tags are handled, validation occurs
- Most Recycled Plastic will still have RFID
- RFID can be used for Recycle Auto-Sorting
### RFID Tagging of Plastics

#### Tag Components (.25-1gm/tag)

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>PolyProp</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
<td>41%</td>
</tr>
<tr>
<td>Adhesive</td>
<td>Acrylate</td>
<td>12%</td>
</tr>
<tr>
<td>IC</td>
<td>Silicon</td>
<td>.1%</td>
</tr>
<tr>
<td>ACP</td>
<td>Epoxy</td>
<td>.3%</td>
</tr>
<tr>
<td>ACPMetal</td>
<td>Nickel</td>
<td>Trace</td>
</tr>
<tr>
<td>Adhesive</td>
<td>PolyUrethane</td>
<td>4%</td>
</tr>
<tr>
<td>Antenna</td>
<td>Copper</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>Alum.</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>Silver</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>Epoxy Carrier</td>
<td>2%</td>
</tr>
<tr>
<td>Substrate</td>
<td>PET</td>
<td>40%</td>
</tr>
<tr>
<td>Adhesive</td>
<td>Acrylate</td>
<td>16%</td>
</tr>
</tbody>
</table>
Recycling Considerations:

- Business Case Drivers (Out of Stock, Warranty, Self Checkout) required RFID tags near impossible for consumers to remove

- IMT RFID and RPC will have essentially the same life span

- IMT RFID will require "milling" to remove

- Economics will likely drive IMT RFID on bottles

- Grinding of Recycle will make RFID tags unremovable by specific gravity

- Is there a technology to remove In-Mold Labels today?
RFID Tagging of Plastics

Questions and Suggestions on Recycling

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