PACKAGING: HOW IT IMPACTS RFID INTEGRATION

By Dr. Robb Clarke
January 24, 2006
Why Packaging?

• As Throckmorton P. Ruddygore III once observed, “Packaging is the Center of the Universe”.

• It is a ground level, hands-on approach as opposed to many 30,000 foot views of RFID.

• Let me now explain WHY this is so.
Packaging: What Is It?

- Different Levels (1°, 2°, 3°, through to unitized pallet loads or cargo containers)
- Different Requirements for Different Industries (Consumer, Industrial, Military, Medical/Pharmaceuticals)
- All with an eye toward:
  - Cost (versus price),
  - Environmental Issues,
  - Ease of Handling, Shipping, Storing, etc
  - And many more…
Functions of Packaging

- Containment (no)
- Convenience/Utility (maybe)
- Communication (yes)
- Protection (yes)
The Impact of This…

• Everything has to be packaged

• All companies and industries use it.

• It should withstand all the rigors of Distribution, Manual and Mechanical Handlings, Warehousing and Storage, not create any problems, and give the ultimate user a sense of ‘value’.
SoP AutoID Laboratory

- We focus on RFID APPLICATIONS in the Supply Chain, particularly warehousing, inventory control and order verification.

- Goal is to develop the “Perfect Purchase Order”. 
Complementary Active and Passive RFID

Active Container Tag associated to a...

Passive Pallet Tag associated to a...

Passive Carton Tag associated to...

8 UID Packaging Tags each with 1 associated UID item

DoD External Briefing, 08/04
Why Look to a University?

Institutional

Packaging University

Users

Consumer

Industrial

Suppliers

Raw materials

Wood, paper, plastic, glass, steel, aluminum

Machinery

Packaging line

Converters

Extrusion & thermoforming, Injection & blowing,
Laminating & coating,
Printing & labeling...

Transportation & distribution

Food, pharmaceutical, cosmetic, automotive,
electronic, construction materials

Life pattern, living culture, preference,

Regulation

FDA
USDA
EPA
Recycle
Reuse
Refill
Reformation

Environmnet

School of Packaging
MSU RFID Lab

Advancing Knowledge.
Transforming Lives.
Packaging Materials

- Wood
- Paper
- Plastic
- Metal
- Glass

P.S., “Cardboard” is NOT a term used within Packaging; it is Solid Fiberboard or Corrugated Board
Material Impacts on RFID

- Different frequencies exhibit different behaviors.
- Metal – large effect.
- Plastic – varies with composition (PP, PET) and thickness.
- Glass – little to no effect (?)
- Paper – little or no effect (?)
- Composites – yet to be evaluated.
Problematic Matchings

- Packaging and Water-based Products.
- Any Product put in Metal Packaging.
Research to Date

• A Model For The Implementation Of A Radio Frequency Identification System Into A Warehouse Environment; Ryan


• Effects Of Frozen And Refrigerated Temperature On Transponder Performance Of Tray-Packed Beef Loin Muscle; Onderko
Research to Date

- The Effect of Tag Orientation and Package Content on the Readability of Radio Frequency Identification (RFID) Transponders; Tazelaar

- Determination Of Radio Frequency Identification (RFID) Tag Failure Modes Of Class 0 Read Only Tags; Jonson

- The Effect of Antenna Configuration, Product and Tag Type on the Readability of Passive UHF RFID Transponders; Crawforth
Research to Date

- Electromagnetic Property Measurement and RFID Signal Absorption Evaluation for Product Simulant; Zhang

- Applications And Implementation Of The U.S. Department Of Defense’s RFID Mandate; Jones
## Results of Total Reads

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>OUT</th>
<th>IN</th>
<th>FORWARD</th>
<th>UP</th>
<th>DOWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty</td>
<td>100% (0%)</td>
<td>97.1% (0.8%)</td>
<td>100% (0%)</td>
<td>100% (0%)</td>
<td>97.8% (0.4%)</td>
</tr>
<tr>
<td>Foam</td>
<td>100% (0%)</td>
<td>98.6% (0.4%)</td>
<td>100% (0%)</td>
<td>100% (0%)</td>
<td>98.0% (0.4%)</td>
</tr>
<tr>
<td>Empty Bottles</td>
<td>100% (0%)</td>
<td>97.0% (0.5%)</td>
<td>100% (0%)</td>
<td>100% (0%)</td>
<td>99.3% (0.2%)</td>
</tr>
<tr>
<td>Rice</td>
<td>99.7% (0.4%)</td>
<td>60.5% (0.9%)</td>
<td>82.6% (0.6%)</td>
<td>82.3% (0.9%)</td>
<td>78.3% (1.3%)</td>
</tr>
<tr>
<td>Water Bottles</td>
<td>67.0% (0.2%)</td>
<td>0.8% (0.3%)</td>
<td>32.3% (0.6%)</td>
<td>25.0% (0%)</td>
<td>0% (0%)</td>
</tr>
</tbody>
</table>

RED = Product Specific  Yellow = Orientation Specific  Orange = Both
Material EM Properties
Defined by Extracted Parameters

- Complex **Permittivity** ($\varepsilon$), Complex **Permeability** ($\mu$)
- Complex mathematical expression
  \[ \varepsilon = \varepsilon' + j \varepsilon'', \mu = \mu' + j \mu'' \]
  - Where, $j = \sqrt{-1}$, $\varepsilon' =$ permittivity, $\varepsilon'' =$ dielectric loss factor, $\mu' =$ magnetic permeability, $\mu'' =$ magnetic loss factor
- $\text{Re}\{\mu\},\text{Im}\{\mu\}, \text{Re}\{\varepsilon\},\text{Im}\{\varepsilon\}$.
  - Real parts are related to the energy storage of the material
  - Imaginary parts are related to the loss mechanisms that convert incident EM radiation into heat.
The Effect of Corrugated Board

Storage condition
• 22°C, 55% RH
• 29.4°C, 70% RH
• 37.8°C, 85% RH

Readability evaluation

Determination of Moisture content

Moisture content
• 8.2%
• 9.6%
• 15.3%
Readability Affected by Moisture Content
The Effect on Corrugated Board

Corrugated board CAN affect RFID operations:

- High humidity
- Low to medium humidity if:
  - Previously subjected to high humidity
  - Exposed to excessive moisture
    - Leakage of liquid product
    - Condensation
- Relationship to RPC’s
Shock Durability Testing on Tagged Cases
Vibration Durability Testing on Tagged Cases
Optimal Tag Locations

- **Column stack, tag outward**

- **Spiral, tag outward**
Bad Tag Locations

- **Column stack, tag inward**
  - 1st tier (bottom)
  - 2nd tier
  - 3rd tier
  - 4th tier (top)

- **Spiral, tag inward**
  - 1st tier (bottom)
  - 2nd tier
  - 3rd tier
  - 4th tier (top)
Reversed Tag Locations

- **Tag outward**
  - 1st tier (bottom)
  - 2nd tier
  - 3rd tier
  - 4th tier (top)

- **Tag inward**
  - 1st tier (bottom)
  - 2nd tier
  - 3rd tier
  - 4th tier (top)
Effect of Corrugated Spacers
Antennae Location and #'s
Water on Corrugated
Water on Corrugated
With UHF Tags:

- Reads stop during water applications
- Reads continue to fail if corrugated is untreated and remains wet
- Reads resume if corrugated is treated and water flow ceases
  - Similar to what happens with an RPC
  - Even if tag is embedded in plastic