High Sensitivity RFID for Tracking Assets

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Outline

- Existing passive EPC Gen2 RFID
- Long read range requirement
- Current solutions & proposed solution
- Design and principle of the active tag
- Experimental results
- Summary & comparison
EPC Gen2 Passive RFID

- Passive tags
  - Energy from readers
  - Without battery
- Typical read range around 10m
Performance of passive RFID

**Reader**
- +30dBm EIRP output power
- −80dBm sensitivity

**Tag**
- Impinj Monza R6 Tag
- Sen. = -22.1dBm

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<table>
<thead>
<tr>
<th>Reader</th>
<th>Impinj Speedway Reader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Interface Protocol</td>
<td>EPCglobal UHF Class 1 Gen 2 ISO 18000-6C</td>
</tr>
<tr>
<td>Operating Frequencies</td>
<td>865-956MHz</td>
</tr>
<tr>
<td>RF Power</td>
<td>+30 dBm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>-80 dBm</td>
</tr>
</tbody>
</table>

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**MONZA R6 TAG CHIP OVERVIEW**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read Sensitivity</td>
<td>-22.1 dBm</td>
</tr>
<tr>
<td>Write Sensitivity</td>
<td>-18.8 dBm</td>
</tr>
<tr>
<td>Die Size</td>
<td>465µm x 400µm</td>
</tr>
<tr>
<td>Memory Write Time</td>
<td>1.6ms for 32 bit write; up to 9,500 tags/min with STP® source tagging platform</td>
</tr>
<tr>
<td>EPC Memory</td>
<td>96 bits</td>
</tr>
<tr>
<td>TID Serial Number</td>
<td>48 bits</td>
</tr>
<tr>
<td>Air Interface Protocol</td>
<td>EPCglobal UHF Class 1 Gen 2 / ISO 18000-63 Gen2V2 Compatible</td>
</tr>
</tbody>
</table>
RFID for Asset Management
Motivations & Objectives

• Enhanced functions needed for wider adoption
  - Longer range: 100m
  - Sensor capability

• Unified reader
  - Current commercial readers can be used for the enhanced functionalities
  - Unified data management software can be used
Current Solutions

- Current long range Manchester BAP
  - Special reader
  - Not compliant with EPC Gen2
- Current active tag
  - ISM band radio
    - ZigBee
    - High power due to beacon
    - Complex protocol
    - High cost
  - Different data infrastructure
Solutions

- Intelleflex
  - ISO-18000-6 BAP
  - Backscatter
  - Tag Sen. -40dBm
  - Reader Sen. -120dBm

<table>
<thead>
<tr>
<th>Parameters</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reader</td>
<td>Increase output power; Modify sensitivity;</td>
<td>Modify sensitivity;</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Tag</td>
<td>Unchanged</td>
<td>BAP tags;</td>
<td>Active tag with excellent sensitivity; Transmit power when necessary.</td>
</tr>
<tr>
<td>Pros and Cons</td>
<td>-</td>
<td>Difficult; High cost with modified reader design; BAP Tag;</td>
<td>Reader unchanged; Low cost; Battery life (4-5 years is possible).</td>
</tr>
<tr>
<td>Comments</td>
<td>Bad idea</td>
<td>Good idea</td>
<td>Good idea</td>
</tr>
</tbody>
</table>

\[ P_{r_{tx}} = 56\text{dBm} \text{ (NOT allowed)}; P_{r_{sen}} = -120\text{dBm} \text{ (Difficult)}; P_{t_{sen}} = -42\text{dBm} \text{ (Battery needed)}; P_{t_{tx}} = -8\text{dBm} \text{ (Battery needed)}; \]

![Graph of RF Power vs. Free-Space Range @ 915 MHz]
Bottlenecks: RF Power

- **Backscatter modulation**
- **Maximum read range**
  - Limited by reader sensitivity
  - Increase tag output power

\[
R_{\text{max}} = \frac{\lambda}{4\pi} \left( K \cdot G_R^2 \cdot G_T^2 \cdot \frac{P_R}{\text{SEN}_{\text{reader}}} \right)^{\frac{1}{4}}
\]

- **Self-jammer in reader**
  - Limited reader sensitivity
  - -80dBm
Proposed Solution

- **Active transmitting**
  - Increased tag output power
- **Carrier recovery**
  - Track reader carrier
  - Hold for tag TX
- **Reader sees the same signal as from passive tags**

(a) Traditional EPC Gen2 passive RFID system
(b) Proposed EPC Gen2 active RFID system
Active Tag Using CRC

- Increased tag sensitivity
- **Increased tag output power**
  - Reader unchanged
- CRC (Carrier Recovery Circuit)
  - Tracking in the CW
  - Holding for the TX
Gen2 compatible Active Tag Prototype

- Envelop demodulator
  - Reader command
- OOT transmitter
  - Tag reply
- Carrier Recovery Circuit
  - Carrier $f_{LO}$
- EPC Gen2 baseband
Functionality Test

- Link timing
- Carrier recovery
Communication Test

- Reader software
  - Read rate
  - Power parameters
- Attenuator
  - Free-space path loss
  - 0~91dB with 1dB step
Power & Read Range

- **Reader**
  - Output power: 30dBm
  - Input power: −74dBm
- **Tag**
  - Input: −39.5dBm
  - Output: −4.5dBm
- **Maximum read range**
  - 154.6m
  - Antenna gain: 6dBi & 0dBi
  - Maximum PL: 69.5dB
Outdoor Test

- Antenna gain
  - $G_{\text{reader}}=6\,\text{dBi}$
  - $G_{\text{tag}}=2\,\text{dBi}$

- Read range
  - 90~105m

- Channel
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Director

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