I. UHF RFID System: Configuration and Functions
II. Code Structure
III. Comparison of Major Air Interface Standard
IV. System Design Issues
V. Sensor Network
VI. Conclusion
UHF RFID System
What is USN?

- USN above RFID
  - Everywhere, everything with RFID tags
  - Sensing ID and environmental information
  - Real time management via network

- Ubiquitous Sensor Network

- Service and application
  - BCN (IP based core network)
  - Cellular PCS
  - IMT-2000 4G
  - WLAN type
  - Wire-line xDSL

- New radio interface

- Ubiquitous Sensor Network

- Hospital
- Logistics, SCM
- Telematics, ITS
- Home network
- Animal tracking
- Environment

ETRI, The Future Wave
From RFID to USN

Read Only RFID  ➔  Read/Write RFID  ➔  Sensing USN  ➔  Networking USN

1st Step: Read only (~2004)
- Identifying product code

2nd Step: Read & Write (~2005)
- Tracking the origin
- Tag with memory

- Sensing & Control

4th Step: Communicating (~2008)
- Broadband peer to peer communication

BCN

USN

RFID Tag/Reader

ETRI, The Future Wave
900 MHz RFID Technology: Passive, Cheap, Long Range up to 10 m
RFID System: Tags, Readers, Hosts, ONS(ODS), PML Servers(EPCIS) etc.
Multimode Reader

- Multimode: EPC Class0, Class1, Class1 Gen2 (UHF Gen2) etc.

Diagram:

- RF Switch
- Antenna switching
- Frequency control
- Tx on/off control
- Multi-antenna
- A/D
- D/A
- Baseband Module (DSP/FPGA)
- CPU (ARM 9)
- Memory
- RS232
- LAN
- Host
- Network
Multimode Reader

Chips for Hand-Held Reader

- RF front-end (hybrid board: Antenna/Filter/Circulator/PA/application parts)
- RF/IF/PLL Analog (single chip/matching parts)
- Digital Processor (single chip: DSP or ASIC/application parts)

Reader CHIP Architecture (ETRI)

Chip Architecture

64 LEAD LPCC Package

ETRI, The Future Wave
Tag: tag chip and antenna

- Alien UHF Tag -

- PENI Tag -

Matrics Chip & Antenna

Antenna on a chip
Tag

Antenna  Chip

Assembly/Package

Smart Packaging

Case  Item  Food/Drinking  Healthcare  ...

Memory  Power generation  Control circuit

Packaging

Battery  Chip  Antenna
Tag Cost

IC Manufacture: 20¢
Antenna Manufacture: 5¢
Antenna/IC Assembly: 5¢
Conversion To Package: 20¢
End User: 50¢
Tag Cost

Assembly and package technology low cost tag

Flip Chip Cost Increases with Smaller ICs

FSA Cost Decreases With Smaller ICs

Cost

Total Flip Chip Inlay

Total FSA Inlay

Chip

Flip Chip Assembly

FSA Assembly

Size of Chip (mm x mm)
**Tag Chip**

### Function Blocks in Tag Chip
- **Analog**: Voltage Multiplier, Clock Generator, ASK Demodulator, Impedance Modulator
- **Digital**: Control Logic (Protocol Processor), EEPROM (+Charge Pump), Timing Control

### Related Standards
- EPC Global Class0, Class1 Gen.2, ISO/IEC 18000-6 Type A, B
Reading Operation

- **No Battery Tag** !! **Reading Distance > 5 m** !! **Reading Capacity > 100 Tags /s** !!

- **Reader Digital Processor**, **Reader Analog Chip**, **Tag Chip**

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Diagram:

- Antenna
- Reader: DSP/FPGA, RF/IF/PLL
- Tags
- Local Network
- Reader: ASK signal (code) (1) 900MHz CW (for wake up power)
- Reader: ASK signal (code) (2) ASK signal (for commands)
- Reader: CW signal (for response power)
- Reader: ASK signal (code) (3) CW signal (for response power)
- Reader: ASK signal (code) (4) ASK signal (code)
- Reader: ASK signal (code) (4) ASK signal (code)
- Reader: ASK signal (code) (4) ASK signal (code)

Distance: > 5 m
Delivered Power

Power Receiving and Scattering of the Antenna

\[
P_e = A_e \cdot S = \left( \frac{\lambda^2}{4\pi} \cdot G_2 \right) \cdot \left( \frac{EIRP}{4\pi R^2} \right)
\]

EIRP = P1 \cdot G1

When power matching (R_1 = R_t; R_v = 0; X_1 = X_\lambda)

⇒ P_e = P_s

⇒ Only half of the power drawn from the antenna is transferred to the Load (R_T)

⇒ The other half is reflected back into the space
Backscattering modulation by impedance variation

- Sending data from transponder to reader by means of modulating the load impedance of transponder ($Z_T$).
- Then, scatter aperture $\sigma$ is modulated. $P_s$ is modulated.
Legacy Systems – ERP, CRM, etc.
Middleware Interface

Application (ERP, SCM, IMS, WMS, etc)

Host (Middleware)

EPC IS Interface

EPC Information Service

Reader Interface

Reader

Reader

Reader

Application Interface

Object Discovery Service

ODS Interface
Conceptual Model of Middleware

RBPTS (Real-time Business Process Triggering System)
- Task Management
- Rule Management
- Task Database
- Rule Database

ODS (Object Discovery Service)
- Configuration Utility
- Client Resolver
- Static ODS Service
- Mapping Database

AIC (Application Interface Component)
- PMH (Processing Module Handler)
  - Core Handler
  - ReaderProxy Handler
  - U/D Handler
- MF (Message Formatter)
  - Message Object
  - SOAP Parser
  - XML Parser
- MTB (Message Transport Binder)
  - Security
  - SOAP-RPC
  - XML-RPC

EMC (Event Management Component)
- EMC Configuration Designer
- EMC Processing Unit Manager
  - Event Filter
  - Event Queue
  - Event Logger
- Event Logger Mapper
- Event Management Module

TMC (Task Management Component)
- TMC Administrator
  - Task Registration Module
  - Task Initiation Module
  - Task Definition List Browsing Module
  - Task Monitoring Module
- Task Scheduler
- Task Database

RIC (Reader Interface Component)
- Reader Controller
- Connection Manager
- Reader Profiler
- Message Generator
- Reader Monitor
ETRI, The Future Wave

Implementation Environment of Middleware

- **Harbor Container Mgmt**
- **Airport Luggage Mgmt**
- **Hospital POC**
- **Warehouse Inventory Mgmt**
- **Warehouse Stock & delivery Mgmt**
- **Postal Service**
- **Shop Mgmt**

- **Product Information Presentation**
  (PML based object information presentation and management)

- **Object Discovery Service**
  (tagged object information searching technology using Tag ID)

- **Real-time BP processing**
  (BP automation of specific tag event)

- **Communication Protocol**
  (HTTP, XML-RPC, SOAP-RPC)

- **Reader Event Management**
  (Event filtering and summarizing)

- **Operating System**
  (Unix, Linux, Windows, …)

- **RFID Reader**
  (Multi reader management, Common reader interface)

- **Computer Platform based on Open Architecture**
  (Open source based, JAVA, WAS(Tomcat), DBMS(Postgres))
Code Structure
ISO/IEC 15963

WG2: Working Group on Data Structure
WG4: Working Group on RFID for Item Management

- SG2: ISO/IEC 15963 Unique identification for RF tags

The reasons why ‘unique identifier’ is necessary

Ways to use Permanent ID

Ways to use Virtual ID
ISO/IEC 15963

Annex A (normative) Numbering system of a permanent unique ID
A.1 General
A.2 UID issuer identifier
A.3 Allocation class (AC) [Highlighted]
A.4 UID issuer registration number
A.5 Serial number
A.6 Allocation classes
A.6.1 In support of ISO/IEC 7816-6
A.6.2 In support of ISO 14816
A.6.3 In support of EAN.UCC standardized numbering
A.6.4 In support of ANS INCITS 256
A.6.5 Reserved for Future User

Annex B (normative) ISO 14816 – Numbering Systems for Supply Chain Applications of RFID

Table A.1 — Structure of the permanent unique ID

<table>
<thead>
<tr>
<th>AC</th>
<th>UID issuer Registration Number</th>
<th>Serial number</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bits</td>
<td>Size defined by AC value</td>
<td>Size defined by AC and UID issuer value</td>
</tr>
</tbody>
</table>
EPC Code Structure

- EPC (Electronic Product Code) maintained by EPCglobal
- EPC Tag Data Standards Version 1.1 Rev.1.24 (2004. April.)
- The standardized EPC data consists of
  - An EPC (or EPC Identifier)
  - An optional Filter Value

EPC Tag Bit-level Encodings

Standard EPC Tag Data

- Header
- Filter Value (Optional)
- Domain Identifier

EPC or EPC Identifier
- e.g. SGTIN, SGLN, SSCC, GID
The EPC Identifier is a meta-coding scheme which includes

- A General Identifier (GID),
- A serialized version of the EAN.UCC GTIN, the EAN.UCC SSCC, the EAN.UCC GLN, the EAN.UCC GRAI, and the EAN.UCC GIAI

At present time, 64-bit and 96-bit code structure are specified in the specification

<table>
<thead>
<tr>
<th>Header Value (binary)</th>
<th>Tag Length (bits)</th>
<th>EPC Encoding Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>64</td>
<td>[Reserved 64-bit scheme]</td>
</tr>
<tr>
<td>10</td>
<td>64</td>
<td>SGTIN-64</td>
</tr>
<tr>
<td>11</td>
<td>64</td>
<td>[Reserved 64-bit scheme]</td>
</tr>
<tr>
<td>0000 0001</td>
<td>na</td>
<td>/1 reserve</td>
</tr>
<tr>
<td>0000 001x</td>
<td>na</td>
<td>/2 reserve</td>
</tr>
<tr>
<td>0000 01xx</td>
<td>na</td>
<td>/4 reserve</td>
</tr>
<tr>
<td>0000 1000</td>
<td>64</td>
<td>SSCC-64</td>
</tr>
<tr>
<td>0000 1001</td>
<td>64</td>
<td>GLN-64</td>
</tr>
<tr>
<td>0000 1010</td>
<td>64</td>
<td>GRAI-64</td>
</tr>
<tr>
<td>0000 1011</td>
<td>64</td>
<td>GIAI-64</td>
</tr>
<tr>
<td>0000 1100</td>
<td>64</td>
<td>[4 reserve]</td>
</tr>
<tr>
<td>0000 1111</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>0011 0100</td>
<td>96</td>
<td>SGTIN-96</td>
</tr>
<tr>
<td>0011 0101</td>
<td>96</td>
<td>GIAI-96</td>
</tr>
<tr>
<td>0011 0110</td>
<td>96</td>
<td>[10 reserved 96-bit schemes]</td>
</tr>
<tr>
<td>0011 1111</td>
<td>96</td>
<td>[reserved for future headers longer than 8 bits]</td>
</tr>
</tbody>
</table>

(GTIN: Global Trade Item Number)
(SSCC: Serial Shipping Container Number)
(GLN: Global Location Number)
(GRAI: Global Returnable Asset Identifier)
(GIAI: Global Individual Asset Identifier)
The Object Directory System (ODS) provides a framework for locating networked services (EPC IS) for objects tagged with EPCs.

ODS is built over the existing DNS framework.

Given an EPC the ODS Framework will either:

- Return the IP address of the EPC IS, at the manufacturer, holding additional information about the EPC.
- Return the IP address of an internal server to which the information about the EPC can be written to.
## ODS Server

- **Local ODS Server**
- **Root ODS Server**
- **Resolver**
- **Stored Application**

### EPC Resolution
- EPC formatted as a domain name
- IP address

### Hierarchical Domain Resolution
- **Manuf1 ODS Server**
- **Manuf2 ODS Server**
EPC Information System (EPCIS)

- Provides information about an EPC-tagged object
  - EPC is used as a database lookup key

- EPC Information Services enable users to exchange data with trading partners based on EPCs.

- Really only provides the interface to this information
  - May interface to existing database, apps & information systems
  - May provide its own persistent data storage

- EPCIS previously known as the PML Server or PML Service
# Data From EPCIS

## Queries on well-defined time-stamped data

1. Time-stamped historical data
2. Observations (Tag readings)
3. Measurements (Sensor data)
4. Symbolic Location/Containment
5. EPC <-> Transaction ID

## Queries on attribute data

1. Attribute data (often static)
2. Attributes defined at serial level, e.g. date of manufacture, expiry
3. Attributes defined at product level, e.g. mass, dimensions

---

### EPC Information Service System

<table>
<thead>
<tr>
<th>Instance-level data</th>
<th>Class-level data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-stamped historical data</td>
<td>Attribute data (often static)</td>
</tr>
<tr>
<td>Observations (Tag readings)</td>
<td>Attributes defined at serial level, e.g. date of manufacture, expiry</td>
</tr>
<tr>
<td>Measurements (Sensor data)</td>
<td></td>
</tr>
<tr>
<td>Symbolic Location/Containment</td>
<td>Attributes defined at product level, e.g. mass, dimensions</td>
</tr>
<tr>
<td>EPC &lt;-&gt; Transaction ID</td>
<td></td>
</tr>
</tbody>
</table>
Physical Markup Language (PML)

Provides a collection of standardized vocabularies to represent and distribute EPC-related information.

Example include:
- observations by sensors such as RFID reads
- configurations e.g. for RFID readers
- e-commerce documents featuring Auto-ID data e.g. ASNs

```xml
<pmlcore:Sensor>
  <pmluid:ID>urn:epc:1:4.16.36</pmluid:ID>
  <pmlcore:Observation>
    <pmlcore:DateTime>2002-11-06T13:04:34-06:00</pmlcore:DateTime>
    <pmlcore:Tag>
      <pmluid:ID>urn:epc:1:2.24.400</pmluid:ID>
    </pmlcore:Tag>
  </pmlcore:Observation>
</pmlcore:Sensor>
```
Comparison of Major Air Interface Standard
## Comparison of the Major Air-Interface Standards

<table>
<thead>
<tr>
<th>항목</th>
<th>ISO 18000-6A</th>
<th>ISO 18000-6B</th>
<th>EPC class0</th>
<th>EPC class1 (V1)</th>
<th>EPC UHF G2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forward link encoding</strong></td>
<td>PIE</td>
<td>Manchester</td>
<td>PWM</td>
<td>PWM</td>
<td>Manchester</td>
</tr>
<tr>
<td><strong>Return link encoding</strong></td>
<td>FM0</td>
<td>FM0</td>
<td>FSK</td>
<td>4-interval bit cell</td>
<td>FM0 or Manchester-modulated Subcarrier</td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>ASK</td>
<td>ASK</td>
<td>ASK</td>
<td>ASK</td>
<td>ASK</td>
</tr>
<tr>
<td><strong>Modulation Index (%)</strong></td>
<td>27 ~ 100</td>
<td>18 or 100</td>
<td>20(EU), 100(US)</td>
<td>50(EU), 100(US)</td>
<td>30 or 100</td>
</tr>
<tr>
<td><strong>Data Rate (kbps)</strong></td>
<td>33 (mean)</td>
<td>10 or 40</td>
<td>slow : 16, fast : 80</td>
<td>15 (EU) 70.18 (US)</td>
<td>40, 80, 160</td>
</tr>
<tr>
<td><strong>Tag unique ID (bits)</strong></td>
<td>64 (SUID: 40)</td>
<td>64</td>
<td>64 or 96</td>
<td>64 or 96</td>
<td>128 or 256</td>
</tr>
<tr>
<td><strong>Tag Data Rate (kbps)</strong></td>
<td></td>
<td></td>
<td>slow : 40, fast : 80</td>
<td>30 (EU) 140.35 (US)</td>
<td>40,80,160 *(1~4)</td>
</tr>
<tr>
<td><strong>Preamble (bits)</strong></td>
<td>No</td>
<td>9</td>
<td>Reset(800us)</td>
<td>8 (64us)</td>
<td>6</td>
</tr>
<tr>
<td><strong>Error Detection (FWD)</strong></td>
<td>5 bit CRC (short), 5bit + 16 bit CRC (long)</td>
<td>16 bit CRC</td>
<td>16 bit CRC</td>
<td>16 bit CRC</td>
<td>16 bit CRC</td>
</tr>
<tr>
<td><strong>Collision Arbitration</strong></td>
<td>Aloha (probabilistic)</td>
<td>Binary (probabilistic)</td>
<td>Binary</td>
<td>Binary</td>
<td>Slotted Aloha</td>
</tr>
</tbody>
</table>
## Comparison of the Major Air-Interface Standards

<table>
<thead>
<tr>
<th>항목</th>
<th>ISO18000-6A</th>
<th>ISO18000-6B</th>
<th>EPC class</th>
<th>EPC class (V1)</th>
<th>EPC UHF S5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tag Inventory Capacity (tags, max)</strong></td>
<td>250</td>
<td>250</td>
<td>Up to 800 (Matrics)</td>
<td>Up to 200 (Alien)</td>
<td>1700(US)</td>
</tr>
<tr>
<td><strong>Collision Arbitration Linearity</strong></td>
<td>Up to 250 tags</td>
<td>Up to 2^{256} tags</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Channel BW (kHz)</strong></td>
<td>150kHz</td>
<td>40kHz (10kbps) 160kHz (40kbps)</td>
<td>100kHz (slow), 500kHz (fast) ← 20dB BW</td>
<td>100kHz (EU), 500kHz (N.A) ← 20dB BW</td>
<td>160, 320, 640 kHz</td>
</tr>
<tr>
<td><strong>EIRP (ISO/N.A.)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spectrum Shape</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of channels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Freq. Spreading</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Duty Cycle(%) or 채널 점유 시간(sec)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hopping Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Local Regulation
3. Comparison of the Major Air-Interface Standards

Major Parameters & comparison (3)

<table>
<thead>
<tr>
<th>항목</th>
<th>ISO 18000-A</th>
<th>ISO 18000-B</th>
<th>EPC class0</th>
<th>EPC class1 (V1)</th>
<th>EPC UHF 5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopping Sequence</td>
<td>Local regulation or Pseudo-Random</td>
<td>Local regulation</td>
<td>Local regulation or Pseudo-Random</td>
<td>Local regulation</td>
<td>Local regulation</td>
</tr>
<tr>
<td>FH rise/fall (sec, max)</td>
<td>30 μ</td>
<td>30 μ</td>
<td>-</td>
<td>-</td>
<td>25 μ</td>
</tr>
<tr>
<td>Tag Unique Identifier</td>
<td>64bits (40bit SUID)</td>
<td>64bits</td>
<td>64bits EPC 96bits EPC</td>
<td>64bits EPC (1a) 96bits EPC (1b)</td>
<td>OID (Object Identification) TID (Tag Identification)</td>
</tr>
</tbody>
</table>

NA: North America  
EU: Europe Union  
LBT: Listen Before Talk  
FHSS: Frequency Hopping Spread Spectrum  
DSSS: Direct Sequence Spread Spectrum  
SUID: Sub-Unique ID

Local Regulations  
• USA: FCC Part-15  
• EU: EN 302–208
System Design Issues
**900MHz Frequency Band in Korea**

- MIC announced to assign 908.5 ~ 914MHz bands for RFID on June 17, 2004

<table>
<thead>
<tr>
<th>Items</th>
<th>ISO/IEC</th>
<th>U.S</th>
<th>Europe</th>
<th>Japan</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tag frequency</strong></td>
<td>860~960 MHz</td>
<td>902~928 MHz (26 MHz)</td>
<td>865~868 MHz (3 MHz)</td>
<td>950~956 MHz (6 MHz)</td>
<td>908.5~914 MHz (5.5 MHz)</td>
</tr>
<tr>
<td><strong>Reader frequency</strong></td>
<td>860~960 MHz</td>
<td>902~928 MHz (26 MHz)</td>
<td>865~868 MHz (3 MHz)</td>
<td>950~956 MHz (6 MHz)</td>
<td>908.5~914 MHz (5.5 MHz)</td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>ASK</td>
<td>ASK</td>
<td>ASK</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>40kbps</td>
<td>40~80kbps</td>
<td>40kbps</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>4W EIRP</td>
<td>3.2, 0.8, 0.16 W EIRP</td>
<td>200kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BW</strong></td>
<td>250, 500 kHz</td>
<td>FHSS</td>
<td>AFA+LBT</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Freq Selection</strong></td>
<td>Local Regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
433MHz Frequency Band in Korea

- The 433MHz frequency band allocated to Amateur Radio
- MIC tries to share 433.67~434.17 MHz frequency band with Amateur Radio for RFID
### RFID Frequency and Standards

<table>
<thead>
<tr>
<th>Country</th>
<th>Frequency Range</th>
<th>Standards</th>
<th>Output</th>
<th>Transmission Speed</th>
<th>Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tag</strong></td>
<td>860 MHz to 960 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reader</strong></td>
<td></td>
<td>860-960 MHz in each country</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>902-928 MHz (ISM band 26 MHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>865-868 MHz (3 MHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>950-956 MHz (6 MHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>908.5-914 MHz (5.5 MHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>US</strong></td>
<td></td>
<td>865 MHz-928 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Europe</strong></td>
<td></td>
<td>40-80 kbps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 kbps *160 kbps added</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4W eirp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td></td>
<td>860 MHz-960 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Korea</strong></td>
<td></td>
<td>865 MHz-928 MHz</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>865-868 MHz (3 MHz)</td>
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<tr>
<td></td>
<td></td>
<td>950-956 MHz (6 MHz)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>908.5-914 MHz (5.5 MHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frequency Band</strong></td>
<td></td>
<td>860 MHz-960 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Output**: 4W eirp, 200 kHz
- **Modulation**: ASK, BFSK
- **Transmission Speed**: 40 kbps, 40-80 kbps
- **Frequency Band**: 860 MHz-960 MHz
- **Country**: US, Europe, Japan, Korea
- **Frequency Range**: 865 MHz-928 MHz
- **Standards**: ISM band 26 MHz, 865-868 MHz (3 MHz), 950-956 MHz (6 MHz), 908.5-914 MHz (5.5 MHz)
- **Output**: 4W eirp, 40 kbps, 3.2, 0.8, 0.16 W eirp
- **Modulation**: ASK, BFSK
- **Transmission Speed**: 40 kbps, 40-80 kbps
- **Frequency Band**: 860 MHz-960 MHz
- **Country**: US, Europe, Japan, Korea
- **Protection**: AFA+LBT, BFSK

---

**ETRI, The Future Wave**
Tag Antenna Design

Antenna Requirement

- Small (small area & low profile)
- Efficient (maximum power transfer to the chip)
- Wideband (860~960MHz, passive)
- Orientation Insensitive (polarization, isotropic pattern, etc)
- Easy to match the chip impedance
- Optimized to object materials
- Robust & Cheap

Possible Antennas

- Printed dipole/loop antenna
- Inverted-F antenna for metal objects
Tag Antenna Design

Dipole Antenna Type

Meaderline Antenna Type
## Tag Antenna Design

### Effects of materials near the RFID tags

- **Dielectric effects** (antenna detuning)
- **Absorption** (loss)
- **Reflection and interference**
- **Complex effects**

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect(s) on RF signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardboard/Wood</td>
<td>Absorption (moisture), Detuning</td>
</tr>
<tr>
<td>Plastics</td>
<td>Detuning</td>
</tr>
<tr>
<td>Conductive liquids</td>
<td>Absorption, Detuning</td>
</tr>
<tr>
<td>Metals</td>
<td>Reflection, Detuning</td>
</tr>
<tr>
<td>Groups of cans</td>
<td>Complex effects (lenses, filters)</td>
</tr>
<tr>
<td>Human body / animals</td>
<td>Absorption, Detuning, Reflection</td>
</tr>
</tbody>
</table>
Antenna Impedance Matching

- **Impedance Matching**

**Why Impedance Matching?**

- **What Method?**

  - Input impedance of detector is so high.
  - Insert matching ckt.: Ant. ↔ Detector
  - Modify antenna to have an impedance matching with the detector

**Antenna Types**

- Folded Dipoles
- Meanderline Antenna

**Designed by PALOMAR**

915MHz

2.45GHz
Sub-Channel Bandwidth

- **Required Bandwidth:**
  
  Data bit rate (40 kbps) * encoding rate (2 sample/1bit) * 2 (DSB AM) = 160 kHz

- **Depends on rising and falling slope**

- **High Reading Speed**

  More frequently try to read

  High Readability @ varying propagation channel
Readeable Range

- Power from Reader Antenna: 30 dBm
- Reader Tx Antenna Gain: 6 dB
- Link Loss in Air: -45.5 dB @ 5m
- Tag Antenna (Rx) Gain: less than 2 dBi
- Other Losses & Link Margin: -2.5 dB (?)

Threshold Voltage of Diode in Voltage Multiplier should be less than 100 mV

Available Max. Voltage = 100mV @ 50Ω Ant. Imp

Power transferred to Tag Chip @ 5m = (30dBm) + (6dB) – (45.5 dB) + (2 dB) – (2.5 dB) ≈ -10 dBm
Power Available at 4 Meters = 110 µW
Rectifier Efficiency = 10%
Power to IC = 11 µW

Rectifier Efficiency = 1-2 %
Power to IC = 1-2 µW

ETRI, The Future Wave
Channel Access Method: FHSS

① 각 리더는 0.4초 이하 간격으로 호핑 패턴 주파수를 랜덤하게 발생시킴
② 타 서비스에 영향을 주지 않고 공유하기 위한 방식으로 채널이 많은 경우에 주로 사용
③ 여러 개의 리더가 동일한 채널 주파수를 발생시킬 수 있으므로 상호 간섭 우려

※ FHSS : Frequency Hopping Spread Spectrum
Channel Access Method: FHSS

Packet transmission for FHSS

Frequency hopping method (Random)

Packet Collision in Random Aloha
Packet collision in Slotted Aloha
Channel Access Method: LBT+AFA

① 주파수를 가변하면서 미사용 채널을 0.1초 동안 찾아서 일정 시간 사용 후(4초) 다른 사용자를 위해 사용을 중지하는 방식
② 채널 수가 적은 주파수를 효율적으로 사용하면서 타 서비스와 공유하는 기술
③ 사용 여부를 확인하고 사용하므로 주파수 간섭 확률이 낮음
※ AFA : Adaptive Frequency Agile, LBT : Listen Before Talk

리더 #1은 채널 #1 신호 센싱하여 미사용 중이면 채널 #1 선택
리더 #2는 채널 #1 신호 센싱하여 사용중일 경우 채널 #2 신호 센싱하여 미사용중이면 채널 #2 선택
리더 #M은 채널 #1, #2 신호 센싱하여 사용중일 경우 채널 #N 신호 센싱하여 미사용중이면 채널 #N 선택
Channel Access Method: LBT + AFA

Packet transmission for LBT

LBT method (Listen before talk): No collision

1. Channel Occupation: Less than 4 sec.
2. Listen time (search for empty channel): 0.1 sec.
Channel Access Method: LBT+AFA

Transmission from other Readers

4 seconds TX then re-look for 0.1s

Don’t go there!

Channel Occupied

Channel Empty
Normalized Throughput versus Reader Density for hopping method

16 sub-carriers

Throughput for Random Aloha:
\[ S = \lambda T \cdot e^{\frac{2\lambda MT}{N}} \]

Throughput for slotted Aloha:
\[ S = \lambda T \cdot e^{\frac{\lambda MT}{N}} \]

Throughput for LBT:
\[ S = \lambda T \cdot \left( e^{-\lambda T} \right)^{M-1} + \sum_{i=1}^{N-1} \binom{M-1}{i} \left( 1 - e^{-\lambda T} \right) \left( e^{-\lambda T} \right)^{M-1-i}, \quad \text{for} \ M < N \]
\[ S = \lambda T \cdot e^{-\lambda T}, \quad \text{for} \ M \geq N \]

\( \lambda \) = arrival rate (Traffic load)
\( M \) = number of readers
\( N \) = number of channels
\( T \) = packet length
Anti-collision scheme

**Aloha (Random)**

- Framed slotted Aloha
  - Fixed frame which is composed of multiple slots
- Dynamic framed slotted Aloha (18000-6 Type A)
  - Adjustable frame according to the number of tags

**Binary tree (Deterministic)**

- ISO 18000-6 Type B: Random value based binary tree algorithm
  - Use internal counter and random generator to identify tag
- EPC class 0: Bit-by-bit binary tree algorithm
  - Bit-by-bit identification with two sub-carrier tones (Data ‘0’ for 2.2MHz, Data ‘1’ for 3.3 MHz)
  - Tree traversal: Data ‘0’ and ‘1’ matching between reader and tags
- EPC class 1: Bin slot based binary tree algorithm
  - Multiple tags Identification using Ping ID command followed by 8 bins (slot)
Framed slotted Aloha

<table>
<thead>
<tr>
<th>READER</th>
<th>1st REQ</th>
<th>Slot 1</th>
<th>Slot2</th>
<th>Slot3</th>
<th>Slot4</th>
<th>2nd REQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATE</td>
<td>101100</td>
<td>IDLE</td>
<td></td>
<td>Collision</td>
<td>101011</td>
<td></td>
</tr>
<tr>
<td>TAG1(1011)</td>
<td>101100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAG2(1010)</td>
<td></td>
<td></td>
<td>010100</td>
<td></td>
<td>010100</td>
<td></td>
</tr>
<tr>
<td>TAG3(0011)</td>
<td></td>
<td></td>
<td>001101</td>
<td></td>
<td>001101</td>
<td></td>
</tr>
<tr>
<td>TAG4(0101)</td>
<td></td>
<td></td>
<td></td>
<td>101011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Frame Size = 4
Applied Protocol: EPC C0

Required iteration for identification of all tags: \( m \times n \)
where \( m \) is the number of tags and \( n \) the length of tag ID.

Reader-to-Tag Data Transmission

Initial Data ‘0’ issuing

Data "0" selected

"001" tag ID singulated

[1st Tag Response]: three '0's

[2nd Tag Response]: two '1's and one '0'

[3rd Tag Response]: one '1'
Applied Protocol: EPC C1

1st Reader-to-Tag CMD

<table>
<thead>
<tr>
<th>CMD</th>
<th>PTR</th>
<th>LEN</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>0000</td>
<td>0001</td>
<td>0</td>
</tr>
</tbody>
</table>

2nd Reader-to-Tag CMD

<table>
<thead>
<tr>
<th>CMD</th>
<th>PTR</th>
<th>LEN</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>0000</td>
<td>0010</td>
<td>001</td>
</tr>
</tbody>
</table>

Tag responses (contention)

< Bin slot >
Binary Tree: Bin Slot

Start

Reader

Tag 1 [CRC][101001001010100]...
Tag 2 [CRC][101001101010010]...
Tag 3 [CRC][11101100110011]...

Reader

Tag 1 [CRC][101001001010100]...
Tag 2 [CRC][101001101010010]...
Tag 3 [CRC][11101100110011]...

Reader

Tag 1 [CRC][101001001010100]...
Tag 2 [CRC][101001101010010]...
Tag 3 [CRC][11101100110011]...

Backscattering

Contention

[Bin modulation]

[EOF]

[EOF]

[EOF]
Sensor Network
RFID with Sensors

RFID Tag with Sensor

MEDIA
- Twisted pair, Coaxial cable
  - Voltage or current message
- Power lines (VI)
  - 220 V Mains line, 24 V for instrumentation
- Optical cable
- Infrared
- Cable-based field buses (max 100 Mb/s)
  - LON, CAN, RS-, Interbus, Ethernet,... (VI)
- Wireless media
  - Bluetooth (1Mb/s), Home RF, IEEE 802.11b, WLAN (11 Mb/s) (2.45 GHz), GSM, GPRS, M2M...(battery)
  - Ultra Wide Band Radio (UWB)
  - RFID tags and sensors
    - Active (battery)
    - Semipassive (battery)
    - Passive (VI)

출처: VTT
Sensor Node Platform
RFID in Wireless Sensor Network

Wireless remote-powered sensor (WRPS, selected)
Bluetooth based or MEMS radio based
Input device (sensors)
Smart accessory (Processors)
Ultra low power, low cost SR radio
Memory (Data logger)
Battery-powered sensor (BPS)
RFID tag (selected)
RFID supported sensor

WRPS
PointMe
Services (e.g., community content)
IP network
Cellular network

Applications
User Interface to AI
Cellular Engine

출처: VTT
Develop a smart transducer interface standard

Make it easier for transducer manufacturers to develop smart devices and to interface those devices to networks, systems, and instruments
IEEE p1451.5 Wireless Standard

- Establish a standard for wireless communication methods and data format for transducers
- Define TEDS based on the IEEE 1451 concept
- Define protocols to access TEDS and transducer data
- Adopt necessary wireless interfaces and protocols to facilitate the use of technically differentiated, existing wireless technology solutions
IEEE p1451.5 Wireless Standard

- Bluetooth™ (802.15.1) has been proposed
- ZigBee (802.15.4) has been proposed
- All wireless standards in 802.X have been proposed
- Proprietary radio link has been proposed
Conclusion

In RFID/USN services and industrialization are more critical than R&D itself.

Purpose of Experimental Test

- To acquire all test data in the controlled environment
- To analyze and solve the found problems (in simple cases)
- Feeding the analyzed information to R&D Team
To make successful story in RFID/USN

- R&D Activities in various areas
  - Sensors, battery, Semiconductor, MEMS, adhoc network, tiny O/S, SAL, Chip-less Tag, etc.
- To start from service modeling
- To spread RFID Technology and Services
- To construct RFID/USN Infra
- To implement Ubiquitous IT using RFID/USN and BcN

Global Activities

- Standardization Activities
  - ISO/IEC JTC1/SC31, EPCglobal, IEEE1451, IEEE802.15.4, SAL-C, u-ID Center etc.
- Regional Country's Cooperation
Thank You

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