Antenna design 3: RFID tag antennas using AMCs

Dongho Kim, Professor, Ph/D
Antennas & EM applications Lab., Sejong University

dongkim@sejong.ac.kr
Overview – RFID

- Normal operation of RFID antennas
  - Applications: identification, management, tracking, etc.
  - Almost all tags are designed for stand-alone operation in air
    - Air has relative permittivity ($\varepsilon_r$) = relative permeability ($\mu_r$) = 1
    - However, are they really installed in air?

**Scenario I**

Successful identification

RFID Reader antenna

RF energy

Tag antenna

Information
Overview – RFID

- Problem of conventional RFID tag antennas
  - Tags do not properly operate on metallic surfaces or high dielectric materials, Why not?
    - On a metallic platform: antenna surface current is shorted out
    - On a high dielectric platform: antenna input impedance severely varies

*Scenario II*

Identification failure

No response (or very poor response) from the tag

RFID Reader antenna

Common Problem !!!
Overview – RFID

- How can we increase reading distances?
  - Platform (or product)-tolerant tags are needed
    - Artificial magnetic conductor (AMC) is the right technique for our problem
    - , which increases recognition distance with the minimum influence of various platforms

**Scenario III**

Identification success with a longer reading distance

**Increased reading distance**

**Stronger response from the tag**

RFID Reader antenna

Metallic body (or water)

AMC

Tag on an AMC
Overview – AMC

Idea: Manipulation of reflection phase

- Reflection phase
  - Perfect electric conductor (PEC): \( \pi (=180^\circ) \)
  - Perfect magnetic conductor (PMC): \( 0 \)
  - Artificial magnetic conductor (AMC): \( \text{freq. dependent, controllable phase response} \)

- Antenna applications
  - Distance between an antenna & a substrate

Reflection phase

\[ \begin{align*}
\text{PEC} & : \pi (=180^\circ) \\
\text{PMC} & : 0 \\
\text{AMC} & : \text{freq. dependent, controllable phase response}
\end{align*} \]

\[ \begin{align*}
\beta h + \beta h & \pm \angle \Gamma (=\pi) = 2m\pi \\
\beta h + \beta h & \pm \angle \Gamma (=0) = 2m\pi
\end{align*} \]

Constructive interference condition

- PEC ground
  \[ h = \frac{2m \mp 1}{2\beta} \pi = \frac{2m \mp 1}{4} \lambda \]
- PMC ground
  \[ h = \frac{2m}{2\beta} \pi = \frac{m}{2} \lambda \]
Applications: long range

- Provides a much longer reading distance
  - Based on a creative idea of impedance matching
    - Using coupling effects between the tag and the cavity
  - Installing the tag in the metallic cavity
  - Target applications: large objects such as metallic containers, cars, trains, aircrafts, etc.

**Single-band application cavity**
(Recessed volume in a metallic object)

910 MHz band (Korea, USA)

**RFID tag antenna**
(Fairly simple geometry)

**Strap type**
Higgs-2 chip: 11-j130 Ω

Applications: long range

- Provides a much longer reading distance
  - Based on a creative idea of impedance matching
    - Using coupling effects between the tag and the cavity
  - Installing the tag in the metallic cavity
    - Target applications: large objects such as metallic containers, cars, trains, aircrafts, etc.

Recessed hollow cavity

모델링: CST Microwave Studio
Applications: long range

- Effect of the cavity size
  - Longer length (in the $x$-direction) $\rightarrow$ increases a resonant frequency
  - Longer length (in the $y$-direction) $\rightarrow$ decreases a resonant frequency
  - which can be explained parasitic inductance and capacitance
Applications: long range & dual bands

- Design of the AMC cells
  - Using offset vias $\rightarrow$ reduced cells $\rightarrow$ we can accommodate the AMC cells in the cavity

- Control the reflection phase
  - It's very easy to control the reflection phase by varying via offset ($l_{\text{offset}}$), (even with the fixed length of the cell)

Unit cell of AMC

CST MWS

Reflection coefficient [deg]

Unit cell of AMC

CST MWS
Applications: long range & dual bands

- Changing coupling effect from the bottom surface of the cavity
  - Installing an AMC on the bottom of the cavity
    - Varies phase values of the wave reflected from the AMC
      - By selecting appropriate reflection phase of the AMC, we can make the tag resonate another frequency of interest
      - At the two frequencies of interest, we can obtain the same phase values

Dual-band application
Cavity + AMC ground

- 869 MHz band (European)
- 910 MHz band (Korea, USA)

RFID tag antenna
(Fairly simple geometry)

Strap type
Higgs-2 chip: 11-j130 Ω

Changing coupling effect from the bottom surface of the cavity

- Installing an AMC on the bottom of the cavity
  - Varies phase values of the wave reflected from the AMC
    - By selecting appropriate reflection phase of the AMC, we can make the tag resonate another frequency of interest
    - At the two frequencies of interest, we can obtain the same phase values

Applications: long range & dual bands

- Effect of the AMC ground plane
  - At the three different resonant frequencies
    - The antenna shows the same overall phase value of about 90 degrees.

- Surface current density of the AMC

CST Microwave Studio 사용

Surface current density on the AMC
### Performance comparison

#### Performance evaluation
- **Reference tag:** commercial Alien ALN-9540
- **Experimental environment**
  - RFID tester: commercial TESCOM TC-2600A
  - Reader: ALR-9800 reader with transmitted power of 30 dBm
- **Experimental results**

<table>
<thead>
<tr>
<th>Items</th>
<th>Simulation</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. gain</td>
<td>Best matching (Min. VSWR)</td>
</tr>
<tr>
<td>Alien ALN-9540</td>
<td>2.1 dB</td>
<td>1.1 @ 915 MHz</td>
</tr>
<tr>
<td>Proposed tag (single band)</td>
<td>7.1 dB</td>
<td>1.2 @ 912 MHz</td>
</tr>
<tr>
<td>Proposed tag (dual bands)</td>
<td>6.74 dB</td>
<td>1.03 @ 864 MHz</td>
</tr>
<tr>
<td></td>
<td>6.46 dB</td>
<td>1.23 @ 910 MHz</td>
</tr>
</tbody>
</table>
Conclusions

- Using the controllable behavior in reflection phase of AMCs, it’s possible to
  - Fabricate RFID tag antennas that are platform tolerant
  - Extend the recognition distance (by using a recessed metallic cavity)
  - Make the tag operate at two different frequencies