Complete Technology and RFID

Overview
Operating Principles
Inductive Coupling
Microwave Coupling
Coupling to Circuit Simulation
Summary

T. Wittig
Overview

Radio Frequency IDentification

Fundamental tool for Automatic Identification: authentication, ticketing, access control, supply management, parking, payment, vending, surveillance

Advantages:
- Contains more information than e.g. Barcodes
- Can be read/write
- Contactless ID (in contrast to phone or bank cards)
- May become cheap mass product (e.g. in supermarkets)
Typical characteristics of RFID:

- Tag is a passive device, energy is transmitted from reader
- Distance mm to 10m (typically ~20 cm)
- Contains silicon chip, can be read only or read/write
- Responds with modulated signal
- Mostly printed (planar) structures
# Frequencies

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>125/134 kHz</td>
<td>Animal identification, industrial applications, very robust, low data transmission (64 bit)</td>
</tr>
<tr>
<td>7.4 - 8.8 MHz</td>
<td>Electronic Article Surveillance (EAS)</td>
</tr>
<tr>
<td>13.56 MHz</td>
<td>&quot;Smart Labels&quot; widely used for product/article ID</td>
</tr>
<tr>
<td>868 - 928 MHz</td>
<td>Logistics,…</td>
</tr>
<tr>
<td>2.4 GHz</td>
<td>Vehicle identification, electronic toll collection</td>
</tr>
<tr>
<td>5.8 GHz</td>
<td>electronic toll collection in Europe</td>
</tr>
</tbody>
</table>
Operating Principles

**Inductive Coupling (125 kHz - 15 MHz)**

- Very small dimensions compared to \( l \)
- Coupling only through magnetic field
- Tag typically a planar coil

**Microwave Coupling (868 MHz - 5.8 GHz)**

- typically a regular antenna
  (e.g. planar folded dipole)
- Matching network important to keep antenna small
Inductive Coupling

RFID tags are mostly **planar coils** with small dimensions compared to $\lambda$.

Hexahedral or tetrahedral F-Solver are typically most suited.

Simple Example for 13.56 MHz

At 13.56 MHz

Measurement: $(7.15 + 398i) \ \Omega$

Simulation: $(7.0 + 334i) \ \Omega$

RLC parallel equivalent circuit fits broadband to simulation results
Reader & Tag
Inductive Coupling: 13.56 MHz

Complex Example for 13.56 MHz
Zoom into Reader
Zoom into Tag
Circuit in CST DESIGN STUDIO
Microwave Coupling: Typical TAG

**SMALL FORM FACTOR TAGS**

**GEN 2 1X1**

- Optimized for operation from 902 to 928 MHz
- Small form factor tag optimized for plastic packaging such as pharmaceutical pill bottles
- Near-field and far-field communication modes
- 25.4mm x 25.4mm

http://www.alientechnology.com/docs/Gen2_TagFam_datsht.pdf
S-Parameter
$|S_{11}|$ in dB, unmatched
Matching Network in CST DS

Parameters to optimize

Goal definition
Surface-Current and Farfield

\( f = 900 \text{ MHz} \)

Current Distribution before matching

Current Distribution after matching

\( \phi \)-component

\( \theta \)-component
Parameter Study of a warped Tag
Parameter Study of a Warped Tag

Farfield at 1.15 GHz

Type: FarField
Approximation: enabled (kR >> 1)
Monitor: Farfield (f=1.15) [1]
Component: Abs
Output: Directivity
Frequency: 1.15
Rad. effc.: 0.2567
Tot. effc.: 0.1617
Dir.: 1.528 dB
Reader: Geometry

Simple, vertically polarized patch-type reader
Reader: Optimization

Parametric model setup

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>24.339</td>
</tr>
<tr>
<td>b</td>
<td>35</td>
</tr>
<tr>
<td>d</td>
<td>5</td>
</tr>
<tr>
<td>offset</td>
<td>4</td>
</tr>
</tbody>
</table>

Goal=S11 min at 900 MHz
Reader: Directivity

f = 900 MHz

Type = Farfield
Approximation = enabled (kR >> 1)
Monitor = farfield (f=.9) [1]
Component = Abs
Output = Directivity
Frequency = 0.9
Rad. effic. = 0.9912
Tot. effic. = 0.9628
Dir. = 3.449 dBi
Tags on medical pill-boxes

Distance = 2000mm
Advanced Meshing
PBA + Subgrid

Without subgridding:
~7.3 million mesh-cells

With subgridding:
313.964 mesh-cells
S-Parameter
$|S|$ in dB

Simulation time: 2.2h on 32bit machine, 400MB
E-Field > e-field (f=900) MHz

Vertical view

Animated top view

Type = E-Field (peak)
Monitor = e-field (f=.9) [S]
Component = Abs
Plane at y = 75.7
Frequency = 0.9
Phase = 67.5 degrees
Maximum 2d = 12624.8 V/m at 2000.7 / 75.7 / 45.72

CST - Computer Simulation Technology
Simulation of tags and reader

New transient task in CST DS

- Tag-load (chip)
- Matching network
- Reader-Port

Ports 2-5: Tag

Pin (nPin)

broadband 0-4 GHz
Summary

- RFID is a general concept using different technical principals

- CST complete technology approach offers best solution for each case
  - CST MWS Frequency Domain / CST EMS for inductive type
  - CST MWS Transient for microwave type

- Coupling between CST DS and CST MWS allows easy combination of circuit and 3D EM analysis, e.g. for
  - Tag matching networks
  - Reader circuits (new transient solver in CST DS)