Near-Field Reader Antenna (NFRA) for RFID Label Printer Applications

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B. Enkhbayar
B.-C. Ahn

Applied Electromagnetics Laboratory, Chungbuk University
(http://ael.chungbuk.ac.kr)
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction</td>
<td>01</td>
</tr>
<tr>
<td>II. State of Technology</td>
<td>02</td>
</tr>
<tr>
<td>III. Reference Tag Antenna</td>
<td>12</td>
</tr>
<tr>
<td>IV. Reference Far Field Antenna</td>
<td>14</td>
</tr>
<tr>
<td>V. Design of Antenna Type 1A</td>
<td>17</td>
</tr>
<tr>
<td>VI. Design of Antenna Type 1B</td>
<td>25</td>
</tr>
<tr>
<td>VII. Design of Antenna Type 1C</td>
<td>33</td>
</tr>
<tr>
<td>VIII. Appendix</td>
<td>41</td>
</tr>
</tbody>
</table>
I. Introduction

- RFID Label Printer

- Antenna Requirements
  - Size: 40mm x 100mm x 15mm
  - Read range: \( h = 0 \) cm from the aperture
  - Do not read tags that are not on the antenna aperture.
  - Do not miss tags on the antenna aperture.
  - Frequency: 915MHz, \( \Delta f = 20 \) MHz
II. State of Technology


  ‘Segmented magnetic antennas for near-field UHF RFID’

  - Size: \( D \) (diameter)=5cm
  - Performance: \( BW=40\text{MHz} \) (890-930MHz)
  - Reading distance: 5.5cm

[Reflection coefficient graph]

[Transmission coefficient graph]

[Read percent vs distance graph]
II. State of Technology

- Paper 2: Qing, Goh & Chen (2009)
  
  ‘UHF near-field RFID reader antenna’
  
  - Size: 160mm x 180mm x 0.5mm on an RF-4
  - Performance: BW= 240MHz (800-1040MHz)
II. State of Technology

- Paper 3: Qing, Goh & Chen (2010)
  ‘A broadband UHF near-field RFID antenna’
  - Size: 175mm x 180mm x 0.5mm on an RF-4
  - Performance: BW= 230MHz (820-1050MHz)
    Read distance (-30dB): 24mm

Reflection coefficient  Current distribution  Magnetic field distribution
II. State of Technology

- Paper 4: Ong, Qing, Goh & Chen (2010)
  
  ‘A segmented loop antenna for UHF near-field RFID’
  
  - Size: 170mm x 180mm x 0.5mm on an RF-4
  - Performance: BW= 300MHz (770-1070MHz)
  
  Reading distance (-30dB): 24mm

\[ H_z \text{ along } x\text{-axis} \]

\[ H_z \text{ along } y\text{-axis} \]

Magnetic field distribution
II. State of Technology


  ‘Planar near-field RFID reader antenna using opposite-directed currents’

  - Size (inner): 120mm x 177mm x 30.6mm
  - Performance: Reading distance: 24cm

  Magnetic field distribution
II. State of Technology

- Patent 1: Shafer, Bomber, Reynolds et all (2010)

‘RFID near-field microstrip antenna’
II. State of Technology

- Patent 2: Choi, Kim, Bae, Choi and Chae (2010)

‘Near-field radio frequency identification reader antenna’
II. State of Technology


  ‘Near-field RFID reader antenna’
  
  - Performance: BW=893-925MHz (32MHz)
II. State of Technology

- Product 1: Impinj Inc. (CS-777-2)

  'Near-Field Reader Antenna’
  - Size: Diameter= 30cm, Height=6cm, Weight= 0.9kg
  - Performance: BW=902-928MHz (26MHz)
    Far Field Gain = 6dBi
    Read Range = 40 cm

- Product 2: GAO RFID Inc.

  'Standalone RFID Reader’
  - Size: 114.3mm x 114.3mm x 50.8mm, Weight= 220g
  - Performance: BW=860-960MHz (100MHz)
    Read Range = 10 cm
    Housing = ABS
II. State of Technology

- Product 3: Kathrein Co. (52010085)
  ‘RFID Low Range Antenna’
  - Size: 90mm x 63mm x 31mm
  - Performance: BW=902-928MHz (26MHz)
    Far Field Gain = -15dBi
    Read Range = 7 cm

- Product 4: Kathrein Co. (52010094)
  ‘RFID Low Range Antenna’
  - Size: 90mm x 63mm x 31mm
  - Performance: BW=865-928MHz (63MHz)
    Far Field Gain = -30dBi
    Read Range = 8 mm
III. Reference Tag Antenna

- 3D View
  - Size: 49mm x 60mm x 0.05mm
  - $S_{11}$: 892.7-942MHz (49MHz)
  - Substrate: PET $\varepsilon_r=3.9$, $\tan\delta=0.003$, $t=50\mu$m

Feed position: $g=2.27$mm
III. Reference Tag Antenna

- Performance

- 3D Gain:
  - $G_{\text{abs}}$: 0.9dB
  - $G_{\theta}$: 0.49dB
  - $G_{\phi}$: 0.9dB

- Near magnetic field: at 2cm above the antenna surface
IV. Reference Far-Field Antenna

☐ 3D View

- Size: 160mm x 160mm x 2mm (horiz. ground plane), 160mm x 30mm x 2mm (vert.)
- $S_{11}$: 877-950MHz (73MHz)
- Dielectric: MC Nylon, $\delta_r=2.7$, $\tan\delta=0.01$, $t=20mm$
IV. Reference Far-Field Antenna

- Performance

- 3D Gain:
  - $G_{\text{abs}}$: 6.55dB
  - $G_{\theta}$: 3.84dB
  - $G_{\phi}$: 3.95dB

- Near magnetic field: at 2cm above the antenna surface
IV. Reference Far-Field Antenna

Tag Read Performance

- Tag position: above the aperture center

\[ S_{11}^{\text{reader}} \]
\[ S_{11}^{\text{tag}} \]
\[ S_{21}^{\text{transmission}} \]
V. Design of Antenna Type 1A

- Type 1A: Cavity GP+ABS Cover

- Antenna Geometry: FR-4 ($\delta_r=4.4$, $\tan\delta=0.02$), 130.2mm x 40mm x 1mm
V. Design of Antenna Type 1A

☐ Antenna Housing

- Metal case: 140mm x 50mm x 15mm, $t=2mm$
- ABS cover: ($\delta=2.8$, $\tan\delta=0.01$) 140mm x 50mm x 2mm
- Antenna-to-ground spacing: 3.5mm

☐ Antenna Performance

- $S_{11}$: 909-928MHz (18MHz)
V. Design of Antenna Type 1A

- **Antenna Performance**

  - **Far-Field 3D Gain:**
    - $G_{abs}$: -25.65dB
    - $G_{theta}$: -35.6dB
    - $G_{phi}$: -25.8dB

  - **Near magnetic field:** at 2cm above the antenna surface

![Graphs showing 2D and 1D results for magnetic field components](image_url)
V. Design of Antenna Type 1A

- Tag Read Performance

- Tag position: above the aperture center

![Graphs showing S11 and S21 parameters]

- Tag position

![Diagram of antenna structure]
V. Design of Antenna Type 1A

- Tag Read Performance
  - Tag position: above the aperture center

![Graphs showing S11reader, S21transmission, and S11tag](image_url)

- Tag position: above the aperture center

![3D illustration of antenna](image_url)
V. Design of Antenna Type 1A

- Tag Read Performance

  - Tag position: above the aperture center

![Graphs showing S11, S21, and S22 parameters]

- Tag position: above the aperture center

![Antenna diagram with tag position highlighted]
V. Design of Antenna Type 1A

- Tag Read Performance
  - Tag position: above the aperture center
Tag Read Uniformity

- Tag position: at $z=2\text{cm}$ above the aperture

$\text{x-variation}$

$\text{y-variation}$
VI. Design of Antenna Type 1B

- Type 1B: Cavity GP+ABS Cover
- Antenna Geometry: FR-4 ($\delta_r = 4.4$, $\tan \delta = 0.02$), 126mm x 37mm x 1mm
VI. Design of Antenna Type 1B

- Antenna Housing
  - Metal backing: 140mm x 50mm (no sidewall), t=2mm
  - ABS cover: ($\delta=2.8$, $\tan\delta=0.01$) 140mm x 50mm x 2mm
  - Antenna-to-ground spacing: 3.5mm

- Antenna Performance
  - $S_{11}$: 903-922MHz (19MHz)
VI. Design of Antenna Type 1B

- Antenna Performance

  - Far-Field 3D Gain:
    - $G_{\text{abs}}$: -8.9 dB
    - $G_{\theta}$: -21.8 dB
    - $G_{\phi}$: -8.9 dB

  - Near magnetic field: at 2cm above the antenna surface

- 2D-|H|  
- 1D-$H_x$  
- 1D-$H_y$  
- 1D-$H_z$
VI. Design of Antenna Type 1B

- Tag Read Performance

- Tag position: above the aperture center

- \( S_{11\text{reader}} \)

- \( S_{11\text{tag}} \)

- \( S_{21\text{transmission}} \)
VI. Design of Antenna Type 1B

- Tag Read Performance

- Tag position: above the aperture center

- Tag position

\[ S_{11\text{reader}} \]

\[ S_{11\text{tag}} \]

\[ S_{21\text{transmission}} \]
VI. Design of Antenna Type 1B

- Tag Read Performance

- Tag position: above the aperture center

- $S_{11}$ reader

- $S_{11}$ tag

- $S_{21}$ transmission
VI. Design of Antenna Type 1B

- Tag Read Performance

- Tag position: above the aperture center

- Graphs showing S\(_{11}\) and S\(_{21}\) performance across frequency

- S\(_{11}\) reader and S\(_{11}\) tag graphs

- S\(_{21}\) transmission graph
VI. Design of Antenna Type 1B

- Tag Distance Uniformity
  - Tag position: at $z=2\text{cm}$ above the aperture

Graphs showing transmission coefficient in dB for $x$-variation and $y$-variation.
VII. Design of Antenna Type 1C

- Type 1C: Cavity GP + Rohacell Cover
- Antenna Geometry: FR-4 ($\delta_r = 4.4$, $\tan \delta = 0.02$), 113mm x 37mm x 1mm
VII. Design of Antenna Type 1C

- Antenna Housing
  - Metal backing: 140mm x 50mm (no sidewall), \( t = 2 \text{mm} \)
  - Rohacell (31 IG/A) fill: \( \delta_r = 1.05, \tan\delta = 0.0003 \)
    140mm x 50mm x 15mm
  - Antenna-to-ground spacing: 4mm (with Rohacell fill)

- Antenna Performance
  - \( S_{11} \): 905-922MHz (17MHz)
VII. Design of Antenna Type 1C

Antenna Performance

- Far-Field 3D Gain:
  - $G_{abs}$: -9.14 dB
  - $G_{theta}$: -19.6 dB
  - $G_{phi}$: -9.14 dB

- Near magnetic field: at 2cm above the antenna surface

2D-$|H|$ | 1D-$H_x$ | 1D-$H_y$ | 1D-$H_z$
VII. Design of Antenna Type 1C

- Tag Read Performance
  - Tag position: above the aperture center

- Diagrams showing S11, S21, and S22 parameters for different frequencies.
VII. Design of Antenna Type 1C

- Tag Read Performance

- Tag position: above the aperture center

- S\textsubscript{11}\text{reader}

- S\textsubscript{11}\text{tag}

- S\textsubscript{21}\text{transmission}
VII. Design of Antenna Type 1C

- Tag Read Performance
  - Tag position: above the aperture center

![Graphs showing S11 and S21 parameters](image)

Tag position: above the aperture center

- Tag position

- S11reader
- S11tag
- S21transmission
VII. Design of Antenna Type 1C

- Tag Read Performance
  - Tag position: above the aperture center

![Graph and diagram showing Tag Read Performance](image-url)
VII. Design of Antenna Type 1C

- Tag Distance Uniformity
  - Tag position: at $z=2$cm above the aperture

![Graph showing x-variation](image)

![Graph showing y-variation](image)
VIII. Appendix

Mesh problem

- Tag position: at \( z = 5 \text{cm} \) above the aperture

- \( S_{11\text{reader}} \) vs mesh
- \( S_{11\text{tag}} \) vs mesh
- \( S_{21\text{transmission}} \) vs mesh
Tuning problem

Antenna type 1B with high mesh

\[ S_{11} \text{ vs cut} \]
1. 4 x 10 cm
Array
2. 20 x 20 cm (segmented loop antennas)

a.
b.
c.
3. 100 x 80 mm