Chipless-RFID Sensors for Motion Control Applications

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Outline

1. Motivation & Objectives
2. Working Principle
3. Reader and Encoder
4. Fabrication and Measurement
5. Conclusion
1. Motivation & Objectives

In **Motion Control applications** it is often required to use a huge amount of sensors in order to determine velocity, acceleration, displacement, among others magnitudes.

Most of such sensors are based on **optical technology**, where by counting the apertures in the encoder the position can be determined (**incremental position**)
1. Motivation & Objectives

The main objective of this work is to implement a **microwave sensor**, to measure displacement & velocity/acceleration, based on the functionality of optical encoders.

The system is inspired by the **Near-Field Chipless-RFID approach**.

The Microwave Sensor:
- Designed on a PCB (planar technology)
- Provide the absolute position (Bruijn)
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2. Working Principle

The proposed system has the same working principle that Near-Field Chipless-RFID:

1. A harmonic signal is generated to operate at certain frequency

2. At the sensitive part of the reader, the encoder motion modulates the injected signal.

3. An envelope detector demodulates the signal and the code is obtained.
2. Working Principle

For **Synchronous reading** it is required to have at least a pair of harmonic signals \((V_1 \& V_2\) pure tones) \(\Rightarrow\) Therefore, **two sensing elements** in the sensitive part of the **reader** are needed.

On the **encoder**, only one chain of metallic patches is employed in this approach and the binary states can be distinguished according the **patch size (width)**.
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3. Reader & Encoder

The **Sensitive Part** of the reader consists of Microstrip Transmission Line loaded with **two CSRRs**, and an outer ring for tailoring the Q factor.

![Diagram of Reader and Encoder](image)

The **Encoder** is made of **metallic patches**. The **presence** of the patch is used for **synchronous** purposes, as well as to obtain the **velocity**. The **binary states** are associated to the **patch size**. The wider and narrow patches correspond to ‘1’ and ‘0’, respectively.
3. Reader & Encoder

The Sensitive Part of the reader has **two operation frequencies**
3. Reader & Encoder

The **Inner** CSRR provides the higher resonant frequency at:

@ $f_{0,v} = 5.31$ GHz

![Diagram of Sensitive Part with CSRR and graph showing resonance frequency]
3. Reader & Encoder

Sensitive Part

The **Outer** CSRR provides the lower resonant frequency at:

@ \( f_{0,ID} = 4.63 \text{ GHz} \)
3. Reader & Encoder

When a patch relies on top of the Sensitive Part, the Narrow Patch only has effect in the inner CSRR, resulting in a shift of the higher frequency.
3. Reader & Encoder

When a patch relies on top of the Sensitive Part

The **Wider** Patch has effect on both the inner and the outer CSRRs, resulting in a shift of the **lower** and the **higher** frequencies.

![Diagram showing the effect of the Wider Patch on CSRRs](image-url)
3. Reader & Encoder

**SUMMARY of the Binary States**

<table>
<thead>
<tr>
<th></th>
<th>$f_{0,ID}$</th>
<th>$f_{0,v}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Reader</td>
<td>'0'</td>
<td>'0'</td>
</tr>
<tr>
<td>Narrow Patch</td>
<td>'0'</td>
<td>'1'</td>
</tr>
<tr>
<td>Wider Patch</td>
<td>'1'</td>
<td>'1'</td>
</tr>
</tbody>
</table>
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4. Fabrication & Measurement

Fabricated in *Rogers RO4003C* (\( \varepsilon_r = 3.38, \tan\delta = 0.0022 \)) by means of a milling machine (*LPKF H100*).

Electromagnetic Simulation and measurement of the sensitive part of the reader (bare reader).

- Fabricated layer: \( h = 0.2 \text{ mm} \)
- Measured layer: \( h = 0.8 \text{ mm} \)
4. Fabrication & Measurement

The measurements were carried out **sequentially**, firstly generating the harmonic signal @ $f_{0,v}$ and later the harmonic signal @ $f_{0,ID}$.

Finally, the results were jointly **processed**.

The **black peaks** allow us to determine the encoder **velocity**, whereas the **blue peaks** are the **identification** (Bruijn sequence).
4. Fabrication & Measurement

The functionality of the system was tested by increasing the encoder velocity up to 14 mm/s.

The encoder was also accelerated at 1 mm/s², and in the middle of the reading, the encoder was decelerated at -1 mm/s².
Finally, the encoder was deliberately cracked in order to test the robustness against wearing or friction.

Encoder before being cracked

Encoder after being cracked
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5. Conclusion & Future Work

- An approach for an **electromagnetic encoder** useful for motion applications, and based on the **Near-Field Chipless RFID approach**, has been proposed.

- The **Reader** consists on a microstrip line loaded with a pair of complementary split ring resonators (CSRRs). The **smaller CSRR** is devoted to determinate the **encoder velocity**, whereas the **longer CSRR** is used to infer the **ID code**.

- **Encoders** are based on a single chain of **rectangular patches**, and the **size** of the patch determines the binary state of the **ID**.

- **Experimental validation** was carried out by reading a **16-bits encoder** by testing different **velocities** and **accelerations**, as well as by cracking the encoder.
Thank you for your attention.