Extending the range of NFC capable devices

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The rise of the cashless city: 'There is this real danger of exclusion'

Cities from Sweden to India are pushing for a totally cash-free society. But as more shops and transport networks insist on electronic payments, where does this leave the smallest traders and poorest inhabitants?

Source: The Guardian

Contactloos betalen vervijfvoudigd in 2016

Datum 25.01.2017 Bron Betaalvereniging Nederland

Het aantal contactloze betalingen is in 2016 bijna vervijfvoudigd tot 630 miljoen betalingen. Afgelopen december was 23,5 procent van alle pinbetalingen contactloos. Bij twee derde van alle betaalautomaten in Nederland kun je inmiddels contactloos betalen. Ruim 19 miljoen betaalpassen en smartphones zijn daarvoor geschikt.

Source: Betaalvereniging Nederland

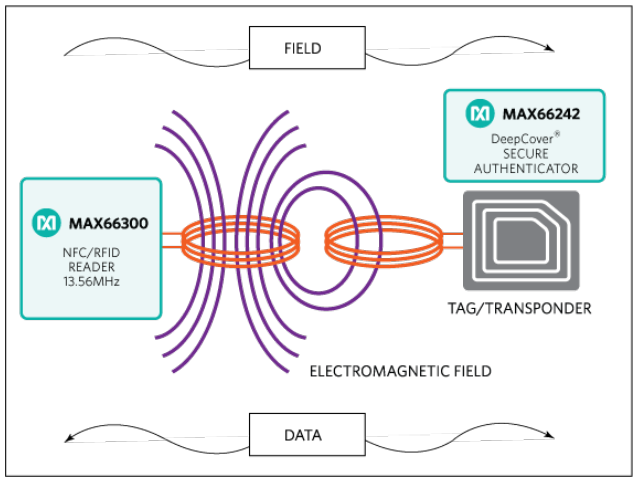
NFC

- NFC is a subtype of RFID
- NFC High frequency 13.56 MHz
- Reader & tags
- Active & Passive devices

Source: NPO

Inductance

- Electromagnetic field $\rightarrow$ coupling
- Inductance of each antenna needs to be within 0.3 - 3μH
- NFC needs to be tightly coupled
- Tags can deduce the data from the power that's being transferred (load modulation)



Source: Maxim Integrated

Calculating self inductance

$$L = N^2 \frac{\mu_0 \mu_r}{\pi} (-2(w+h) + 2\sqrt{h^2+w^2} - h \times$$
$$\log\left(\frac{h+\sqrt{h^2+w^2}}{w}\right) - w \times \log\left(\frac{w+\sqrt{h^2+w^2}}{h}\right)$$
$$+ h \times \log\left(\frac{2h}{a}\right) + w \times \log\frac{2w}{a}) \div 10000$$

Source: Missouri University of Science and Technology

Formula explained

- N equals the number of rounds of wire
- w is the width and h is the height of the rectangular antenna in cm
- a equals the radius of the wire in cm
- μ_r is the relative permeability of the medium, which is 1 (air)
- μ_0 equals the physical constant (vacuum permeability)

The result is the self-inductance of a rectangular loop antenna in μH

Problem statement & Research Questions

- What properties of the rectangular loop antenna of an NFC reader and the NFC tag influence the effective range of communication with passive NFC devices?
  - Thickness and length?
  - Orientation and angle?
  - Multiple NFC tags?

Methodology

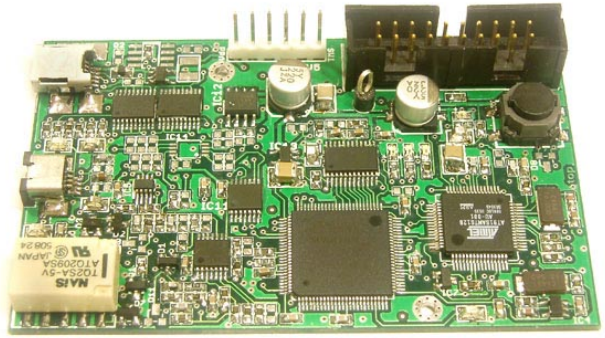
- Conducting literature research
- Defining experiments
- Preparing the experimental tools and setup
- Conducting the experiments
- Analyzing the results
- Defining a conclusion

Experiments

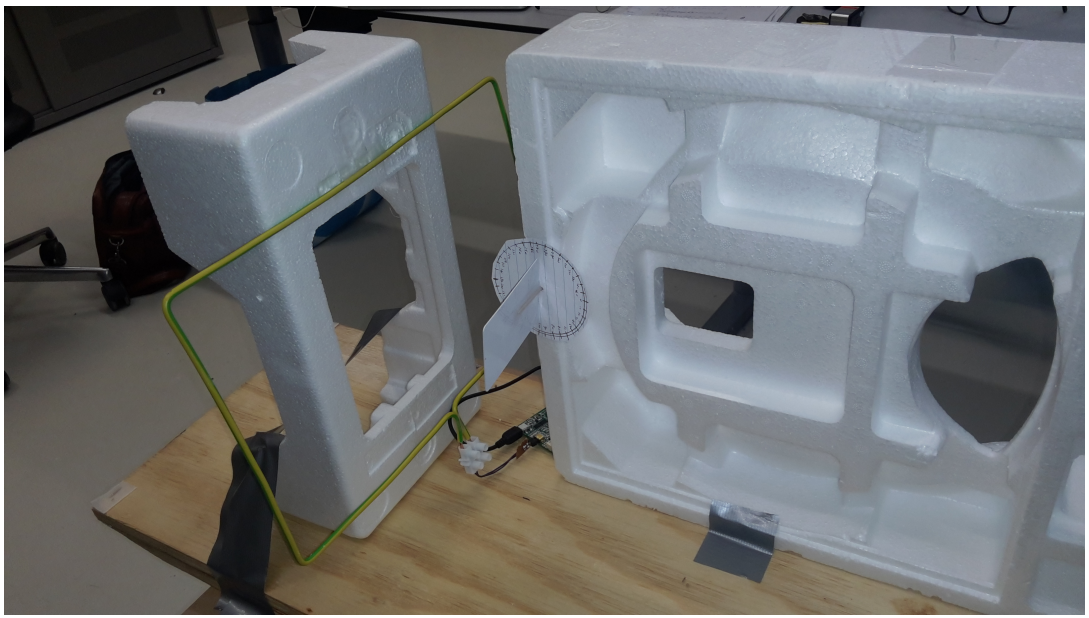
- **Experiment 1:**Creating four different antennas of different sizes and wire diameter
- **Experiment 2:**Analyzing the effect of altering the orientation and angle of the smart card
- **Experiment 3:**Analyzing the effect of having multiple smart cards within the range of the Proximity Coupling Device (PCD)

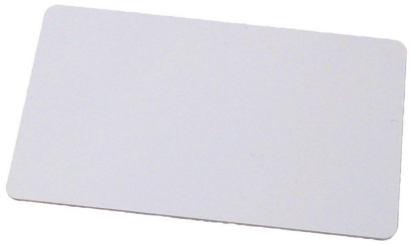
Experimental setup

- Proxmark3
- Blank card (Mifare classic 1K)



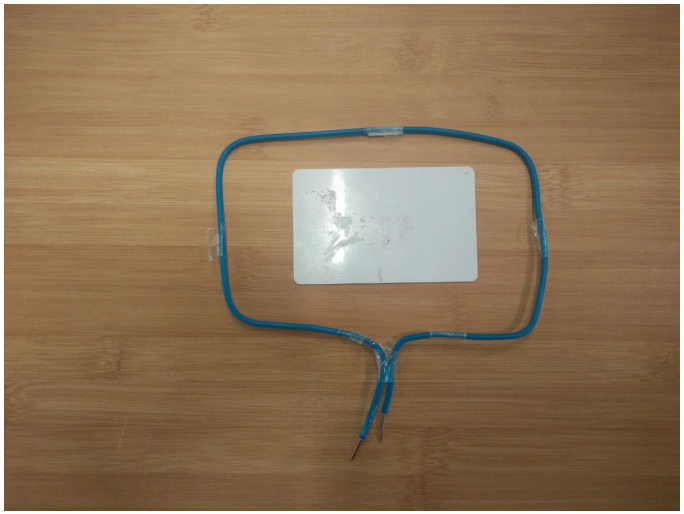
Source: Proxmark



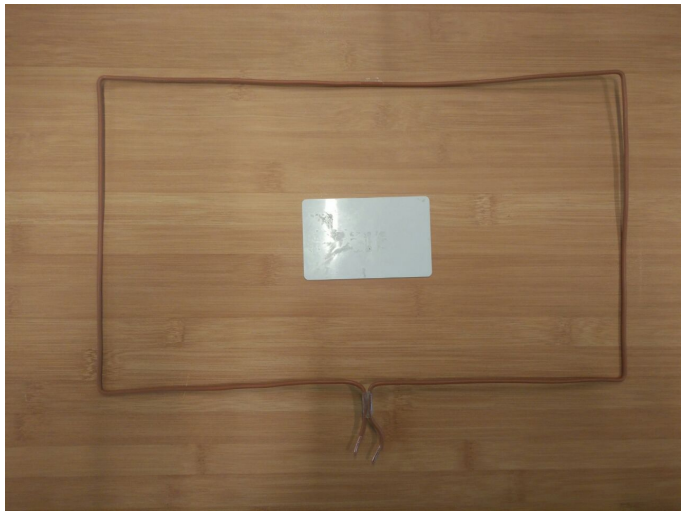


Source: Canada Robotix

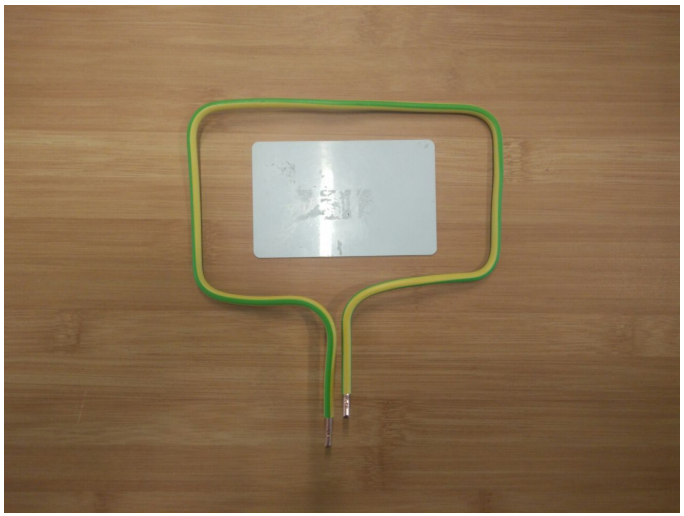
Results experiment 1



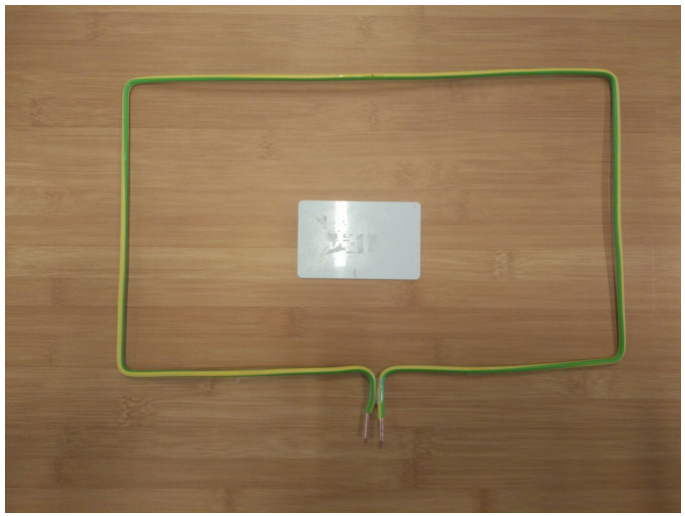
$L = 0.36 \pm 0.02\ \mu\text{H}$



$L = 1.11 \pm 0.03\ \mu\text{H}$

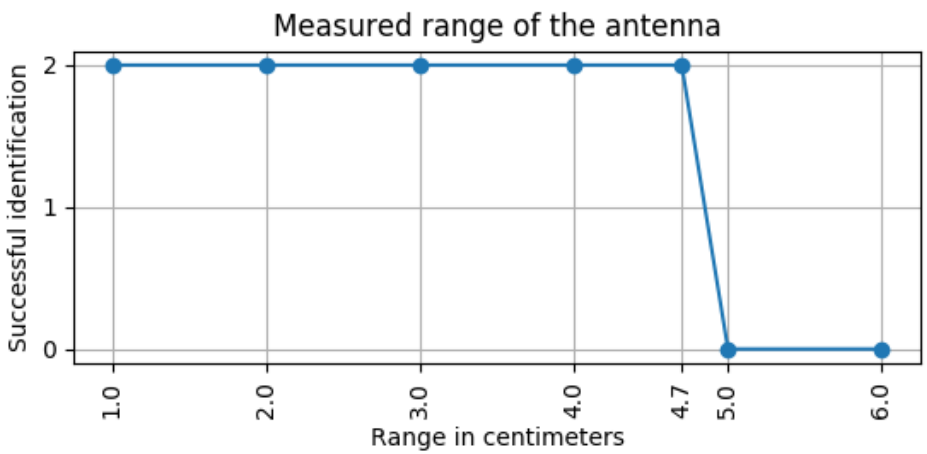


$L = 0.31 \pm 0.02\ \mu\text{H}$



$L = 0.98 \pm 0.02\ \mu\text{H}$

Results experiment 1



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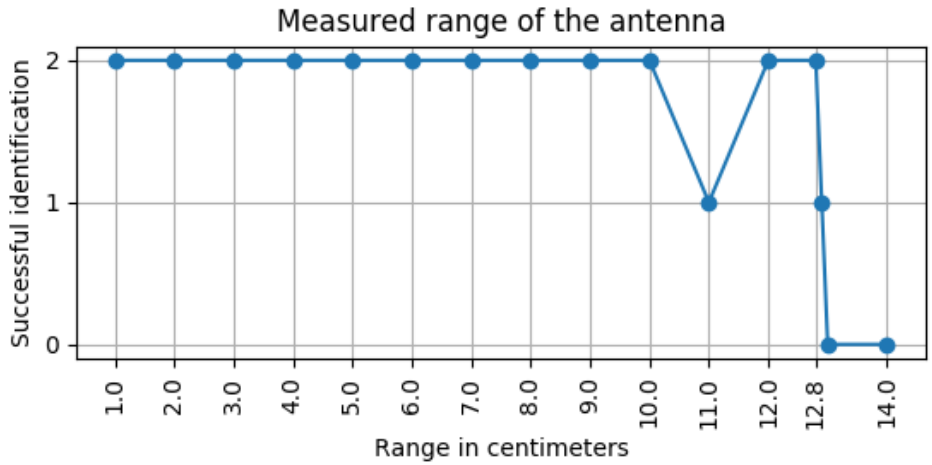

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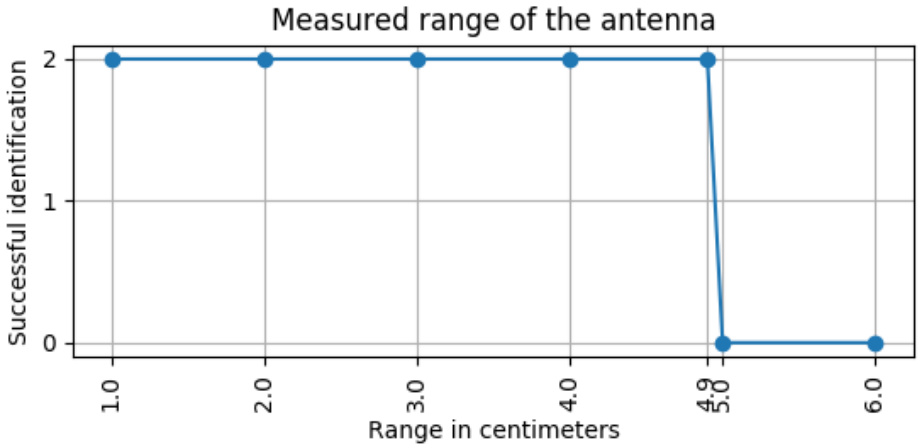

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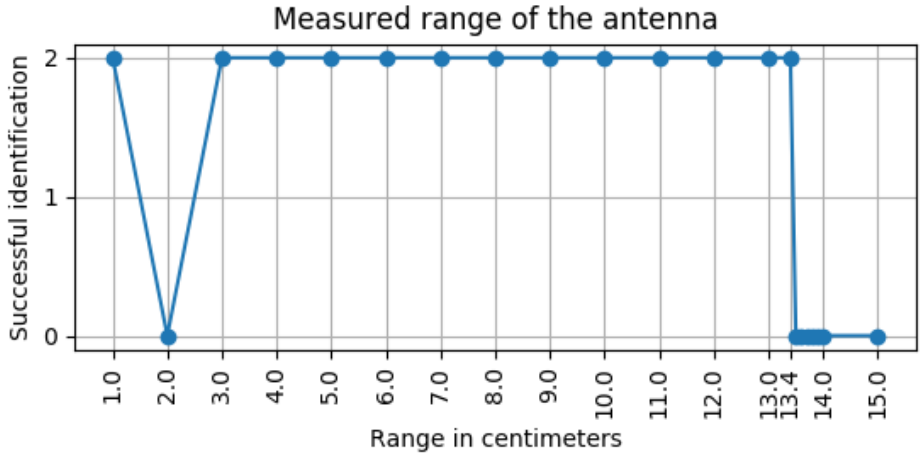
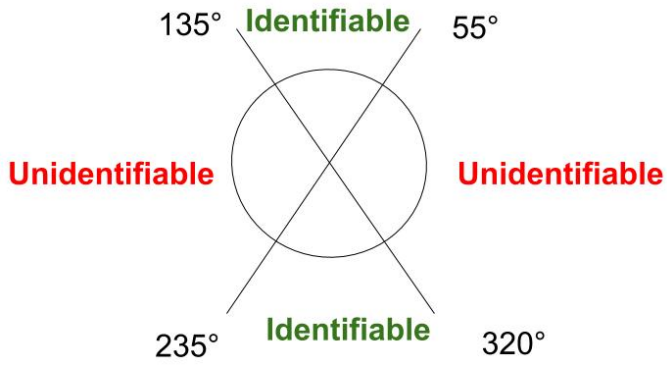
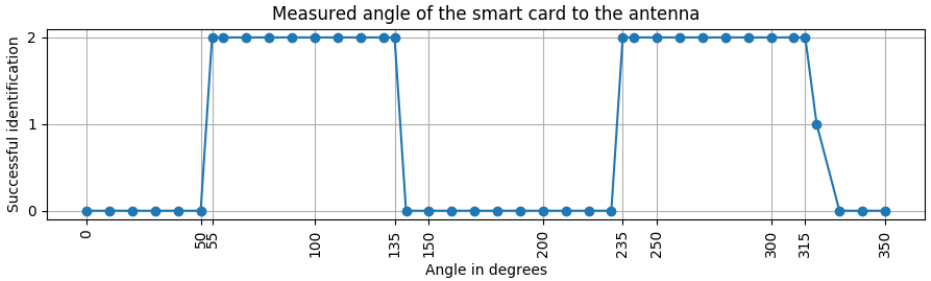


$L = 0.98 \pm 0.02\ \mu\text{H}$

Results experiment 2

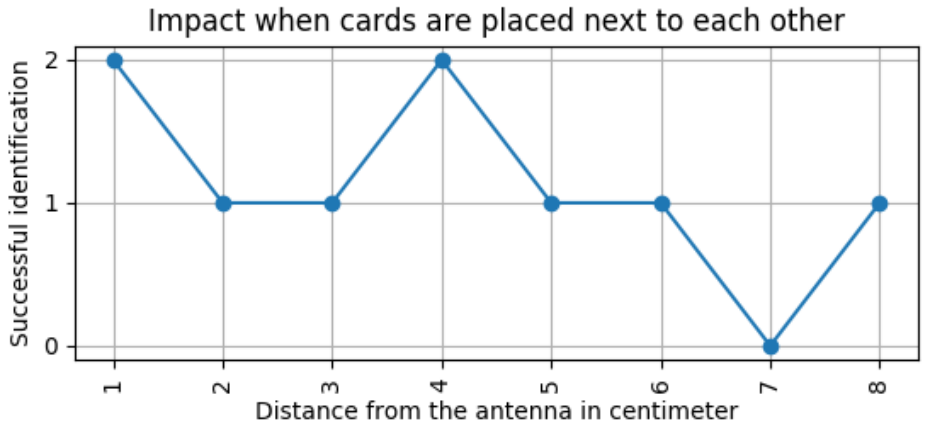


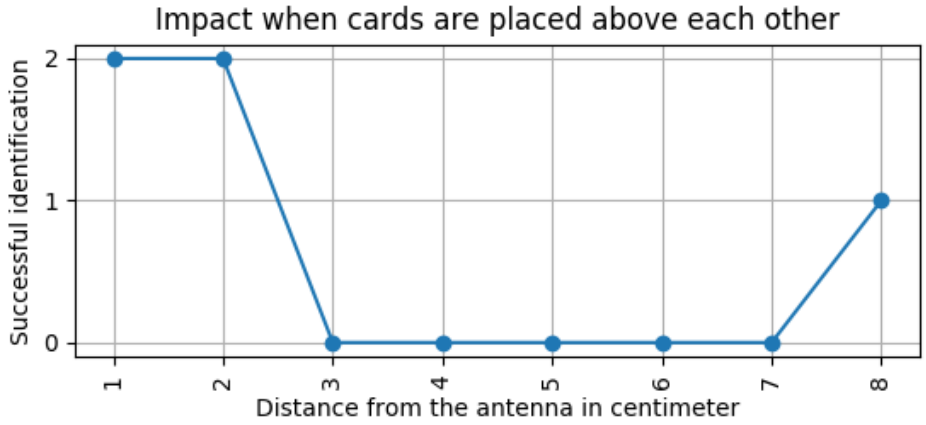
1. Orientation: clockwise
2. Angle: counter clockwise



Results experiment 3

1. Above each other
2. Next to each other
3. Stacked parallel to the reader





Conclusion

- Maximum identification range extended to 13.4 cm
- Key properties that define range
  - Thickness and length of wire **DO** influence the range: self-inductance is key
  - Orientation **DOES NOT**
  - Angle **DOES** (within 35-45° still readable)
  - The amount of cards **DOES**

Future work

1. Research the impact of having antennas with a different geometrical shape
2. Determine what the impact of using a different smart card is on the range
3. Devising a formula for calculating the coupling coefficient of a rectangular antenna
4. Research an optimal self-inductance value

Future work cont.

1. Research the impact on the range of altering the amplification with the antennas we created
2. Research into the minimum amount of spacing
3. Repeating this research with an oscilloscope to identify the reason why the smart card was unable to be identified at specific distances


ANY
QUESTIONS?

Measurement appendix

Antenna	Dimensions	Ratio	Radius	Length	Resistance	Inductance
1	13.8 $\times$ 8.2 cm	1:2	0.075 cm	52 cm	0.0049 $\pm$ 0.0001 Ω	0.36 $\pm$ 0.02 μH
2	34.5 $\times$ 20.5 cm	1:5	0.075 cm	118 cm	0.0112 $\pm$ 0.0001 Ω	1.11 $\pm$ 0.03 μH
3	13.8 $\times$ 8.2 cm	1:2	0.135 cm	52 cm	0.0015 $\pm$ 0.00002 Ω	0.31 $\pm$ 0.02 μH
4	34.5 $\times$ 20.5 cm	1:5	0.135 cm	118 cm	0.0034 $\pm$ 0.00002 Ω	0.98 $\pm$ 0.02 μH

- Measurement error tape measure: 5 mm.
- Measurement error digital protractor: 5°