AN11180

UCODE I2C PCB antenna reference designs

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229310

Application note
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Document information

Info	Content
Keywords	UCODE EPC Gen2, inter-integrated circuit, I²C, Antenna Reference Design, PCB Antenna Design
Abstract	This application note describes five antenna reference designs for the UCODE I²C IC for implementation on a Printed Circuit Board (PCB). It also provides instructions for the layout of the I2C connection lines with the rest of the electronics on the PCB.

Revision history

Rev	Date	Description
1.0	20121024	First release

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1. Introduction

The UCODE ICs (or chips) with an Inter-Integrated Circuit, or I^2C, interface provide a platform for embedding RFID transponders onto PCBs in electronic devices. For proper operation the RF front end of the UCODE chip must be connected to an antenna that is integrated on the PCB in the device and the I^2C interface must be connected to the electronics of a device, for example to a microprocessor.

This combination of interfaces provides a wireless serial communication link between an RFID reader and the electronics in a device.

This capability enables all kinds of traceability and automation solutions for electronics manufacturing; Track & Trace, activation of features on the PCB, wireless exchange of data (parameters, diagnostics), even when the PCB is unpowered and located in a factory-sealed box!

The UCODE tag is compliant with the GS1 EPC™, Class-1 Generation-2 standard [1] and can be read by various RFID readers like fixed-mount-, gate-, tunnel- or handheld-readers. The read distance is dependent (amongst other things) on the type of the reader antenna and the design of the antenna on the PCB. Related to the design on the PCB the read distance for a large part depends on the size of the UHF antenna on the PCB. this document mainly describes the influence of the size of the antenna. More general information regarding the design of UHF antennas is described in [1]

Real life applications may require different reading distance. The UCODE tag works with an antenna that is integrated on the PCB in the device. This application note describes three antenna reference designs with a large, medium and small antenna for a large, medium and small read distance. Conceptually the antennas utilize the ground planes of the PCB. The read performance is dependent upon the amount of copper in the ground plane. As a rule of thumb, more copper surface means more reading distance.

This application note provides measurement results with maximum and minimum amount of copper surfaces in the ground plane. For real life application the performance can be expected to be in the middle of the measured results. All measurements are done with "broadband" antenna designs (not specifically tuned for a certain geographic area).

The measurements in this application notes are optimized for optimal antenna orientations of both the reader and the tag antennas. All measurements are done in "free air", so without any loss due to some kind of shielding for example by the housing or other materials surrounding the PCB.

The measurement setup for the measurements in this application note is described in section 2. Section 3 described general design rules. Sections 4, 5 and 6 describe the antenna reference designs for the large, medium and small antennas respectively.

All three antenna reference designs contain four pads to connect the I^2C bus. The I^2C interface is compliant with [3].

Section 7 describes an antenna reference design with an I^2C connection to a connector on a two layer PCB.

Section 8 describes an antenna reference design with an I^2C bus between the UCODE IC and a microcontroller on the PCB.

The UCODE tags with I^2C interface could also be utilized as a wireless interface for active or semi-active sensors, for example to track temperature, humidity, gas or pH levels for cold chain applications. Antenna reference designs for these applications are different than designs for passive antennas and therefore fall outside the scope of this application note.

2. Measurement Setup

This section describes the setup for the measurements in this application note.

2.1.1 Connection of UCODE I^{2}C adapter

All antenna reference design contains connections for connecting a UCODE I^{2}C adapter. Connecting the (externally powered) adaptor has a huge impact on the measurement results.

Most of the measurement results are provided without and with the powered adapter connected.

Fig 1 shows how the UCODE I^{2}C adapter is connected to the PCB.

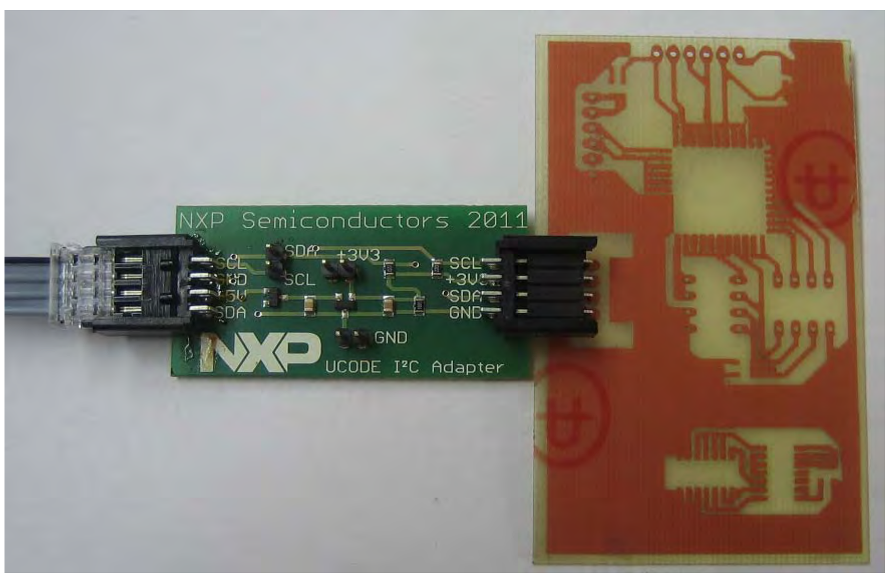

Fig 1. Connection of UCODE I^{2}C adapter with the PCB

2.2 Measurement setup

The minimum power measurements are carried out in a shielded chamber, according to the measurement setup described in the EPC global document “Tag Performance Parameters and Test Methods Version 1.1.1”.

The information gained from this measurement method is the minimal required power level at the label for powering the IC. This minimal power (P_{min}) is measured for a defined frequency range from 840MHz to 960MHz.

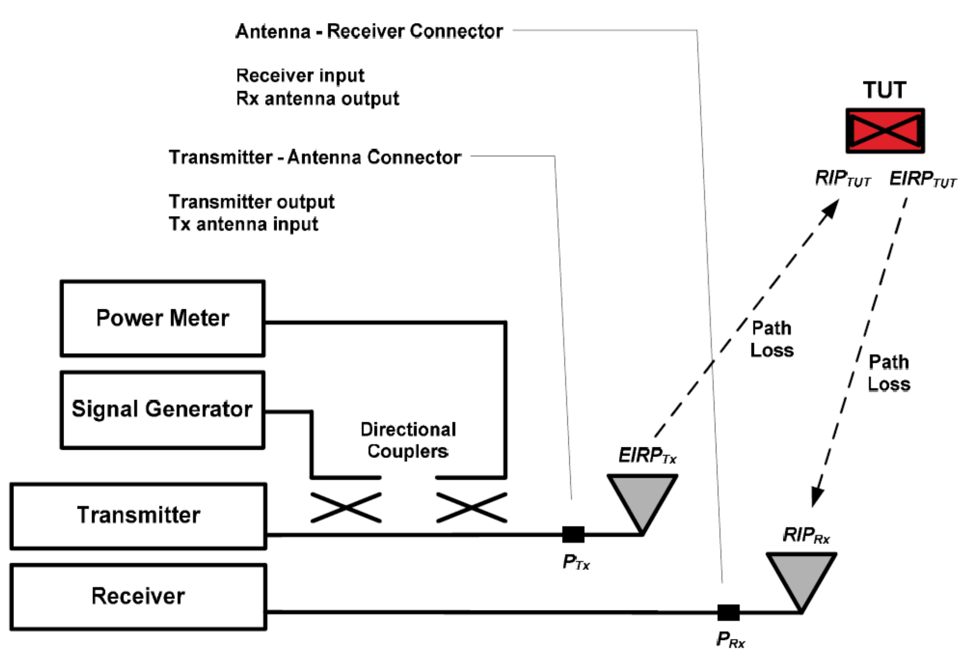

Fig 2. Measurement Setup

2.3 Measurement in anechoic chamber

The read performance also depends on various environmental parameters. To eliminate all environmental factors as much as possible all measurements have taken place in an anechoic chamber.

Fig 3. Measurement Setup: Anechoic chamber

Note: The red arrow shows Tag position, PCB position horizontal

Details of the measurement setup:

- **Reader antennas:** two bi-static horns with step attenuator
- **Reader antenna power:** 4W EIRP
- **Tag orientation:** PCB Horizontal (main beam of slotted antenna)
- **Distance between reader and PCB antenna:** 1meter

3. General design rules

This section describes some general design rules for the antenna designs.

3.1 Antenna slot characteristics

The functional behavior of the PCB antenna is for a large part defined by the design of the antenna slot. The size of the slot defines the reading distance performance and the perimeter of the slot defines the antenna tuning.

3.2 Adaption for different geographical regions

The operating frequency of an RFID system differs in various regions of the world. It is possible to optimize the tuning for a specific region, for example specific for Europe, the US and Asia and Japan. In Europe the RFID systems must operate within the 865.6MHz - 867.6MHz band, in the US and Asia the RFID systems must operate within the 902MHz – 928MHz band and in Japan the RFID systems must operate within the 952MHz – 954MHz band.

For optimal operation the tag antennas need to be tuned to the correct frequency by varying the antenna slot perimeter values.

3.3 Design considerations for connecting the I^2C interface

3.3.1 Decoupling chip inductors

When the I^2C bus lines between the UCODE chip and the I^2C connector or microcontroller are longer than 2cm they start to act as an antenna. Therefore it is necessary to add decoupling chip inductors like

Johanson Technology

L-07W82NJV4T 0402 format Q (900MHz) =39 SRF=1.5GHz or 100nH

L-014W82NJV4E 0603 format Q (900MHz) =35 SRF=1.7GHz or 100nH

3.3.2 Position of decoupling chip inductors

The chip inductors should be placed as close as possible to the UCODE I^2C IC. The UCODE I^2C IC's ground line must be connected to a solid ground plane after the decoupling inductor (and not in between the inductor and the UCODE I^2C IC).

3.4 Design Hints

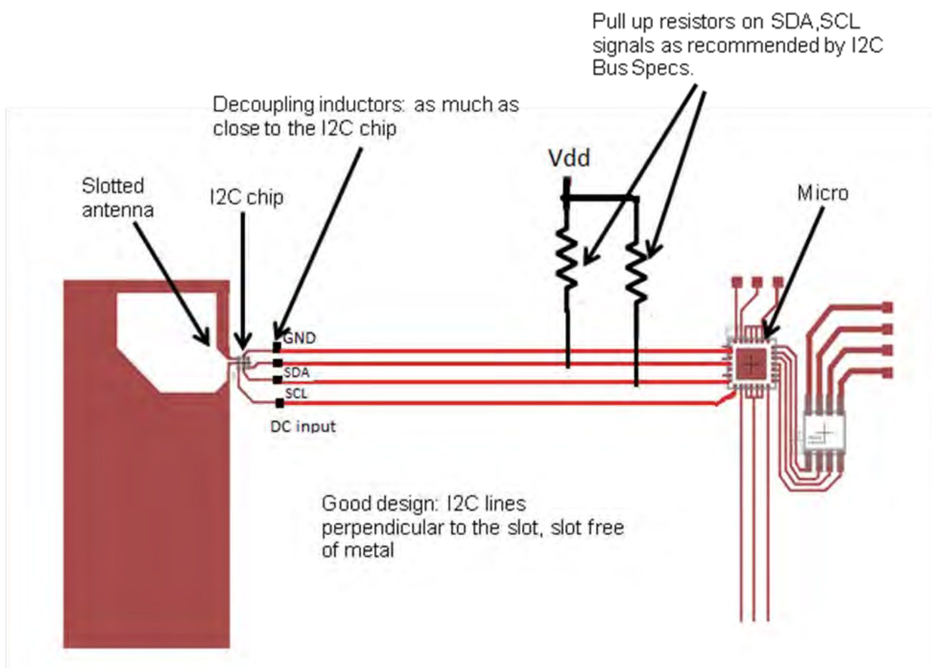

Fig 4. Routing I2C lines

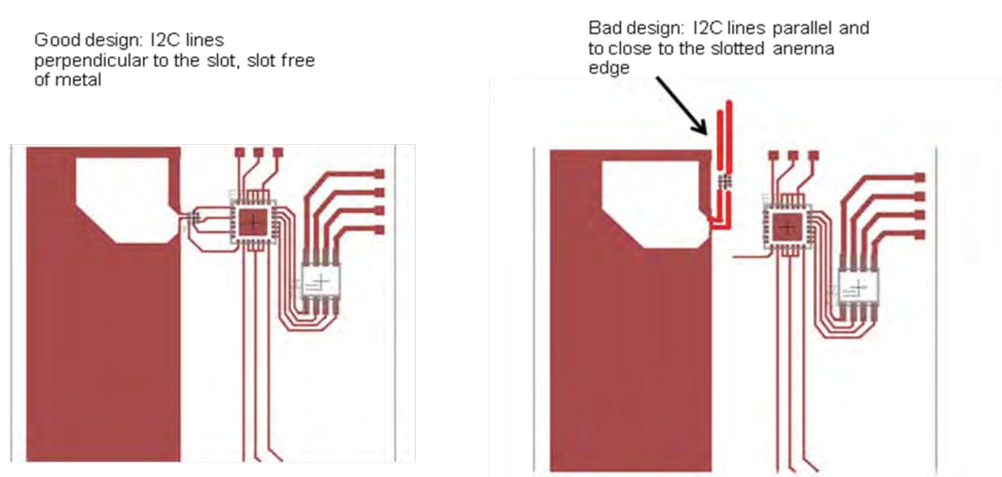

Fig 5. Routing I2C lines (2)

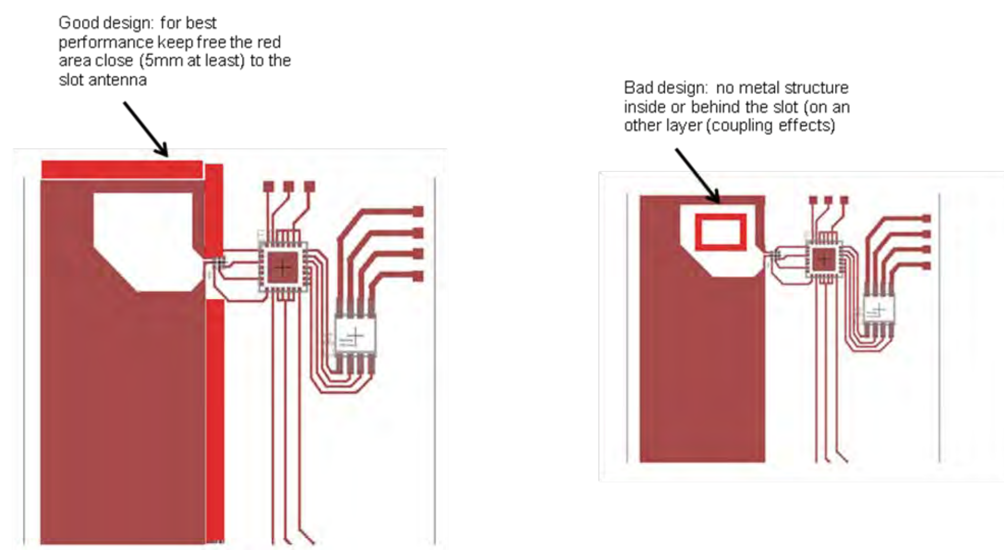

Fig 6. Slot area free

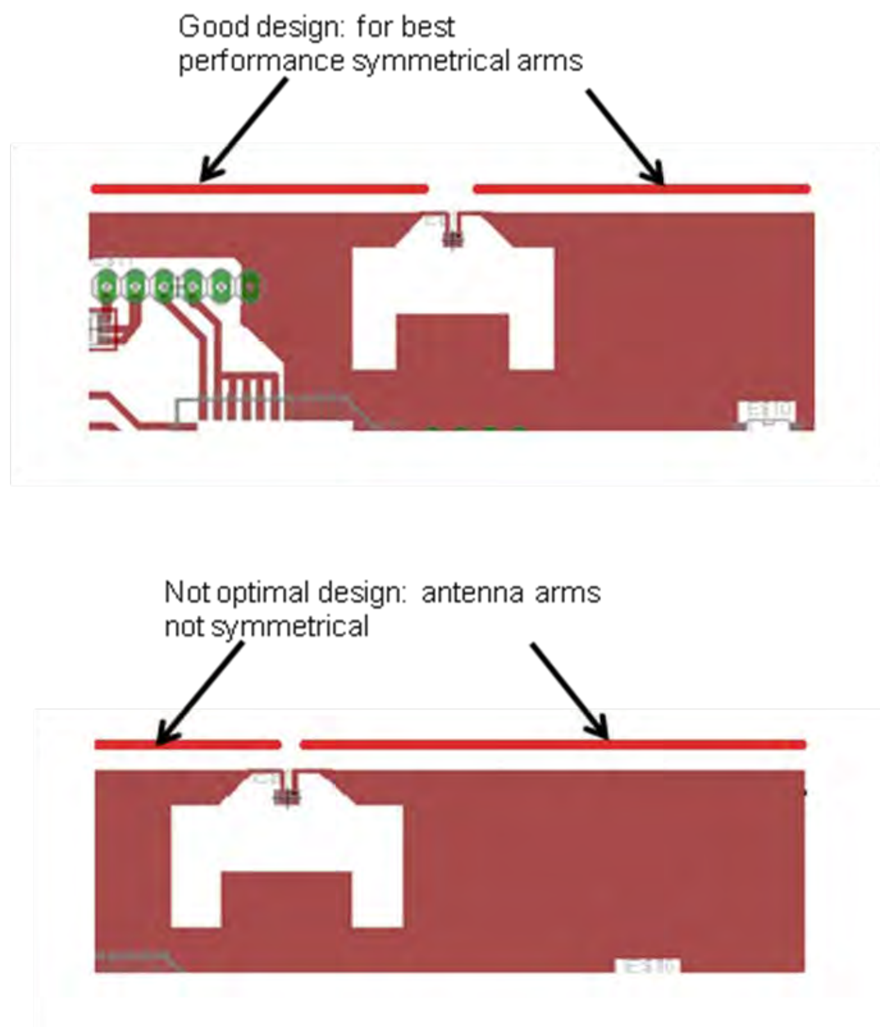

Fig 7. Symmetric designs

4. Large Reference Antenna Design

This section describes the design of a broadband antenna with the largest reading distance.

4.1 Antenna Geometry

The antenna is an integral part of the PCB. The yellow part in Fig 8 represents the ground plane (in this case the antenna fills the entire PCB).

The surface that is marked with the dotted line marks the minimum size of the ground plane. Fig 9 shows the dimensions of the antenna slot.

In a real life application most of the ground plane surface will be occupied by electronic components and therefore the read/write performance may be less than the performance of this reference design antenna.

The I^2C interface can be connected to the four pads in the antenna.

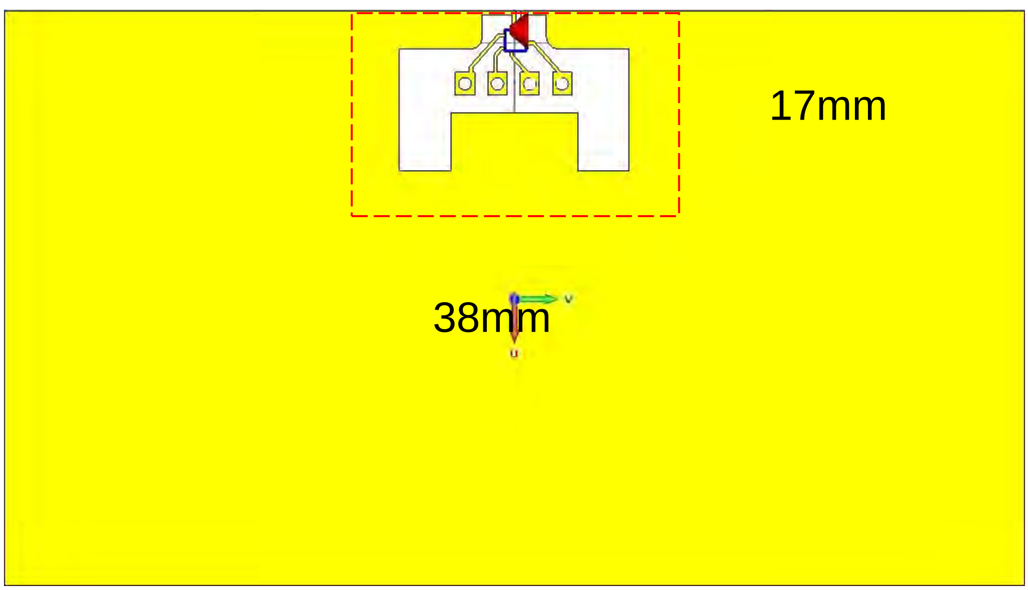

Fig 8. Large Antenna Reference Design

Details of the antenna design:

- Dimensions of the board: 80x45mm
- Dimensions of the UHF antenna: 18mm x 12.5mm (see figure Fig 9)
- Antenna material: copper; thickness 35µm;
- Substrate material: FR4; thickness 0.5mm;

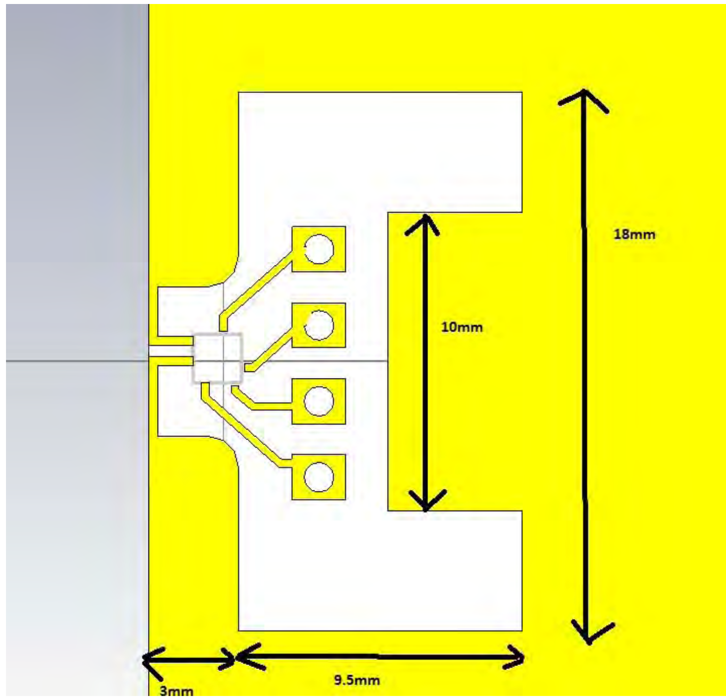

Fig 9. Dimensions antenna slot of Large Reference Antenna Design

4.2 Measurement results

Fig 10 and Fig 11 show the read distance in meters over the frequency spectrum from 840MHz to 960MHz for the broadband antenna design. The blue line shows the reading distance for maximum amount of copper surface in the ground plane and the black line shows the read distance for minimum amount of copper surface in the ground plane. For real life applications the performance can be expected to be in the middle of the measured results.

Fig 10 shows the results without the (externally powered) UCODE I^2C adapter connected and Fig 11 shows the results with the (externally powered) UCODE I^2C adapter connected.

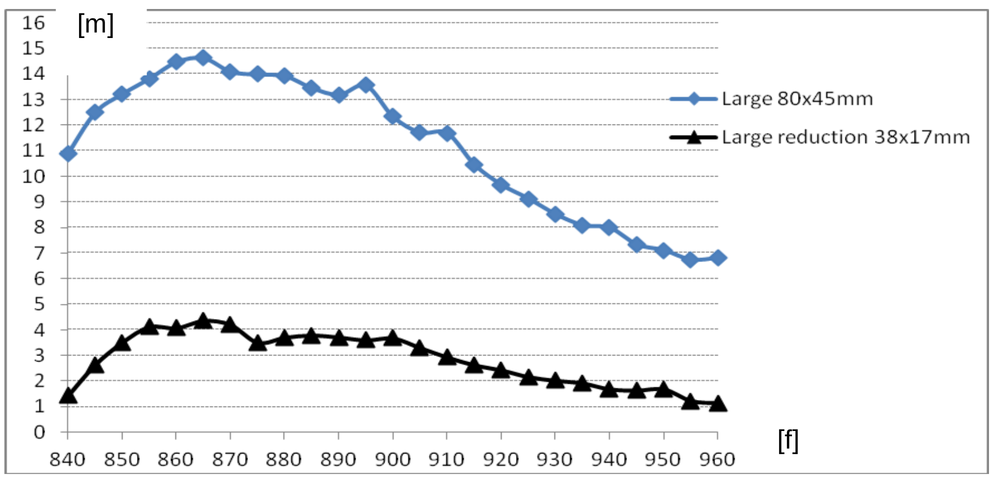

Fig 10. Large design: Reading distance in meters

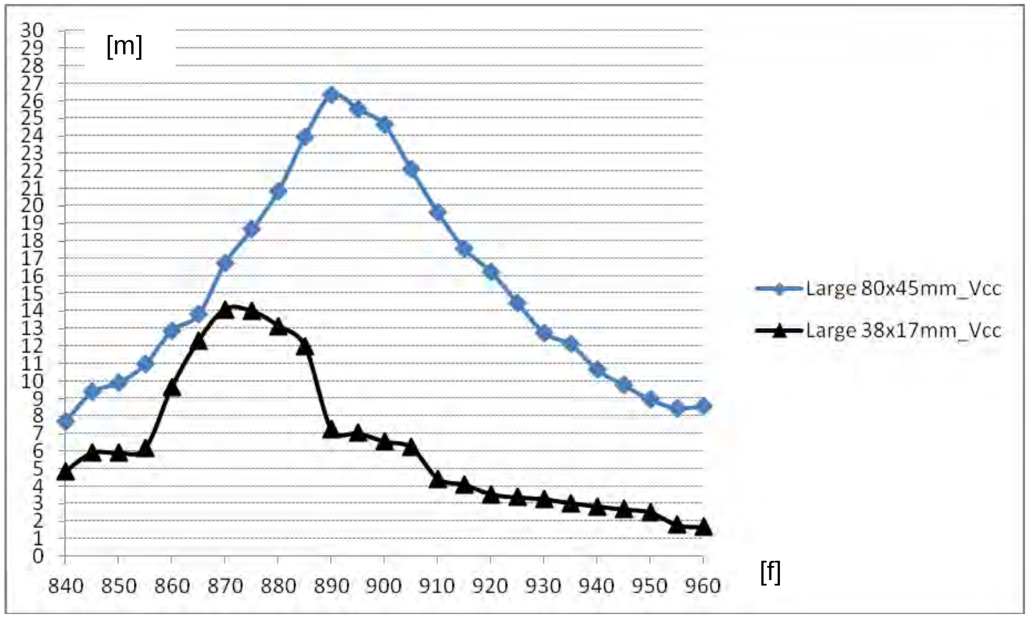

Fig 11. Large design: Reading distance in meters I²C Powered

4.3 Adaption for different geographic areas

Fig 12 shows the antenna slot perimeter dimensions for EU band and Fig 13 shows the antenna slot perimeter dimensions for the US and Asia band.

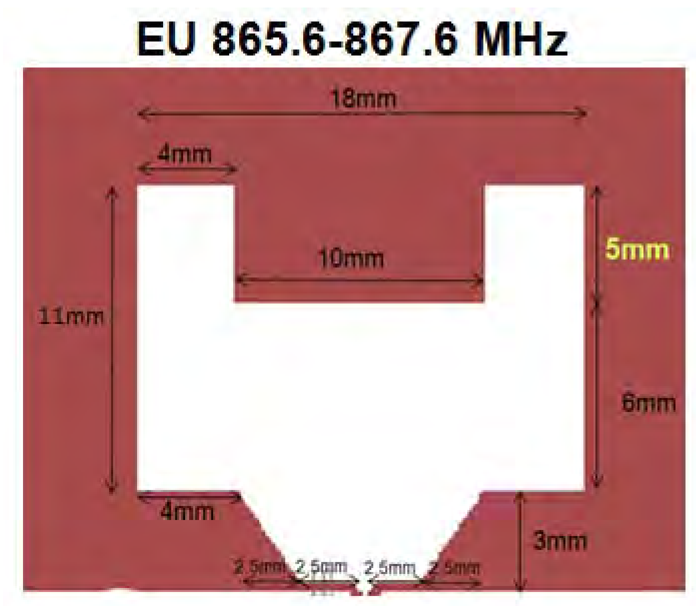

Fig 12. Antenna tuning for EU band 865.6 - 867.6MHz

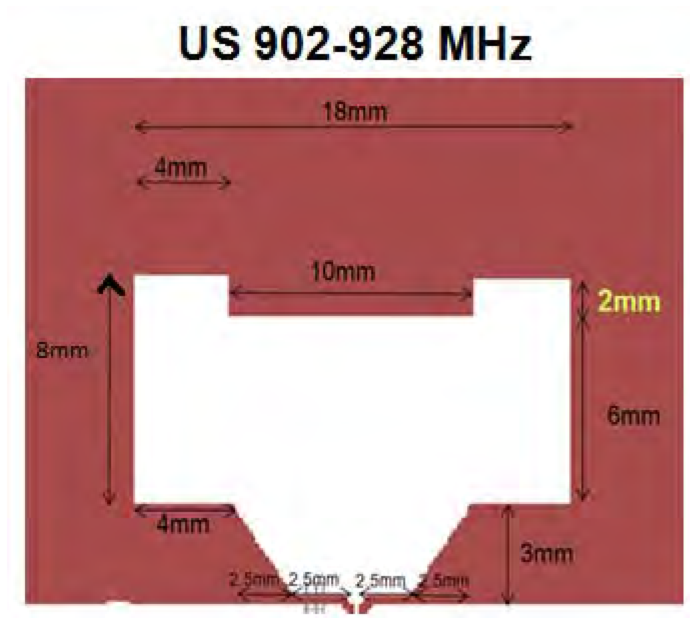

Fig 13. Antenna tuning for US and Asian band 902 - 928MHz

5. Medium Reference Antenna Design

This section describes the design of a broadband antenna with a medium reading distance.

5.1 Antenna Geometry

The antenna is an integral part of the PCB. The yellow part in Fig 14 represents the ground plane. In a real life application most of the ground plane surface will be occupied by electronic components and therefore the read/write performance may be less than the performance of this reference design antenna.

The I^2C interface can be connected to the four pads in the antenna.

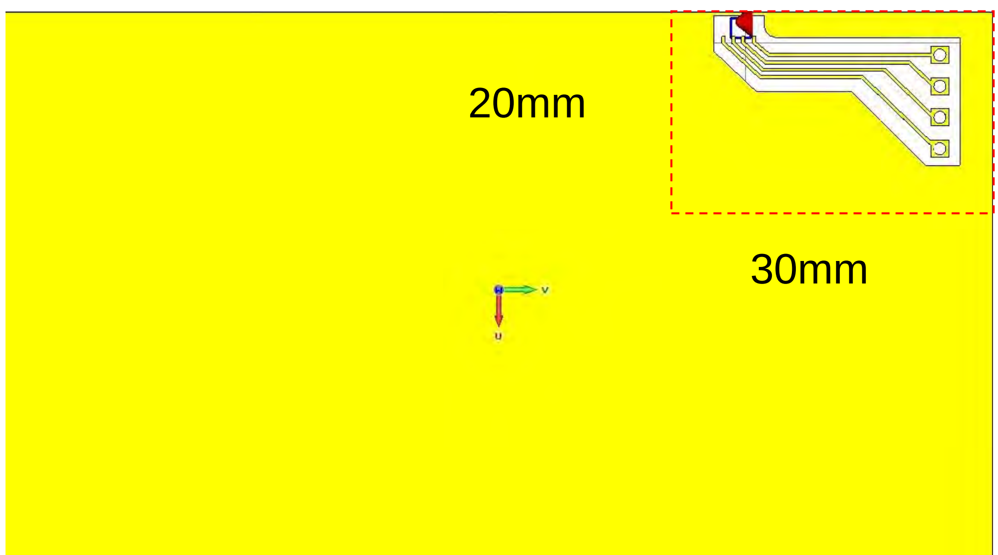

Fig 14. Medium Antenna Reference Design

Details of the antenna design:

- Dimensions of the board: 80x45mm
- Dimensions of the UHF antenna: 20mm x 14.1mm (see Fig 15)
- Antenna material: copper; thickness 35µm;
- Substrate material: FR4; thickness 1mm;

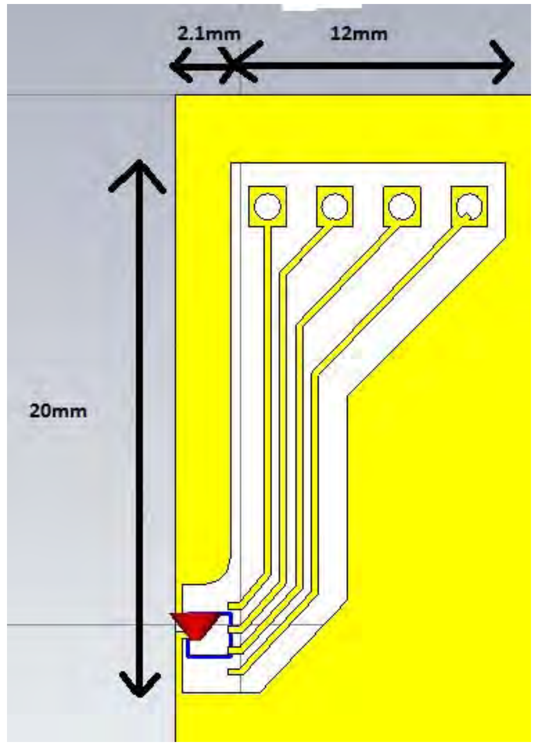

Fig 15. Dimensions Medium Antenna Reference Design

5.2 Measurement results

Fig 16 and Fig 17 show the read distance in meters over the frequency spectrum from 840MHz to 960MHz. The blue line shows the reading distance for maximum amount of copper surface in the ground plane and the black line shows the reading distance for minimum amount of copper surface in the ground plane.

For real life applications the performance can be expected to be in the middle of the measured results.

Fig 16 shows the results without the (externally powered) UCODE I^2C adapter connected and Fig 17 shows the results with the (externally powered) UCODE I^2C adapter connected.

Note: The mounting of electronic components could cause a change in the resonance frequency and therefore this could have a negative influence on the reading distance.

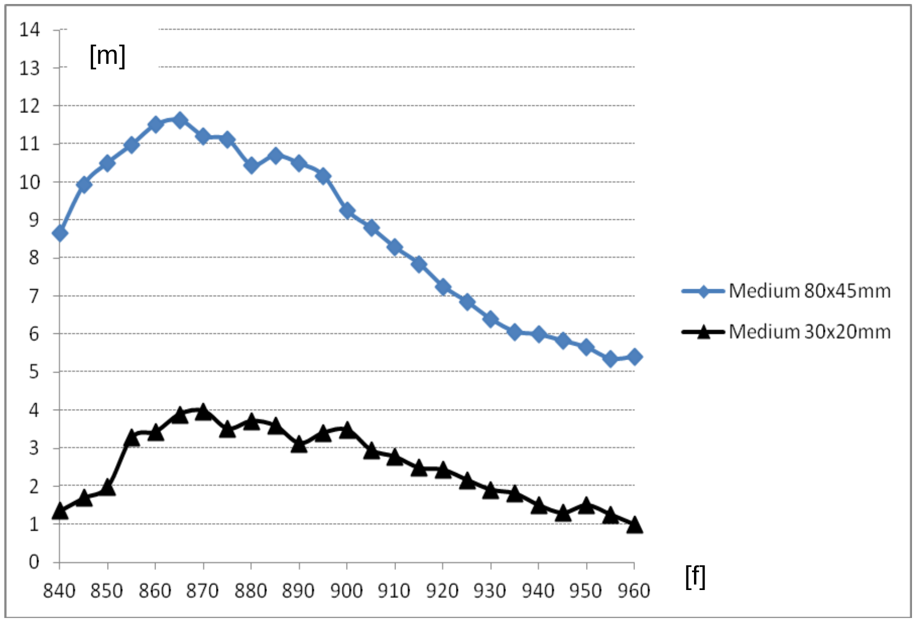

Fig 16. Medium design: Reading distance in meters

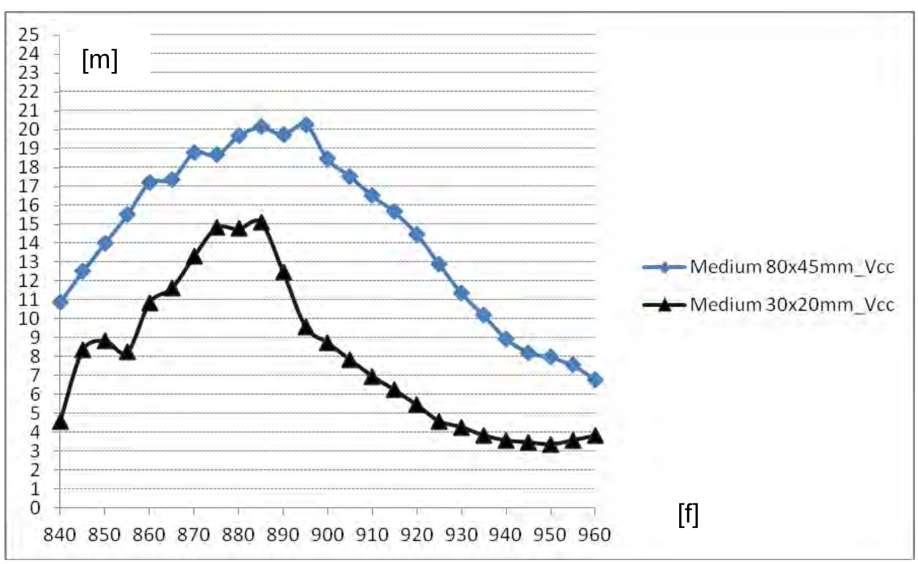

Fig 17. Medium design: Reading distance in meters I^{2}C Powered

5.3 Adaption for different geographic regions

Fig 18 shows the antenna slot perimeter dimensions for the EU band and Fig 19 shows the antenna slot perimeter dimensions for the US and Asian band.

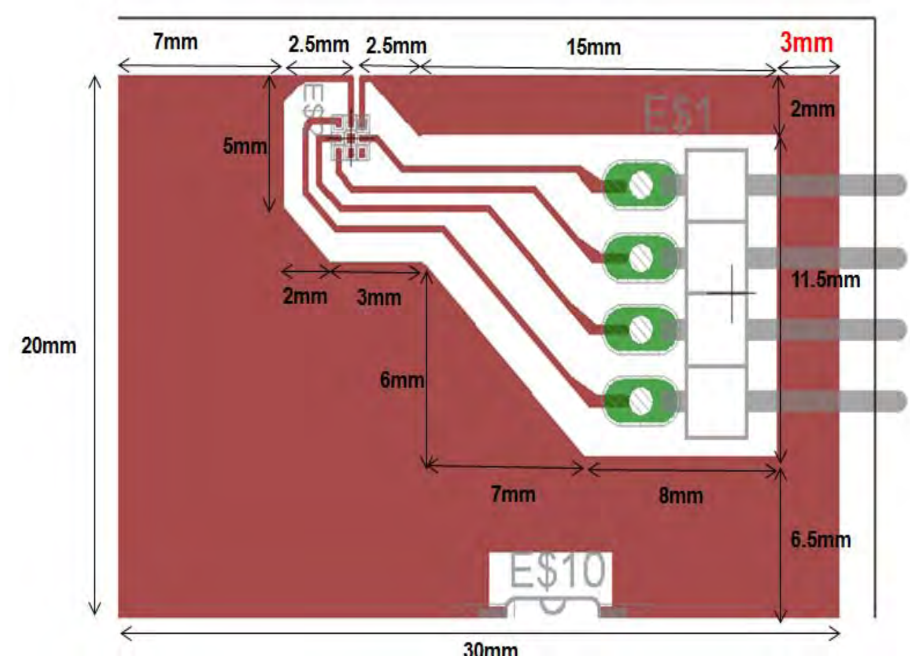

Fig 18. Antenna tuning for EU band 865.6 - 867.6MHz

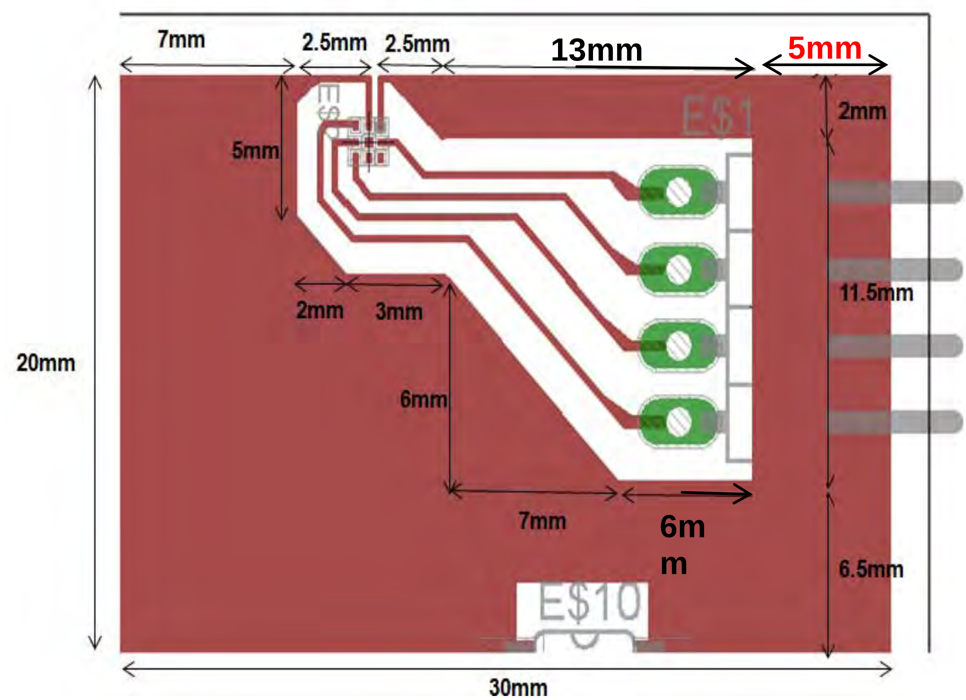

Fig 19. Antenna tuning for US and Asian band 902 - 928MHz

6. Small Reference Antenna Design

This section describes the design of an antenna with a small read distance.

6.1 Antenna Geometry

The antenna is an integral part of the PCB. The yellow part in Fig 20 represents the ground plane. In a real life application most of the ground plane surface will be occupied by electronic components and therefore the read/write performance may be less than the performance of this reference design antenna. Fig 21 shows the dimensions of the antenna slot.

The I^2C interface can be connected to the four pads in the antenna.

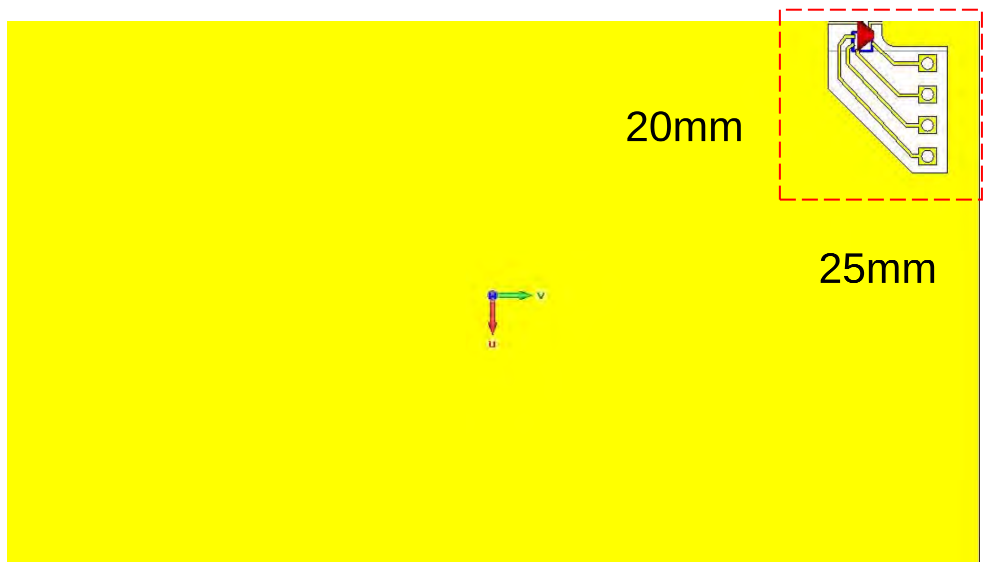

Fig 20. Small Antenna Reference Design

Details of the antenna design:

- Dimensions of the board: 80x45mm
- Dimensions of the UHF antenna: 12.5mm x 10mm (see Fig 21)
- Antenna material: copper; thickness 35µm;
- Substrate material: FR4; thickness 0.5mm;

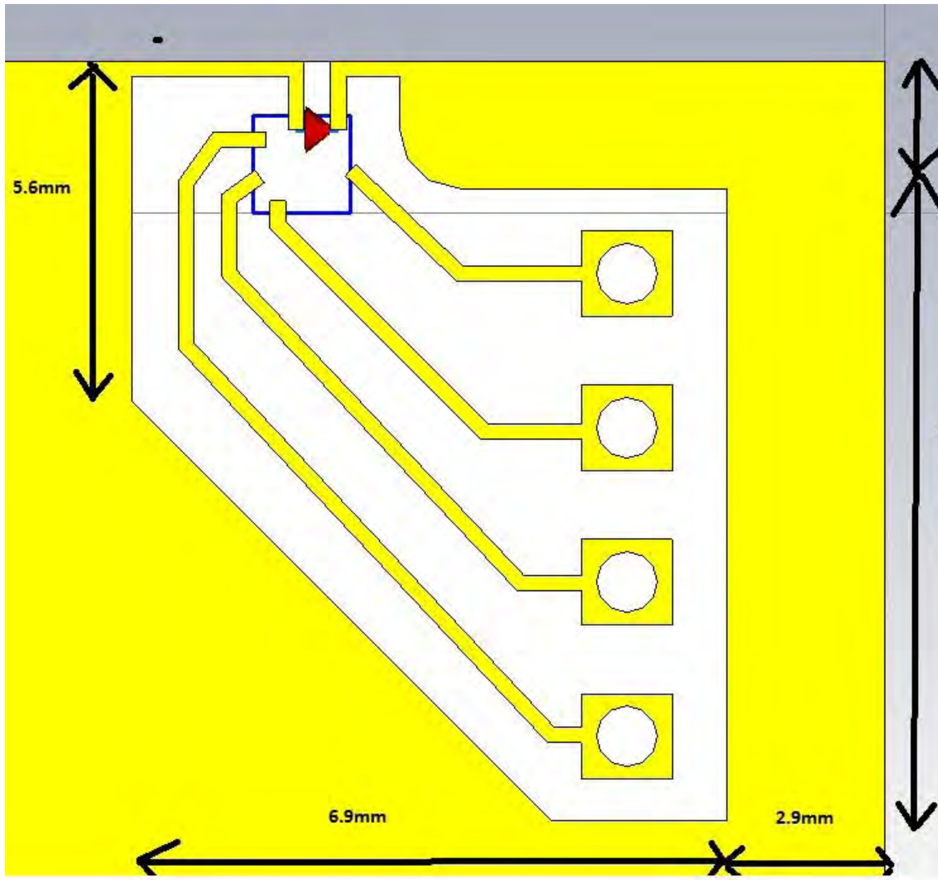

Fig 21. Dimensions Small Antenna Reference Design

6.2 Measurement results

Fig 22 and Fig 23show the read distance in meters over the frequency spectrum from 840MHz to 960MHz. The blue line shows the reading distance for maximum amount of copper surface in the ground plane and the black line shows the reading distance for minimum amount of copper surface in the ground plane.

For real life applications the performance can be expected to be in the middle of the measured results.

Fig 22 shows the results without the (externally powered) UCODE I^2C adapter connected and Fig 23 shows the results with the (externally powered) UCODE I^2C adapter connected.

Note: The mounting of electronic components could cause a change in the resonance frequency and therefore this could have a negative influence on the reading distance.

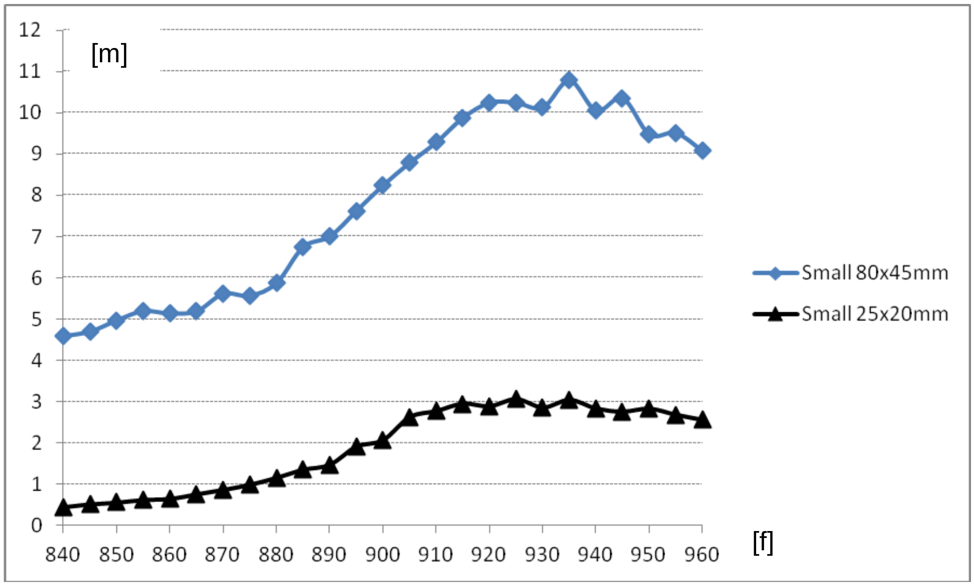

Fig 22. Small design: Reading distance in meters

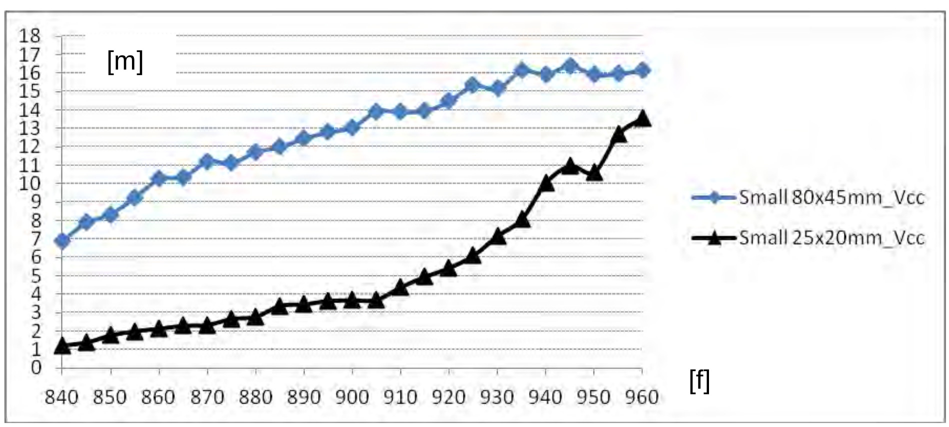

Fig 23. Small design: Reading distance in meters I²C Powered

6.3 Adaption for different geographical regions

For a small antenna it is not necessary to tune the antenna for the European or US bands. The inner diameter is too small.

7. Reference Antenna Design for two layer PCB

This section describes an antenna reference design with I^2C connections to a connector on a two layer PCB.

7.1 Geometry

In a design on a two layer PCB it is recommend to connect the ground planes at both sides of the PCB with "via holes" between the two planes around the antenna slot area. This ensures a solid ground connection around a well defined antenna slot.

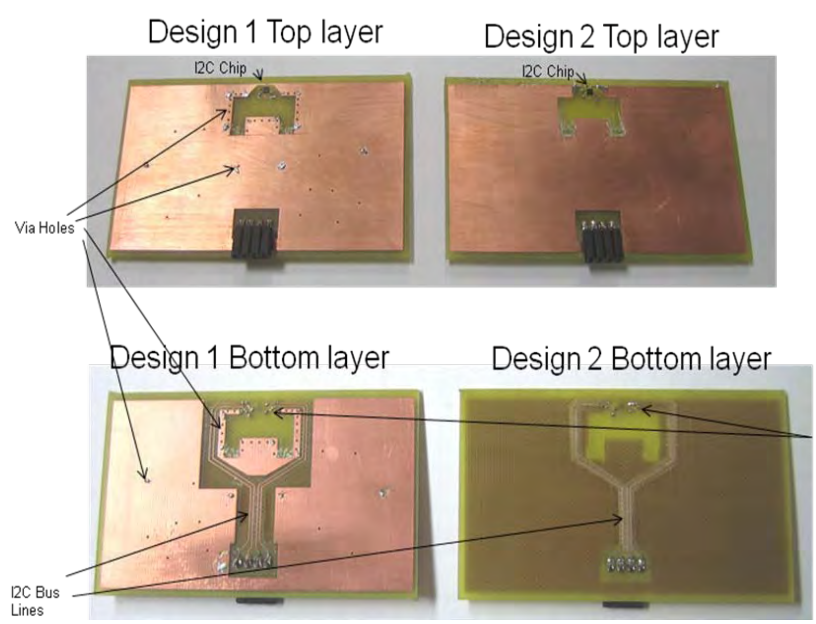

Fig 24. Reference Antenna Design with connector

Details of the antenna design:

- Dimensions of the board: 80x45mm
- Dimensions of the UHF antenna: 80mm x 40mm
- Antenna material: copper; thickness 35µm;
- Substrate material: FR4; thickness 1.5mm;

7.2 Measurement results

Fig 25 shows the read distance of the two-layer design in meters over the frequency spectrum from 840MHz till 960MHz. The blue line shows the read distance for EU design and the red line shows the results for the US design.

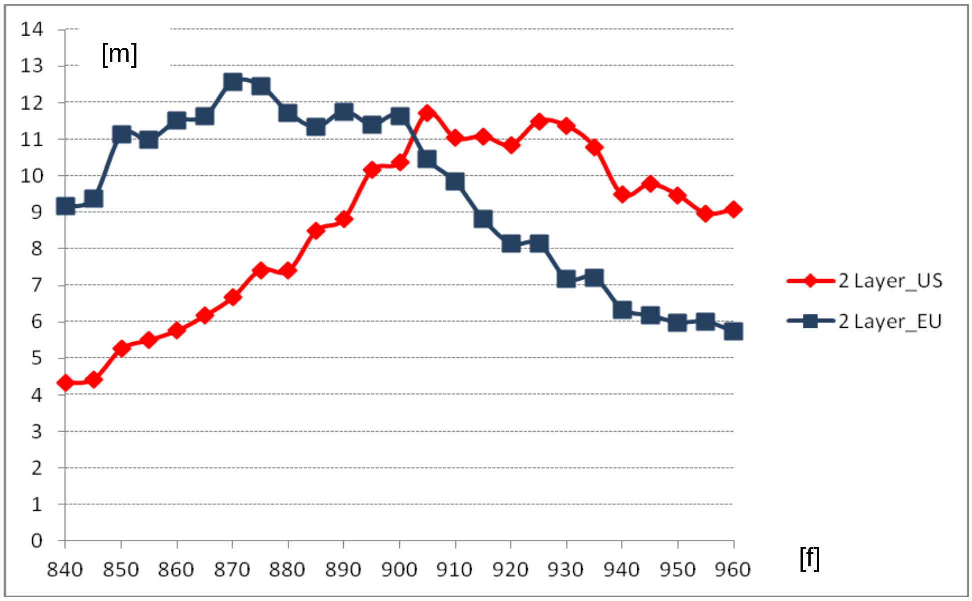

Fig 25. Read distance in meters for two-layer antenna design

8. Reference Antenna Design for one layer PCB with Microcontroller

The connection of the I^2C interface influences the read performance of the UCODE tag. This section describes the antenna layout with I^2C connections to a microcontroller on a one layer PCB1.

8.1 Antenna Geometry

Fig 26 shows the design of an antenna with the I^2C bus connecting the UCODE chip and the microcontroller. Fig 27 shows the dimensions of the antenna slot.

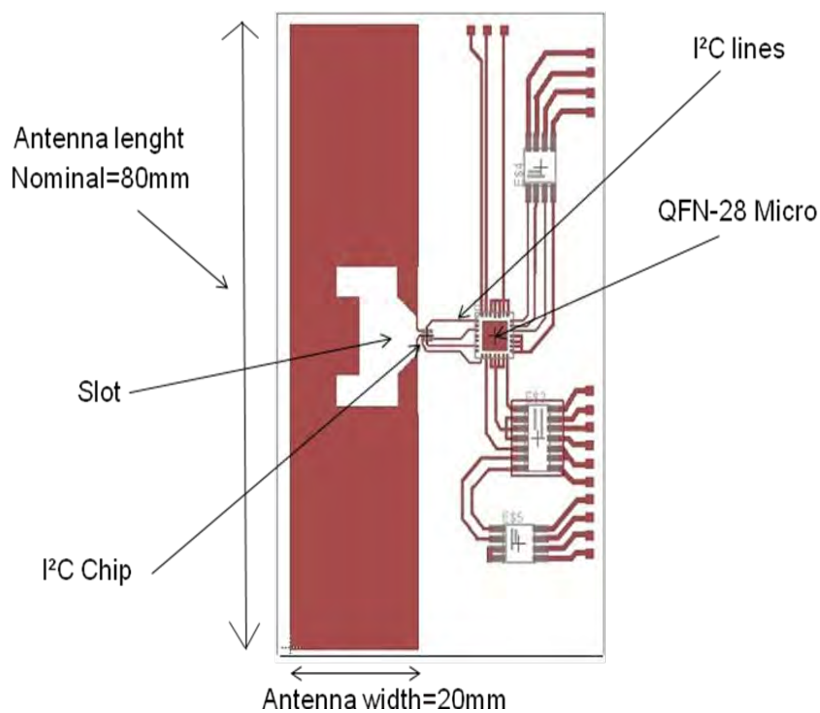

Fig 26. Antenna reference design with Microcontroller

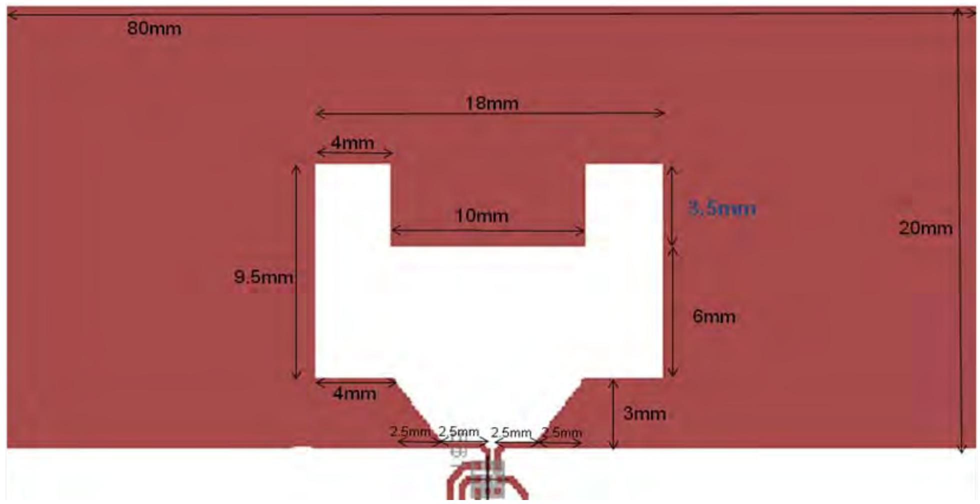

Fig 27. Slot dimensions for antenna reference design with microcontroller

Details of the antenna design:

- Dimensions of the board: 80x45mm
- Dimensions of the UHF antenna: 80mm x 20mm
- Antenna material: copper; thickness 35µm;
- Substrate material: FR4; thickness 0.5mm;

8.2 Measurement results

Fig 28 shows the reading distance in meters over the frequency spectrum from 840MHz to 960MHz. The blue line shows the reading distance for an antenna with a nominal length of 80mm, the red line shows the reading distance for an antenna with a nominal length of 48mm and the black line shows the reading distance for an antenna with a nominal length of 24mm.

Note: The mounting of electronic components could cause a change in the resonance frequency and therefore this could have a negative influence on the reading distance.

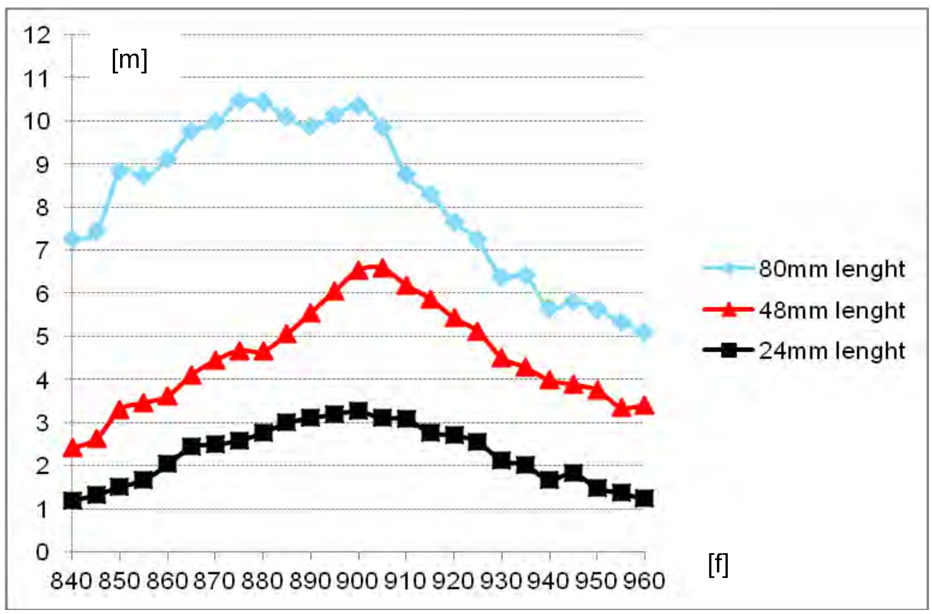

Fig 28. Reading distance in meters

9. References

[1] EPC™ Radio-Frequency Identity Protocols, Class-1 Generation-2 *UHF RFID, Protocol for Communications at 860MHz – 960MHz, Version 1.2.0; EPCglobal™ Inc.* http://www.nxp.com/redirect/gs1.org/gsmp/kc/epcglobal/uhfc1g2

[2] NXP Application Note, AN1715 - UHF RFID PCB antenna design http://www.nxp.com/documents/application_note/096917_UCODE_G2XM_G2XL_an.zip

[3] NXP User Manual, UM10204 - I^2C-bus specification and user manual Rev. 4 http://www.nxp.com/documents/user_manual/UM10204.pdf

[4] Short data sheet: SL3S4001_SDS; UCODE I^2C (BLID 2113) http://www.nxp.com/documents/short_data_sheet/SL3S4011_4021_SDS.pdf

[5] ISO/IEC 18000-1, *Information technology — Radio frequency identification for item management — Part 1: Reference architecture and definition of parameters to be standardized*

[6] ISO/IEC 18000-6, *Information technology — Radio frequency identification for item management — Part 6: Parameters for air interface communications at 860MHz to 960MHz*

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11. Contents

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