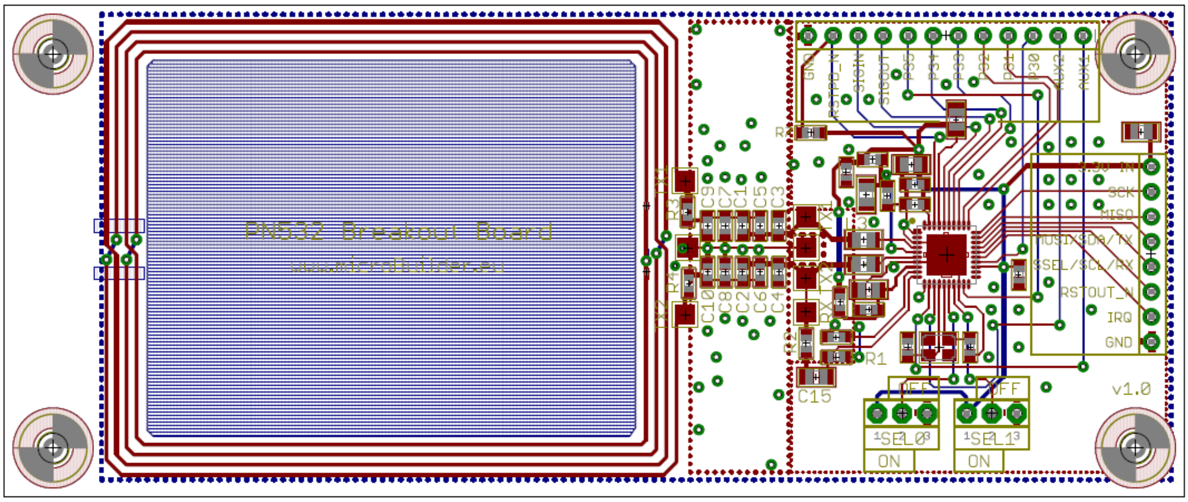
Changes PN532_Breakout board



Document:	Changes PN532_Breakout board
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Contents

1. Introduction

The PN532_Breakout board contains the PN532 chip of NXP Semiconductors for contactless communication. Together with the pcb-antenna it forms an NFC reader for the ISO 14443 standard. To increase the communication range of the PN532_Breakout board the antenna had to be matched to the PN532 chip. Apart from that the signal coming back from the tag and picked up by the antenna had to be optimized. This document describes the measurements and improvements done on the PN532_Breakout board at the Techno Centrum of the Radboud University in Nijmegen.

Because the PN532 chip delivers a square wave of 13.56MHz a low-pass filter (see Figure) follows the output pins to end-up with a clean sine wave. In the reader–antenna setup below, most power is send when the impedance of the antenna is matched to the impedance of the chip. The capacitors $C_{1,2}$ transform the impedance of the antenna to a 50Ω impedance at the resonance frequency (13.56MHz in this case). In order to receive the modulated signal from the tag the quality-factor (Q-factor) of the antenna should not be too high. This factor is an indication how well the antenna performs at its resonance frequency. Normally it should be as high as possible because most power is radiated in that case. However, it acts like a filter and if the Q-factor is above 30 it cuts off the desired frequencies send back by the tag. Resistors R_Q reduce the Q-factor to the optimal value.

The measurements described in this document are done with the Agilent 4396B Network/Spectrum analyzer. Together with the Agilent 16093A option it can be used to measure the impedance of an antenna and the other parameters that are necessary for the calculations. Besides the network analyzer a standard scope is used (Tektronix TDS3052) to measure the return signal from the antenna. Together with a low capacitance probe (Tektronix P6243 1MHz- 1GHz, <1pF) the desired signals could be measured with the necessary precision.

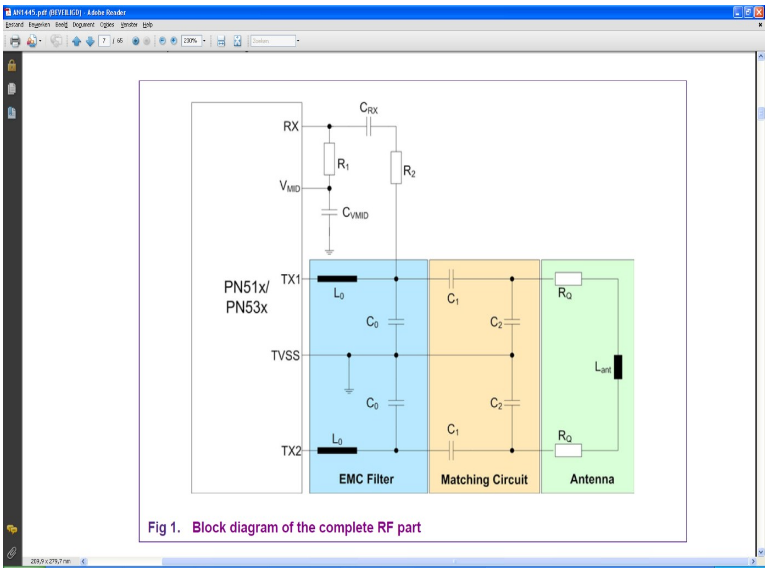

Figure : Reader-antenna setup

2. Matching components

2.1 Measurements

To tune the antenna and calculate the correct values for the components the following document is used: NFC Transmission Module Antenna and RF Design Guide (AN144511) from NXP Semiconductors. This document describes in detail the properties of the antenna for the PN532 chip and it comes with a spreadsheet to calculate the correct matching components. It can be found using the following link: [http://www.nxp.com/#/page/content=[f=/dynamic/applicationnotes/all/data.xml](http://www.nxp.com/#/page/content=[f=/dynamic/applicationnotes/all/data.xml)]

As a start the inductance of the antenna is calculated and it results in an inductance of 1.91µH. Later on this value is confirmed by measurements done with the Agilent network analyzer. To calculate the components of the matching circuit two equivalent antenna circuits must be used. The value for resistor R_Q (see: Figure) follows from figure 2. The values of capacitors $C_{1,2}$ can be calculated from the parallel circuit of figure 3

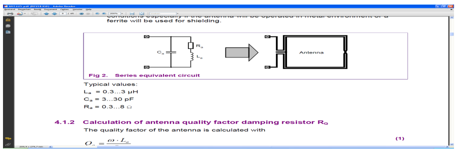

Figure : Series antenna circuit

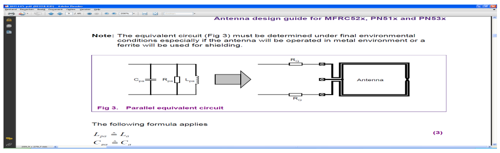

Figure : Parallel antenna circuit

The measurements of the parameters that are necessary to obtain the component values are listed below.

Parameter	Value	Comment
L_a	1.83µH	Series inductance
R_a	1.42Ω	Series resistance
R_{pa}	19.9kΩ	Resistance at f_{res}
f_{res}	38.3MHz	Resonance frequency antenna

Table : Measurements without R_Q

To reduce the Q-factor of the antenna two resistors (R_Q) of 1.5Ω are placed in series with the antenna. The calculation of the final values for the matching network must be done after a second measurement with the series resistors in place.

Parameter	Value	Comment
L_{pa}	1.90µH	Series inductance
R_a	4.46Ω	Series resistance
R_{pa}	18.4kΩ	Resistance at f_{res}
f_{res}	37.3MHz	Resonance frequency antenna

Table : Measurements with RQ

Using the parameters from Table 2 the component values for the matching circuit are: C_0=220pF, C_1=24pF and C_2=103pF. (see: Figure : Reader-antenna setup). The closest available values in the market for the capacitors are 220pF, 22pF and 100pF respectively. These components should result in a matched antenna–reader system with a resonance frequency of 13.56MHz and a Q-factor of 30 or less. For the results see paragraph: Results Results.

2.2 Return signal from antenna

The chip is protected from an over voltage by means of a voltage divider (see: Figure : Reader-antenna setup). To calculate the necessary ratio the voltage on the antenna is measured with a low capacitance probe. If you use a regular probe the antenna is detuned and the results are not correct. The reason for this effect is mainly because of the added capacitance of the probe. For this purpose the P6243 probe of Tektronix is used with a capacitance of <1pF.

Figure : Tektronix probe

Several other probes are tried including a high frequency probe of Agilent that must be used together with the network analyzer. Also a standard scope probe is used with an added resistor to the probe tip to reduce the capacitance. However these measurements showed to be less stable and straightforward as was the case with the Tektronix probe.

Because the antenna generates an electromagnetic (EM) field continuously, it is important to keep a short connection to ground i.e. close to the point where the measurement is done. If the ground wire is in the EM-field a voltage is induced in the probe and the measurement becomes unreliable. Special care is taken to reduce this problem to a minimum.

According to the datasheet of the PN321 chip the maximum allowed voltage on the receive pin of the chip is AV_{DD} +1V. The (analog) supply AV_{DD} is 3.3V and this results in a maximum allowed voltage of 4.3V on pin RX (see: Figure : Reader-antenna setup). This must be valid for an RF-field that is switched on continuously and for a chip in communication mode. If the antenna is detuned by a tag the voltage increases on pin RX. Also in this situation the voltage may not exceed the 4.3V. To get to an optimal result an iterative process is used to reach the largest communication distance without exceeding the allowed voltage. Resistor R2 is varied from 1kΩ to 2k2Ω and the communication distance is measured. Unfortunately this did not increase the communication distance significantly. A difference from 74mm (2k2) to 77 (1k7) was found varying the resistor. In contrary to the specification with an Urx higher than 4.01V the sine clips and is deformed. Values for R2 of 1k5 or less influence the reading range negatively and should be prevented.

R2 [Ω]	Uc_0 [V]	Urx [V]	Urx [V] (detuned)	Com. dist. [mm]

2nd	1k	4.60	2.97	4.05	75
3rd	1k5	4.75	2.68	4.01	75
4th	1k7	4.88	2.59	3.98	77
5th	2k	4.90	2.55	3.71	75
1st	2k2	4.92	2.47	3.50	74

Table : Determination R2, resistor divider

2.3 Results

The most power is sent by the antenna when the input impedance is matched to 50Ω and the reactance is 0Ω at the resonance frequency. This is measured with the Agilent 4396B impedance analyzer and the reflexion coefficients from the antenna are displayed in a so-called Smith chart. Optimal power transfer takes place when the line goes through the middle of the chart at a frequency of 13.56MHz.

With the components, mentioned in the previous paragraphs, in place the following results are measured. At the resonance frequency of 13.56MHz the impedance is 41.8Ω and the reactance is 25.2Ω. (see: Figure Figure) The reactance is too high for an optimal power transfer, however, if the antenna is detuned by a tag the Smith chart shifts to Figure . The impedance is 56.4Ω at 13.56MHz with a reactance of 1.5Ω.

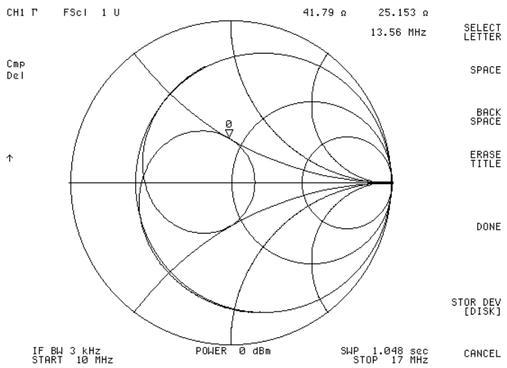

Figure : Antenna impedance

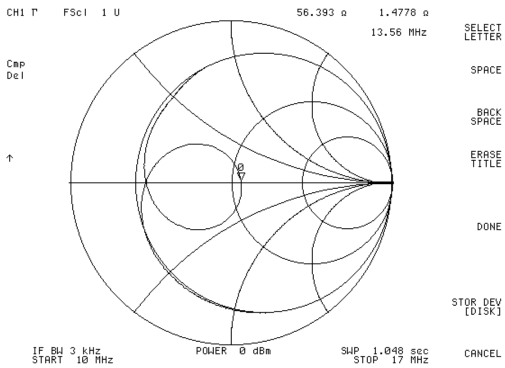

Figure : Antenna impedance, detuned by tag

Figures 7 and 8 are just for a reference to the original antenna design. Even though the matching is far from optimal communication is still possible but only if the card is practically laying on the antenna.

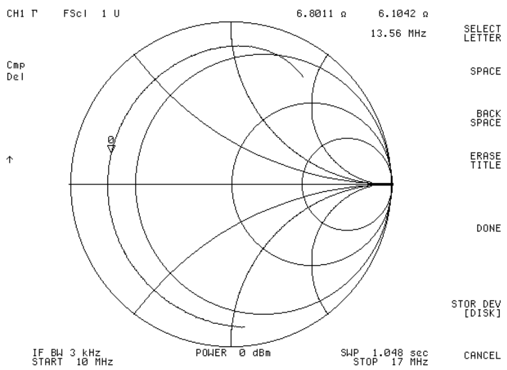

Figure : Original antenna impedance

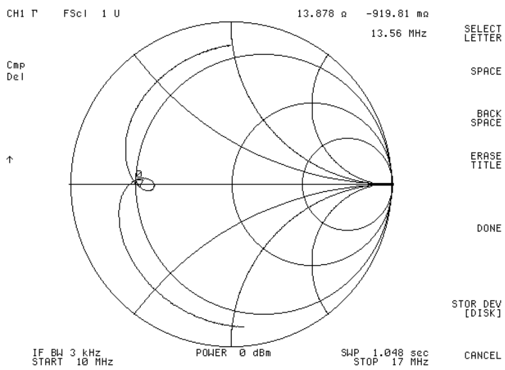

Figure : Original antenna impedance, detuned by tag

3. Conclusion

Figure : Tag

Several components from the original design are changed to optimize the complete reader-antenna system. This results in a doubled communication range for a standard card and even a factor of 3.8 for a small tag (Figure).The biggest increase in communication distance results from the change of capacitors $C_{7,8}$ and resistors $R_{3,4}$ (see: Figure : Board schematic). The difference in communication range because of the other changed components is not significant and is just a fine tuning of the system. The capacitors $C_{7,8}$ provide a better matching to the chip in order to deliver more power from the reader to the antenna. (Less power is reflected back.) The addition of $R_{3,4}$ decreases the quality-factor of the antenna. This results in a better reception of the modulated signal coming from the tag.

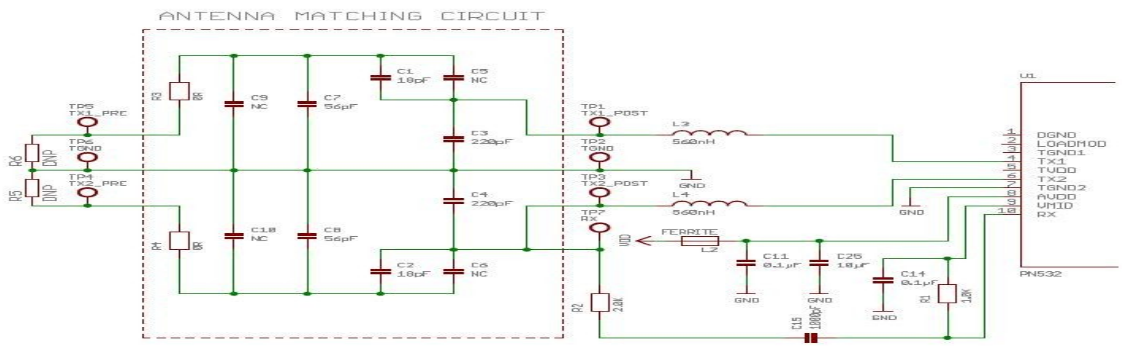

Figure : Board schematic V1.0

An overview of the changed components from the initial version 1.0 to version 1.5 is listed in Table .

Components	Version 1.0	Version 1.5
C1 [pF]	18	22
C2 [pF]	18	22
C7 [pF]	56	100
C8 [pF]	56	100
R2 [Ω]	2k	1.7k
R3 [Ω]	0	1.5
R4 [Ω]	0	1.5

Table : Changed components

A comparison in range and parameters between the two versions can be found below.

Results	Version 1.0	Version 1.5

Com. Range	**Card**	38[mm]	77[mm]
	Tag	13[mm]	50[mm]
Max. field strength		<1[A/m]	1[A/m]>max. field<1.5[A/m]
Q-factor antenna		Unknown	20.40

Table : Final results