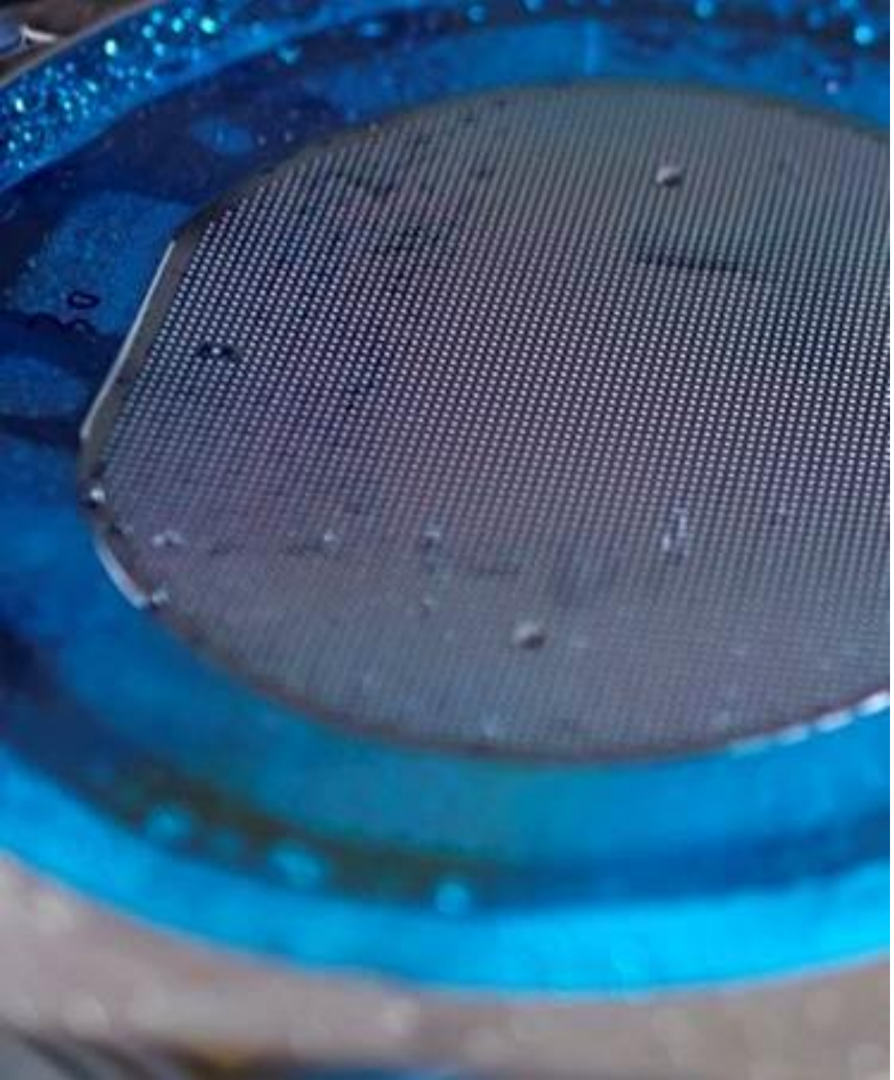
DESIGN AND IMPLEMENT NFC APPLICATIONS

SESSION 2: ANTENNA DESIGN CONSIDERATIONS FOR NXP NFC READERS

September 2016

Training Mobile Knowledge

SECURE CONNECTIONS
FOR A SMARTER WORLD



Agenda

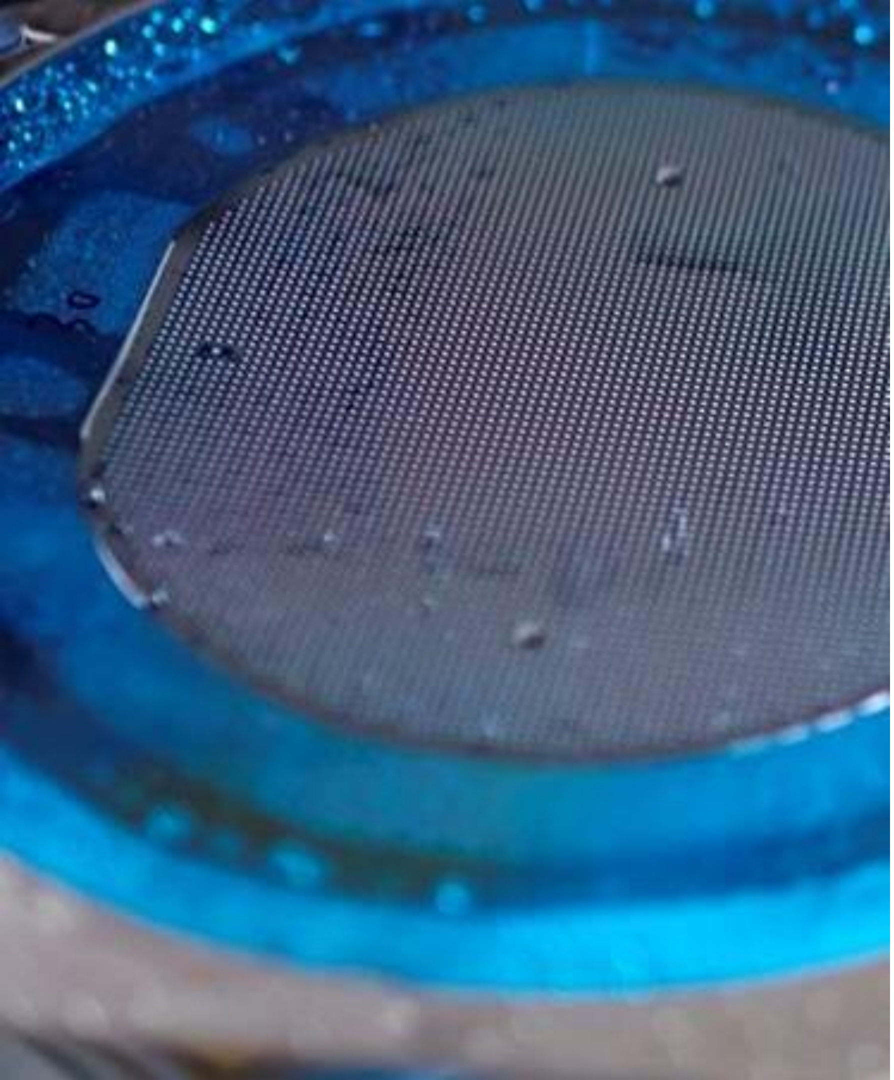
Design and implement NFC applications

Session I, 7th September
Product support package for NXP NFC readers
https://attendee.gotowebinar.com/rt/2329750067403618817

Session II, 28th September
Antenna design considerations for NXP NFC reader solutions
https://attendee.gotowebinar.com/rt/2826826173451860449

Session III, 18th October
The NFC Cockpit - the complete design tool for engineers
https://attendee.gotowebinar.com/rt/4665515186055692545

Session IV, 31th October
NFC Reader Library - SW support for NFC frontend solutions
https://attendee.gotowebinar.com/rt/7151741873899128067



Agenda

Design and implement NFC applications

Session 2, 28th September
Antenna design considerations for NXP NFC reader solutions

- NFC antenna design support (e.g. PN5180)
- Theoretical fundamentals and antenna principles
- “Asymmetric” versus “symmetric” antenna design
- NFC antenna tuning for a “symmetric” antenna (DPC)

NFC implementation process

Evaluate the functionality

Investigate, which NFC functionality you need for your application (e.g. only read cards or write tags or exchange information with another device etc.)

Select IC

Nobody gives you more options to choose from. Start with the specs given in this brochure, then go online to get detailed parametric searches.

Evaluate Features

Explore the possibilities with one of our development boards, then use that same board to start prototyping.

Prototyping

Hardware

PCB design & antenna design

Software

CONNECTED TAGS
Write your code for your MCU using the available code example. Connect additional memory over I2C to your controller enabling e.g. firmware update.

NFC FRONTENDS & CONTROLLER WITH CUSTOMIZABLE FW
Write your code for your MCU using the NFC Library incorporating support for all relevant cards and phones.

NFC CONTROLLER
Write your code for your MCU using the available code examples calling the functions already embedded in the FW of the NFC controller

Test & Debug

Standards-based design and support for the most popular development tools make it easy to fine-tune performance, catch errors, and fix bugs.

Get Certified

Our NFC solutions are designed to help you meet CE, FCC, and other regional requirements, and make it easier to pass EMVCo certification.

NXP support

- Product selection app
- Parametric search and product details on nxp.com
- Z-card with NFC Reader Portfolio
- NFC Everywhere brochure, pp. X-Y

- Full range of development kits for every NFC product, partly coming with precompiled images
- Compatibility with common single board computers including Raspberry Pi, BeagleBone and Arduino boards
- NFC Cockpit for NFC frontends

- Possibility to re-use designs of NXP development kits

- NFC library
- NFC cockpit
- Sample code
- App notes
- Online training
- Tutorials
- ...
- Design files of demokits

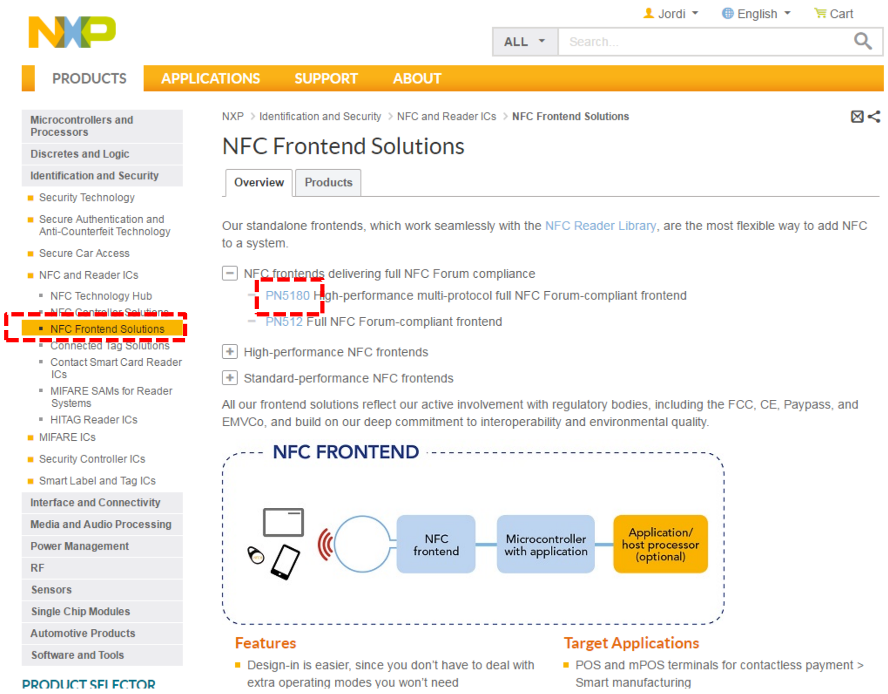
- Development boards for X, Y, Z are pre-certified for EMVCo

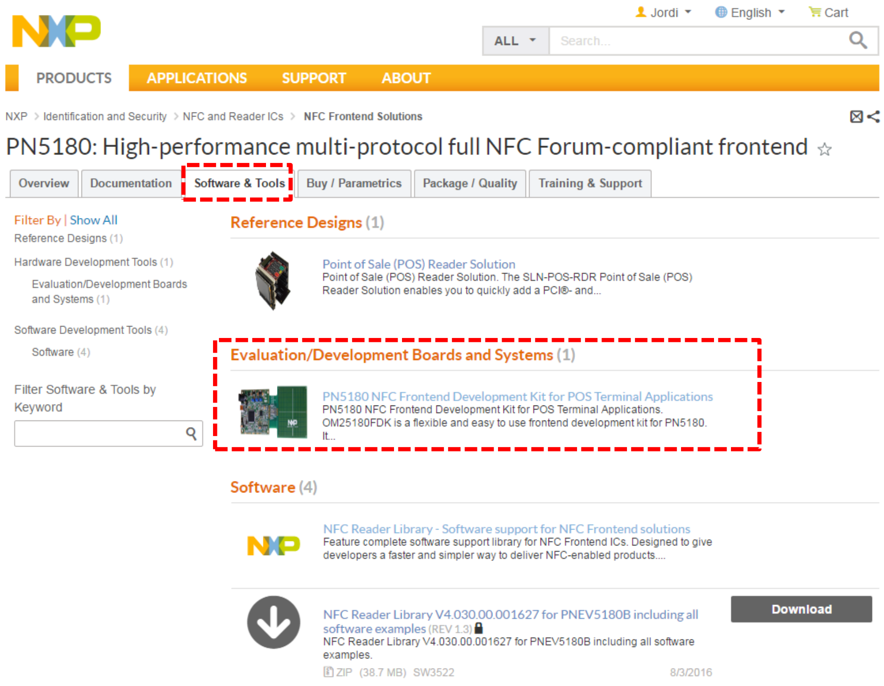
- Technical NFC Community

- Independent Design Houses certified by NXP

NFC ANTENNA DESIGN SUPPORT (E.G. PN5180)

Where to find NFC antenna tuning support material e.g. PN5180

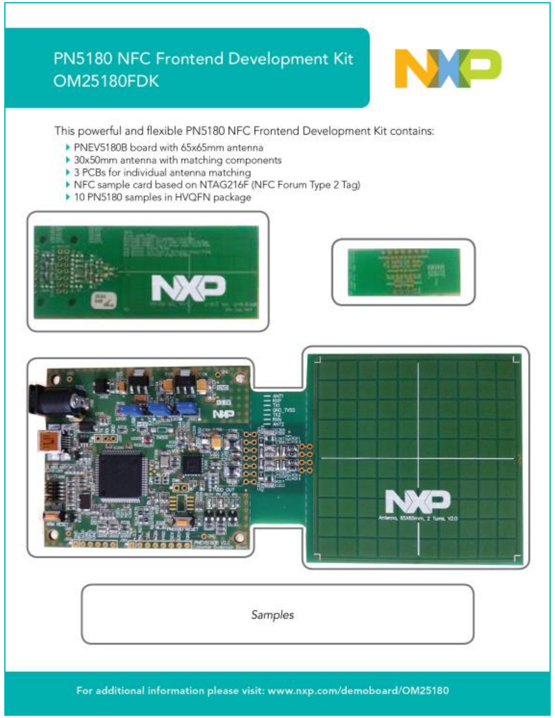




Training Mobile Knowledge

Where to find NFC antenna tuning support material

OM25180FDK: PN5180 NFC frontend development kit



Contents

- PNEV5180B board with 65x65mm antenna optimized for EMVCo applications
- 30 mm x 50 mm antenna with matching components optimized for NFC applications
- **Three small antenna matching PCBs for custom antenna matching**
- NFC sample card (NTAG216)
- 10 PN5180 IC samples (HVQFN package)

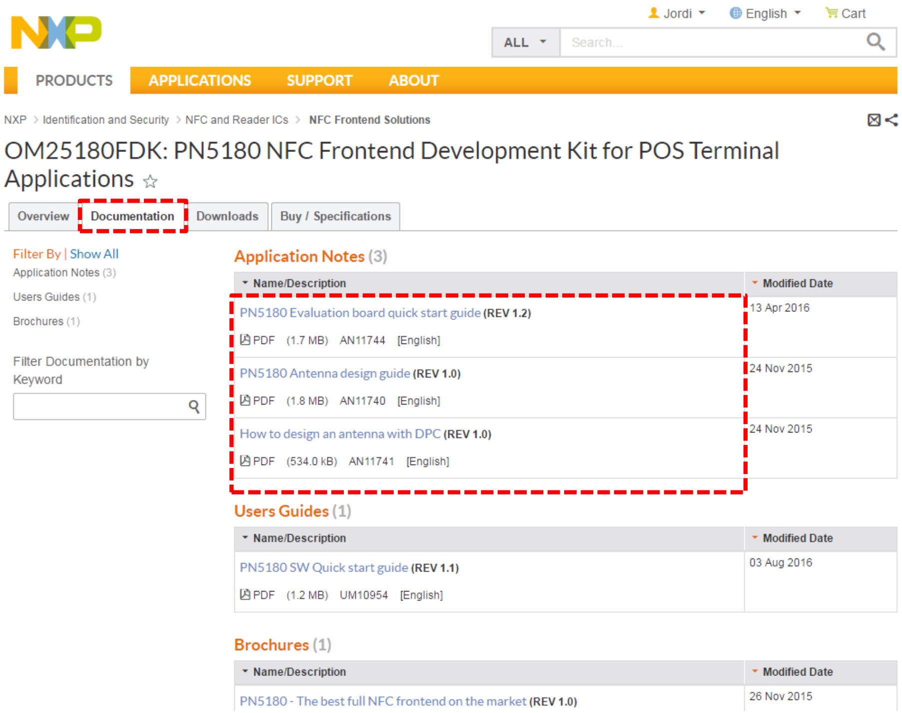
Features

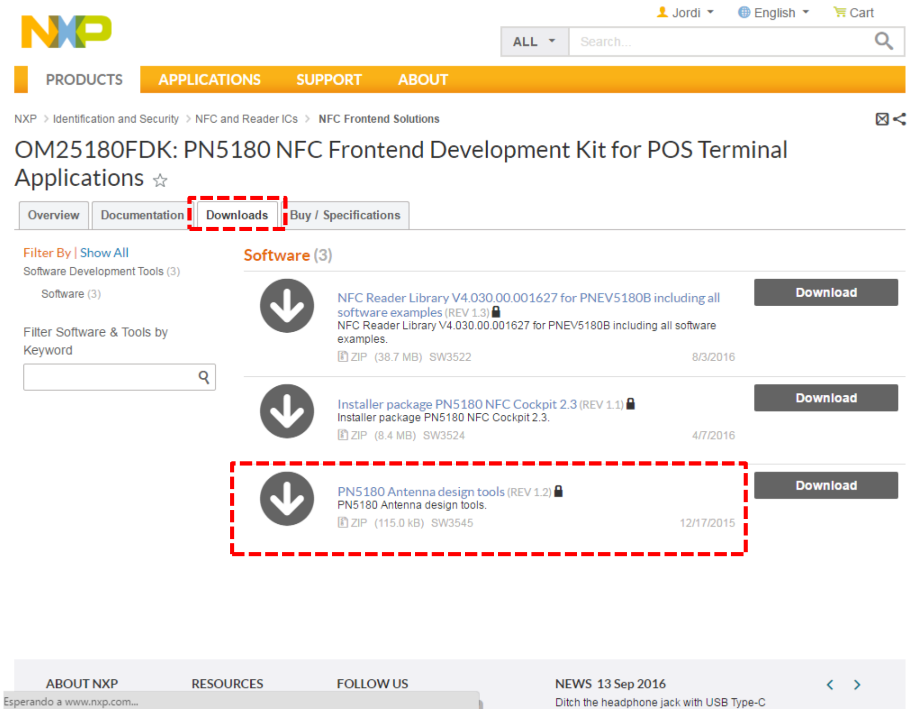
- Quick evaluation of PN5180 NFC frontend IC.
- **Connect a custom antenna to PNEV5180 board**
- **Define and optimize the analog settings for any connected antenna**
- Develop NFC applications based on the NFC Reader Library

Ordering details

- Orderable part number: OM25180FDK
- 12NC: 935307319699
- URL: http://www.nxp.com/demoboard/om25180fdk.html

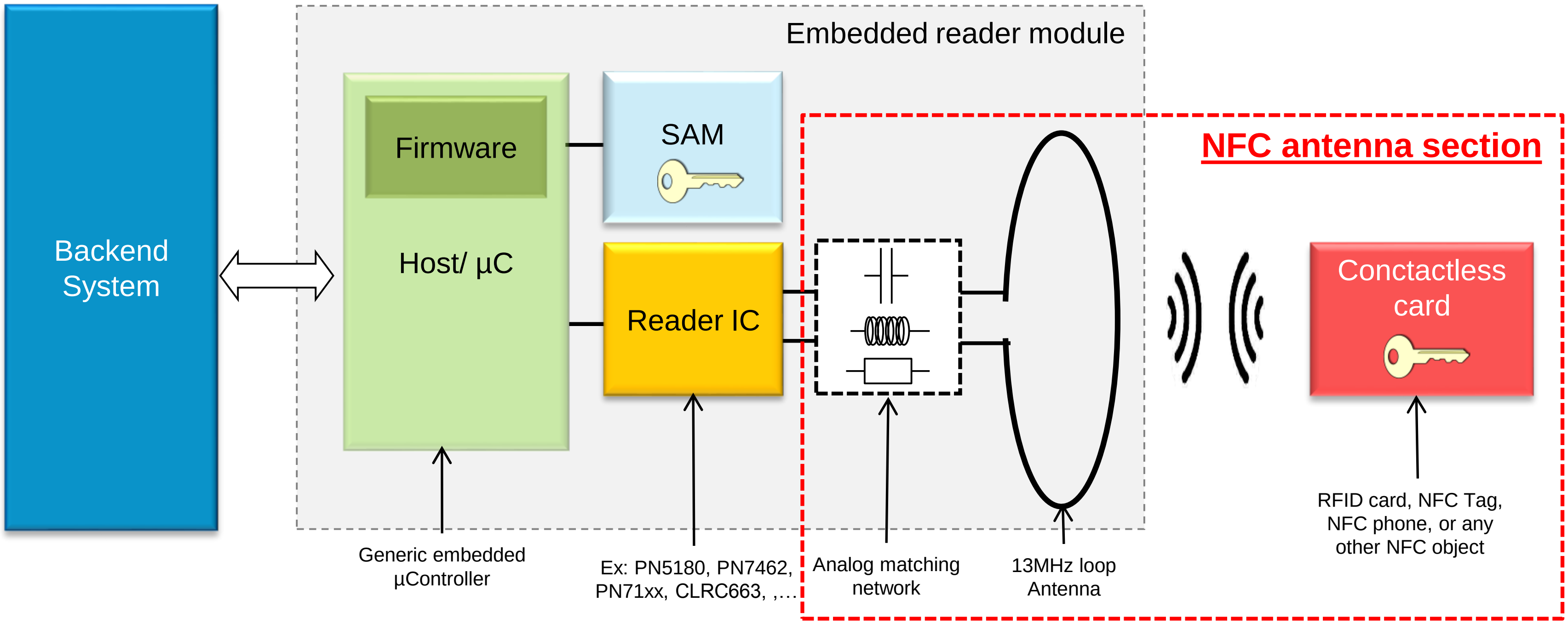
Where to find NFC antenna tuning support material e.g. PN5180



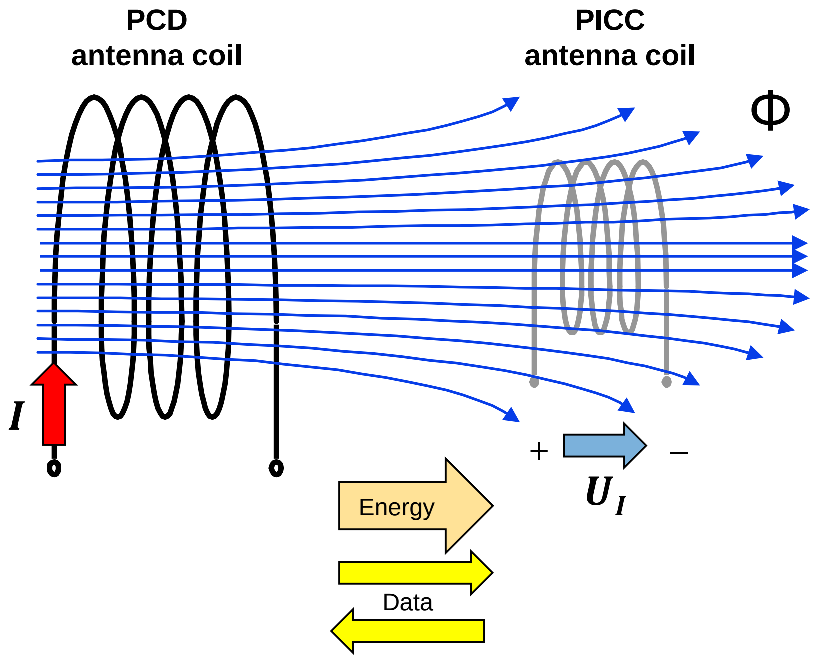


THEORETICAL FUNDAMENTALS AND NFC ANTENNA PRINCIPLES

Typical contactless reader architecture



NFC antenna: Transformer principle

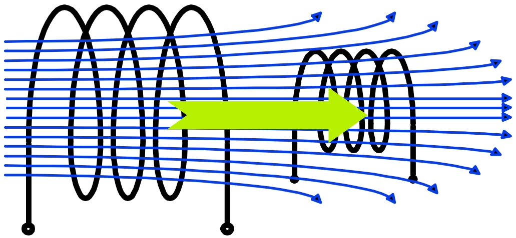


- The vast majority of RFID systems operate according to the principle of ***inductive coupling***.
  - Typical contactless smartcards contain no internal power supply. They need to get all their required energy from the magnetic field in which they operate
- The PCD transmitter coil generates an electromagnetic field with a frequency of 13,56Mhz.
- A small part of the emitted field penetrates the antenna coil of the transponder, which is some distance away from the reader coil.
- A voltage U_I is generated in the transponder's antenna by inductance. This voltage is rectified and serves as the power supply
  - A transformers-type coupling is created between the reader coil and the transponder coil.
- The PCD energy must be available to the PICC during the entire transaction.

NFC antenna: Transformer principle

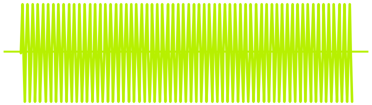
Reader & contactless card communication

FIELD STRENGTH

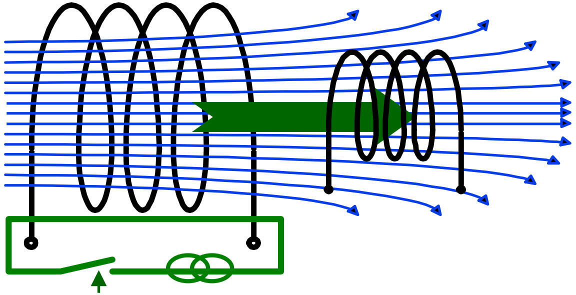


PCD → PICC

13.56 MHz Carrier

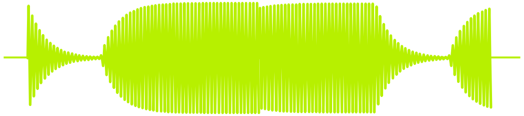


WAVE SHAPES

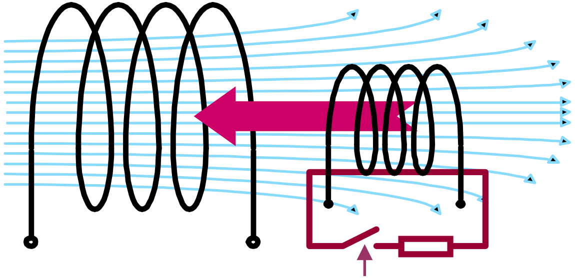


PCD → PICC

MILLER coded DATA

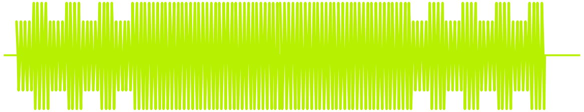


LOAD MODULATION



PCD ← PICC

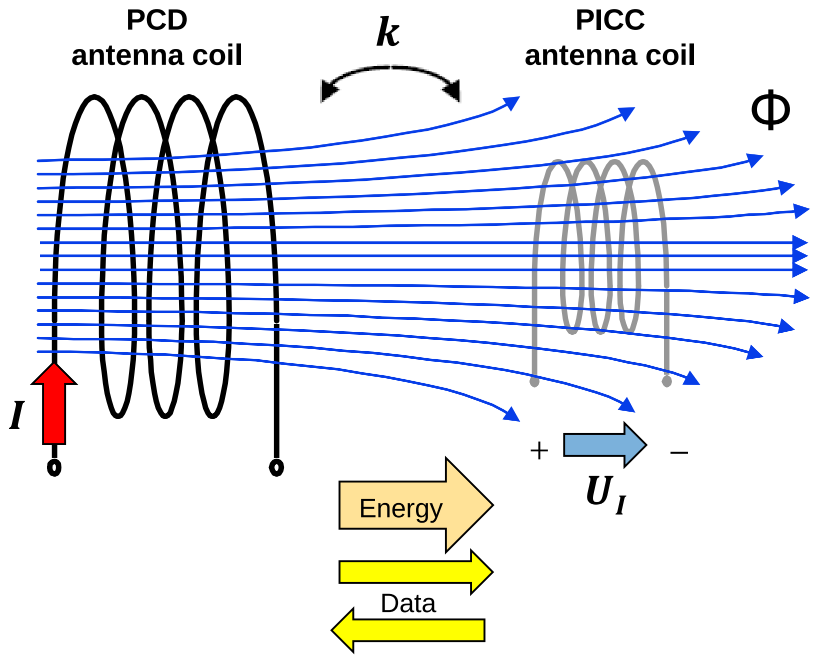
LOAD modulated DATA



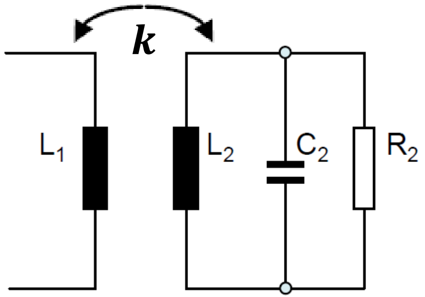
PCD: Proximity Coupling Device (“reader“)
PICC: Proximity Integrated Circuit Card (“card“)

NFC antenna: Transformer principle

Coupling coefficient



- The coupling coefficient depends on:
  - The geometric dimensions of both conductor loops.
  - The position of the conductor loops in relation to each other
  - The magnetic properties of the medium (μ_0)



$$0 < k < 1$$

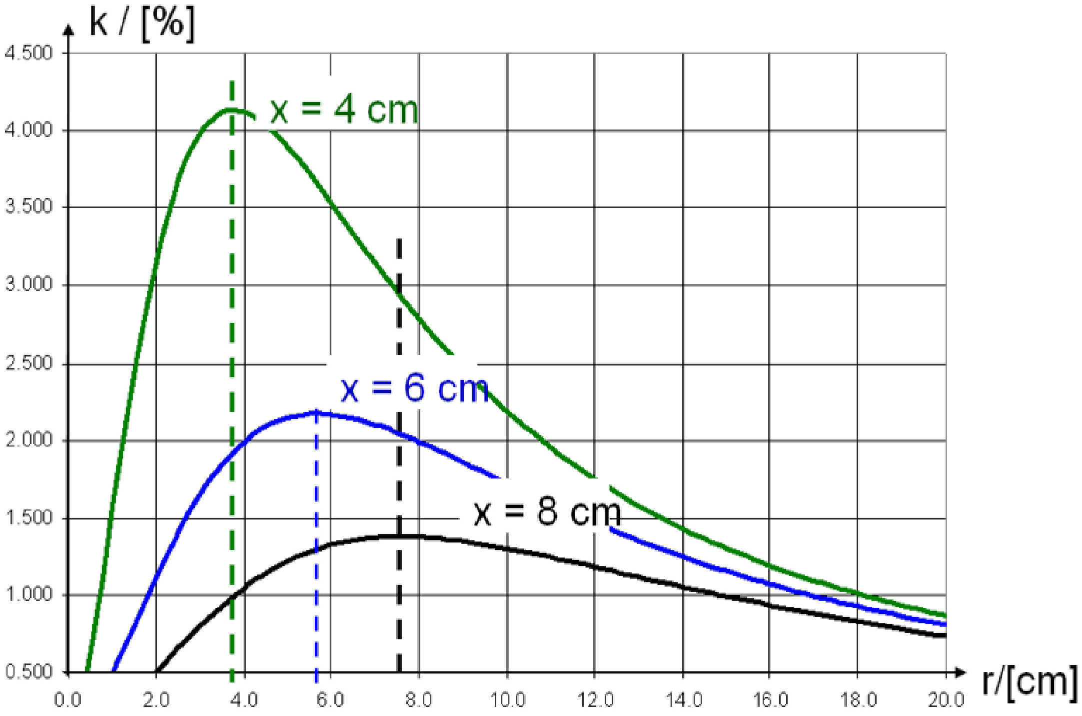
k =1 → total coupling

k =0 → full decoupling

$$k = \mu_0 \cdot \frac{r^2}{2\sqrt{(r^2+x^2)^3}} \cdot \frac{A_2}{\sqrt{L_{01} \cdot L_{02}}}$$

Permeability constant — *Geometrical quantity* — *"Fixed"*

Optimum antenna size (radius)

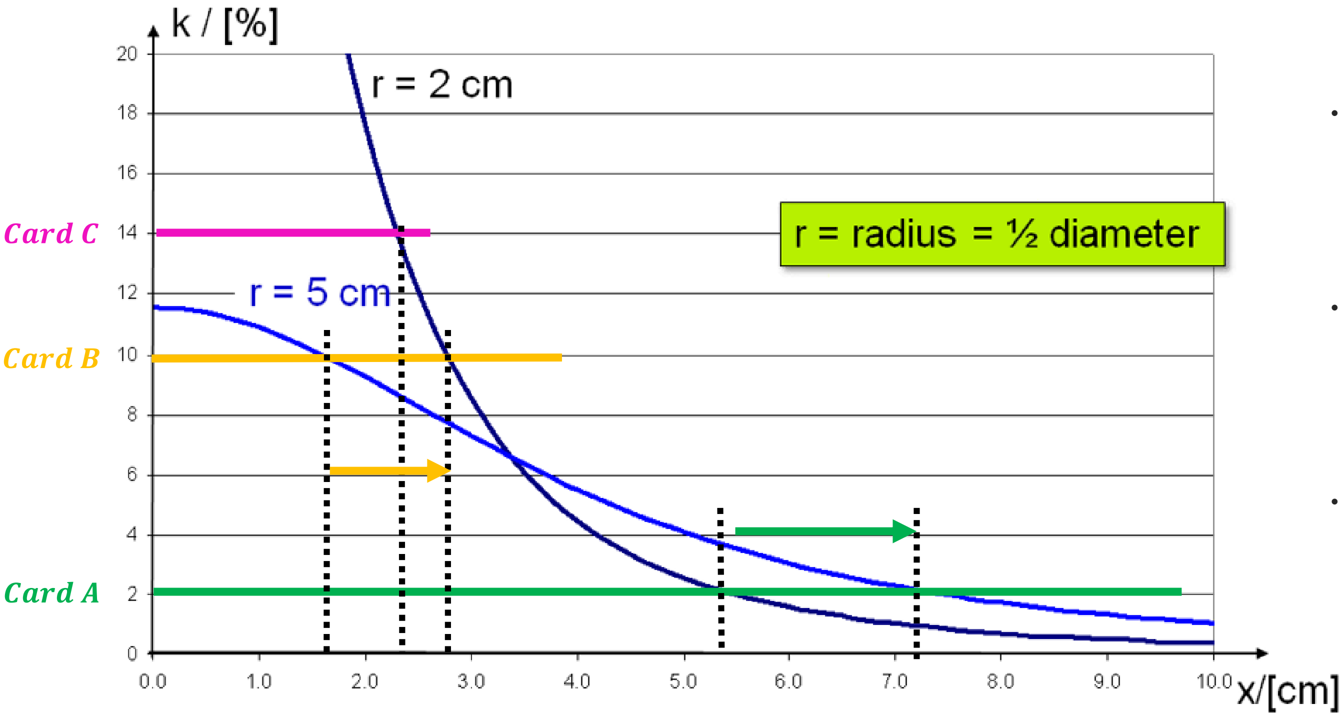


- For every read range $\boldsymbol{x}$ of an NFC system, there is an optimal antenna radius $\boldsymbol{R}$.
- A rough approximation is that :

$$k = \mu_0 \cdot \frac{r^2}{2\sqrt{(r^2+x^2)^3}} \cdot \frac{A_2}{\sqrt{L_{01} \cdot L_{02}}}$$

$$\boxed{r = x}$$

Large antenna vs small antenna



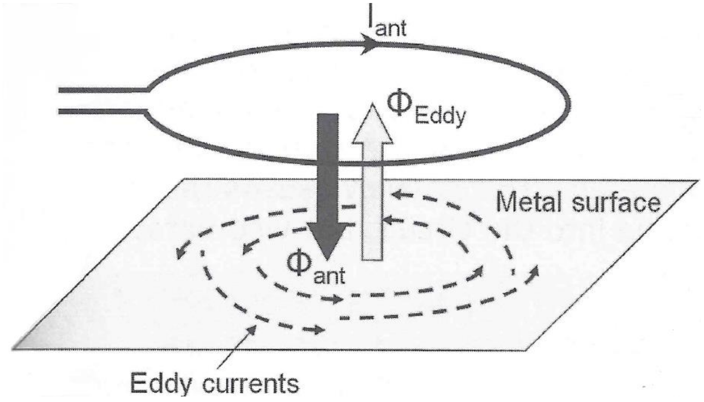
- Card A:
  - PCD r=2 cm → x ≈ 5.5 cm
  - ***PCD r=5 cm → x ≈ 7.2 cm***
- Card B:
  - ***PCD r=2 cm → x ≈ 2.8 cm***
  - PCD r=5 cm → x ≈ 1.8 cm
- Card C:
  - ***PCD r=2 cm → x ≈ 2.2 cm***
  - PCD r=5 cm → x ≈ - cm

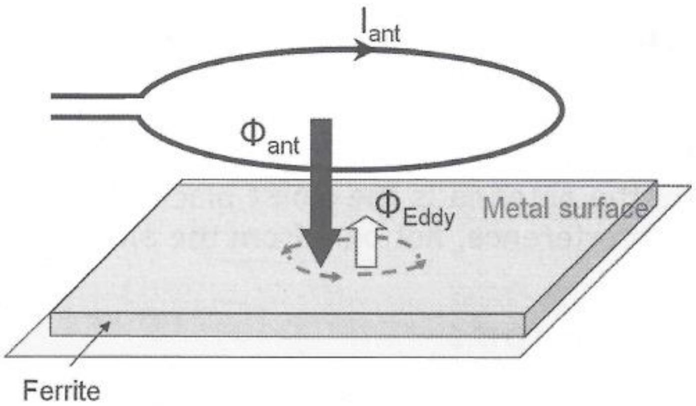
Metal environment influences

Eddy currents

- Metal surfaces in the immediate vicinity of the reader antenna have several negative effects.
- Our reader antenna’s magnetic field generates eddy currents in metallic surfaces.
- These eddy currents produce a magnetic flow opposite to that of the reader device

- Ferrites are basically poor electrical conductors but are very good at propagating magnetic flux (mostly of iron oxide Fe2O3)
- The ferrite material “shields” the metal behind it.
- It significantly reduces the generated eddy currents

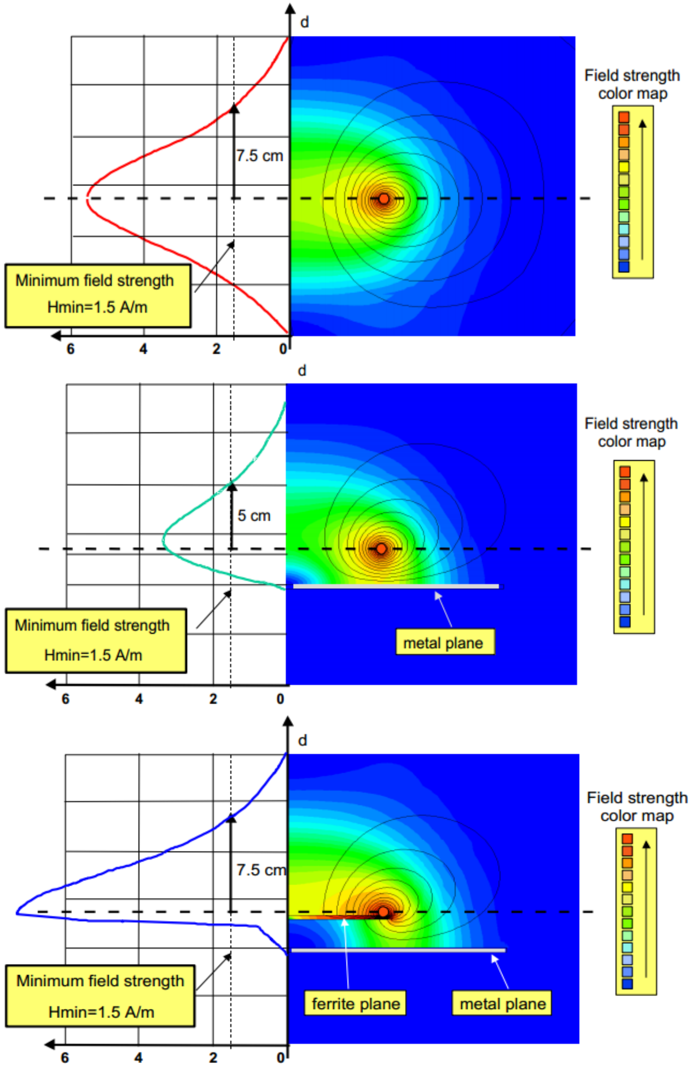




Shielding and environment impact

- The figures show three different field strength characteristics over reading distance x, for the same antenna coil:
  - Free air coil (7.5 cm)
  - Coil surrounded by a metal plate (5 cm)
  - Coil surrounded by a metal plate shielded by a ferrite plate (7.5 cm)
- We can achieve almost original operating distance using ferrite shielding. However, the ferrite detunes the antenna and produces:
  - Increased inductance
  - Increased Q-factor
  - Changed magnetic field distribution

Conclusion: The antenna must be suited to its environment

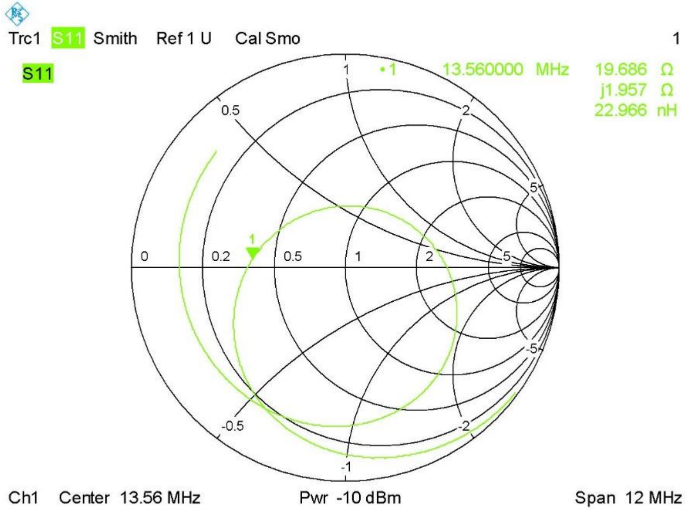


“ASYMMETRIC” VS “SYMMETRIC” ANTENNA TUNING

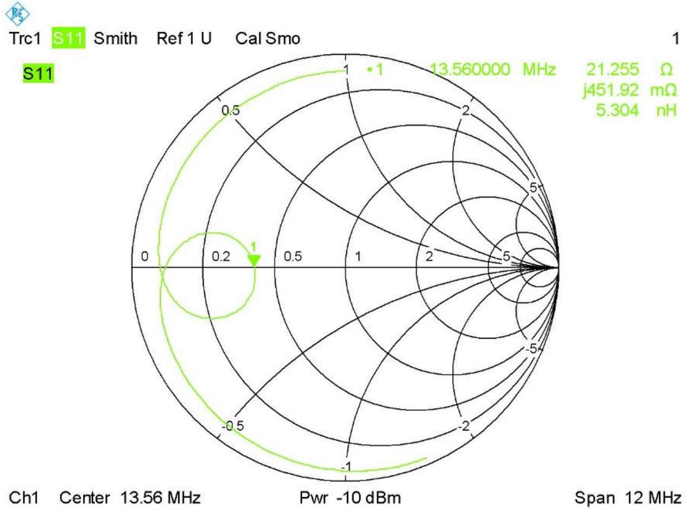
NFC antenna tuning naming convention

“Asymmetric” and “symmetric” antenna tuning

“Asymmetric“ antenna design (e.g. CLRC663)
Automatically limits the current and field strength under loading/detuning
Not optimum transfer function



“Symmetric“ antenna design (new for e.g. PN5180)
Provides more power transfer and better transfer function
Requires current / field strength limiter



Typical load detuning effect in “asymmetrical” antenna tuning

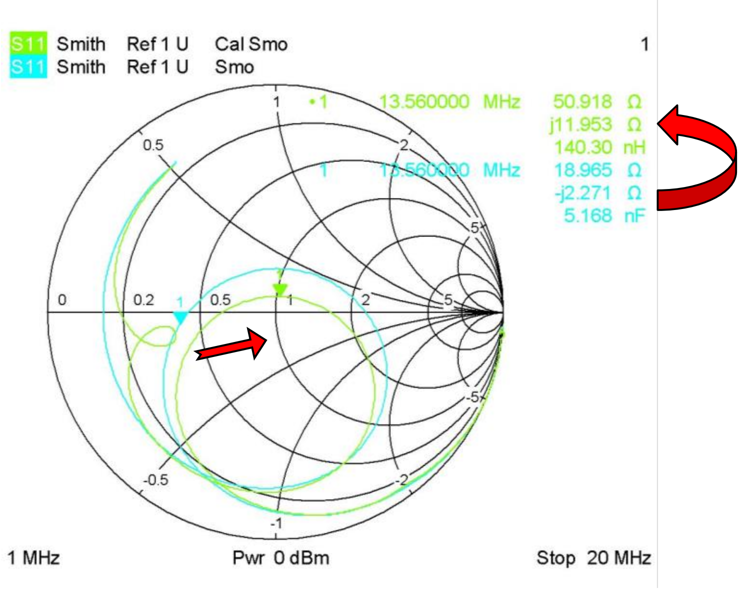


Fig. Loading with Reference PICC

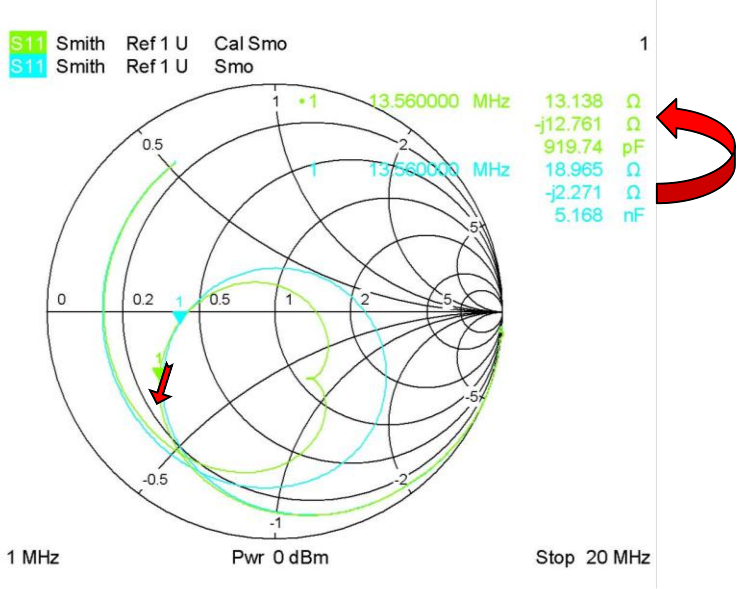


Fig. Loading with smartphone (metal)

The load increases → I_{TVDD} **and field strength is reduced**

The load decreases, but I_{TVDD} does **not** exceed the limit

Typical load detuning effect in “symmetrical” antenna tuning

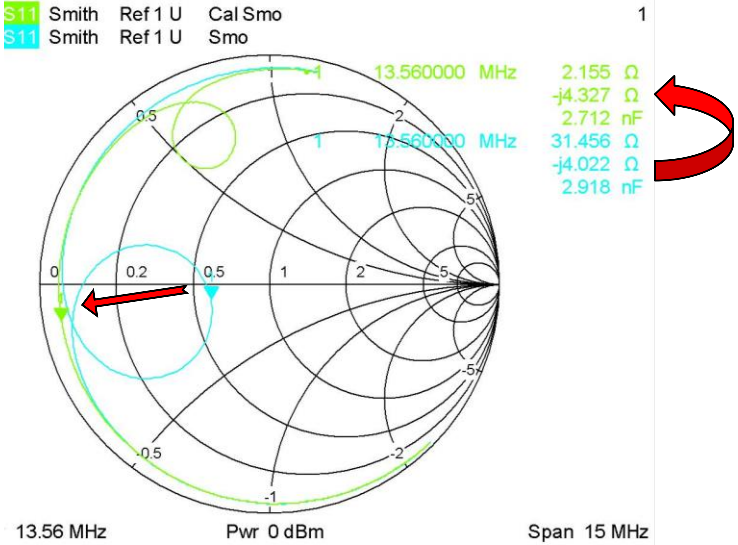


Fig. Loading with Reference PICC

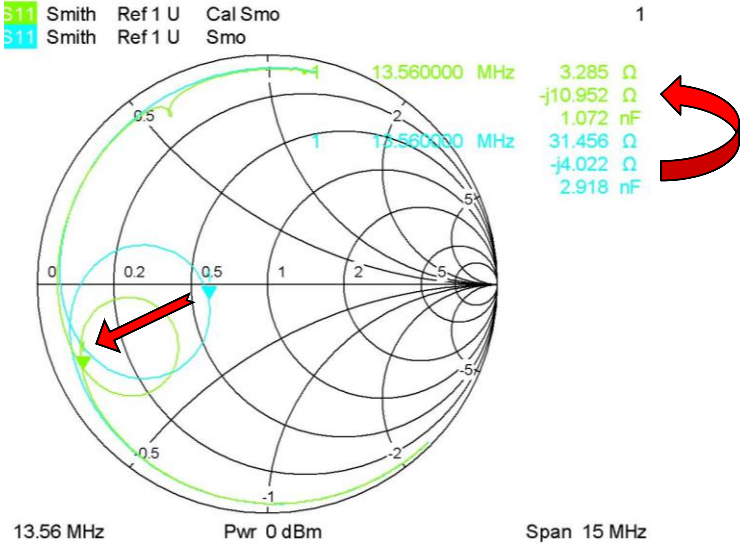


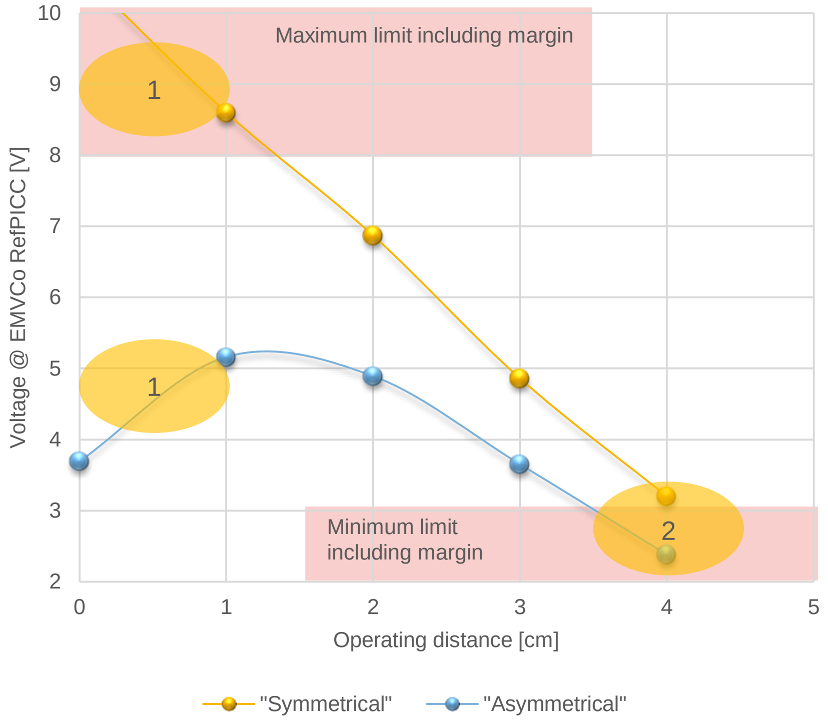
Fig. Loading with smartphone (metal)

The load decreases→ Increases power and I_{TVDD}
I_{TVDD} & field strength may exceed the limit !!!

Solution: Dynamic Power Control

“Asymmetrical” vs “symmetrical” small antenna tuning w.o. DPC

Fig. EMVCo “asymmetrical and “symmetrical” tunings with small antenna



Behavior at short distance

1 **Asymmetric** antenna delivers enough field strength at close distance

1 **Symmetric** anntena at close distance (= strong coupling) the detuning to a lower impedance

- causes higher ITVDD.
- causes higher field strength.
- might kill the reader IC.
- might exceed ISO and EMVCo limits.

Behavior at long distance

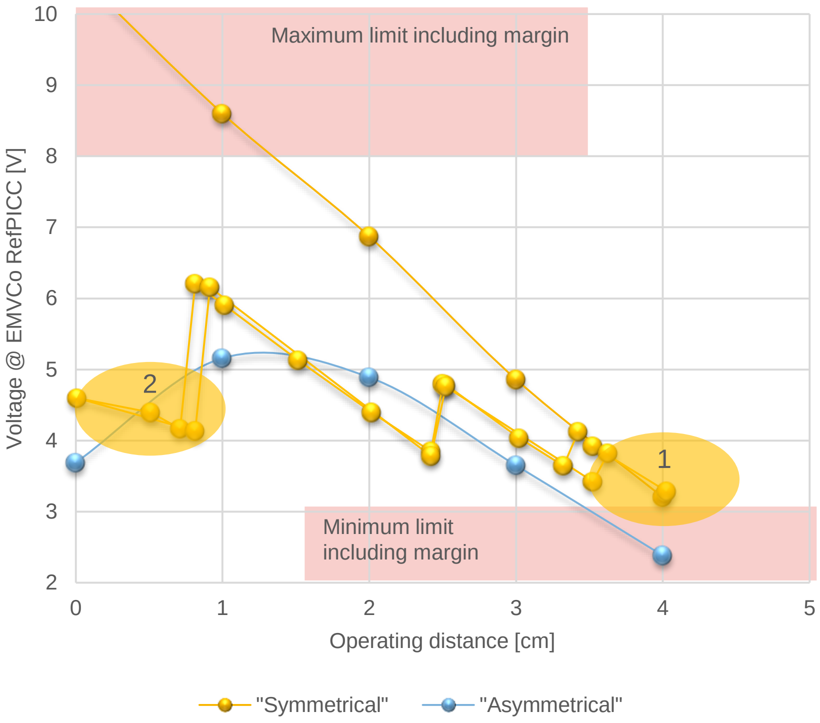
2 **Asymmetric** antenna does not deliver enough field strength at large distance

2 **Symmetric** antenna at long operating distance (= low coupling) the improved transfer function

- allows a higher Q-factor in the antenna coil circuit.
- improves the Tx shaping (options).
- improves the power transfer (RF field).
- improves the Rx filtering, i.e. the “Rx sensitivity”.

“Asymmetrical” vs “symmetrical” small antenna tuning with DPC

Fig. EMVCo “asymmetrical and “symmetrical” tunings with small antenna



Behavior at long distance

1

Symmetric antenna at long operating distance (= low coupling) the improved transfer function

- allows a higher Q-factor in the antenna coil circuit.
- improves the Tx shaping (options).
- improves the power transfer (RF field).
- improves the Rx filtering, i.e. the “Rx sensitivity”.

Behavior at short distance

2

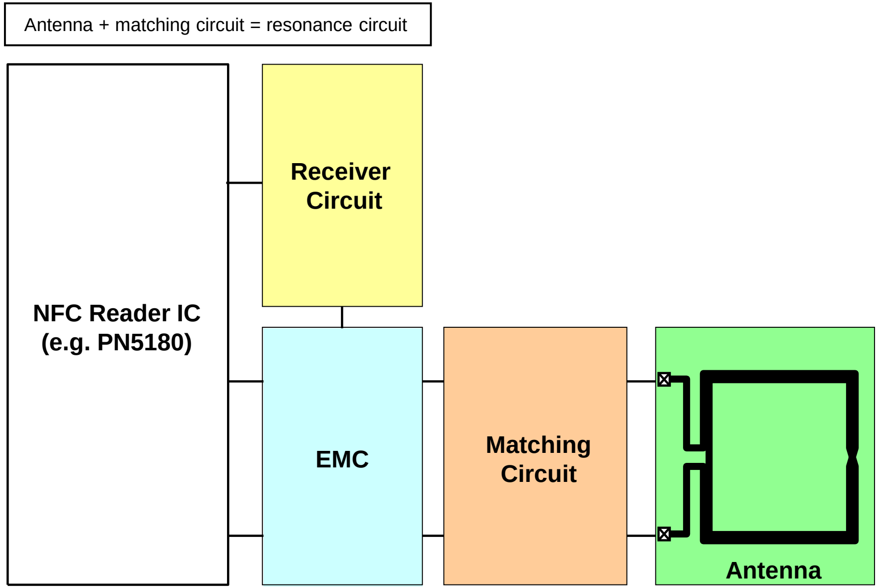
Symmetric antenna at close distance (= strong coupling) **with DPC** delivers enough field strength but not too much due to the DPC regulation

- controls (and limits) the ITVDD.
- controls (and limits) the field strength.
- protects the reader IC.
- ensures to keep the ISO and EMVCo limits.

NFC ANTENNA TUNING PROCEDURE (E.G. SYMMETRIC ANTENNA FOR DPC)

NFC antenna tuning procedure

1. Define target impedance and Q factor
   To optimize RF output power or battery life
2. EMC filter design
   Filtering of unwanted harmonics
3. Measure antenna coil
   Determine LCR values of the antenna coil
4. Calculate matching components
   Using provided excel sheet
5. Assembly and measurement
   Physically test the impedance calculated
6. Adapt simulation
   Correct antenna coil measure
7. Correction and re-assembly
   Solder new matching circuit and test
8. Receiver circuit
   Tune reader sensitivity

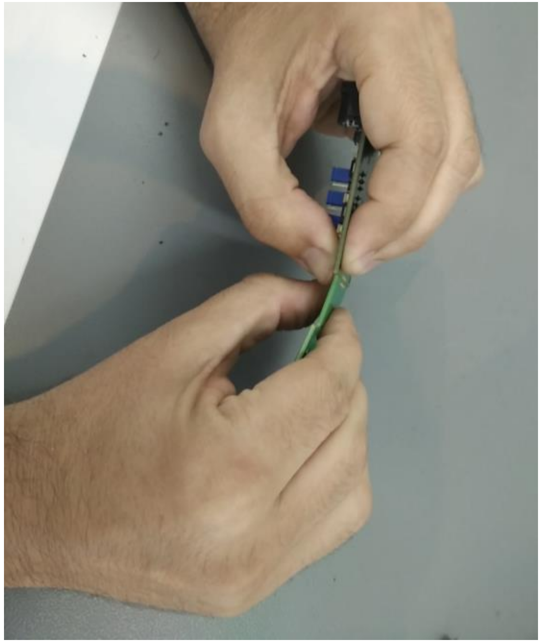


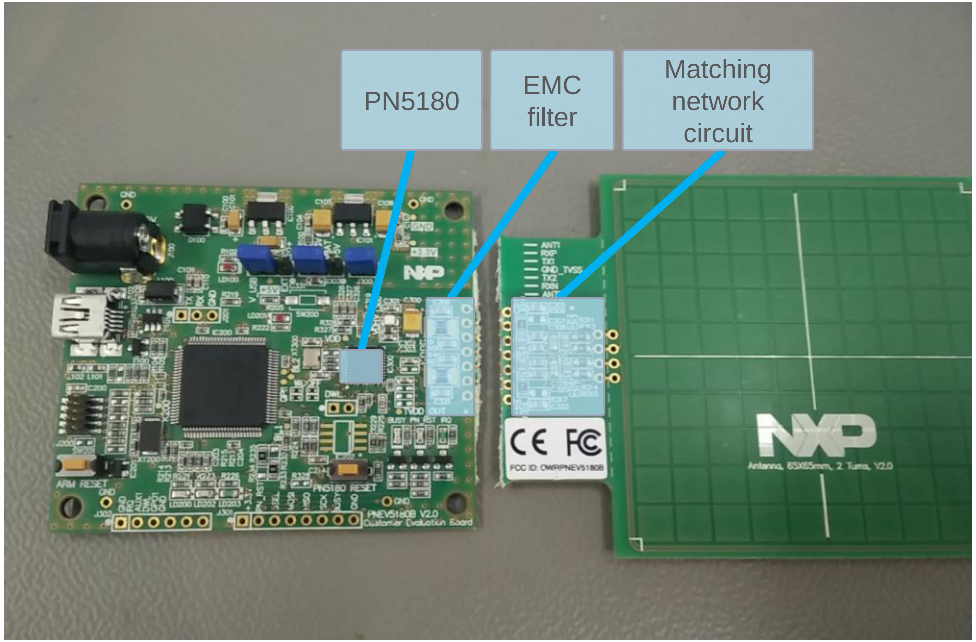
Procedure is exactly the same for "asymmetric and "symmetric" antenna tuning

Antenna tuning with PNEV5180B board

Breaking antenna section

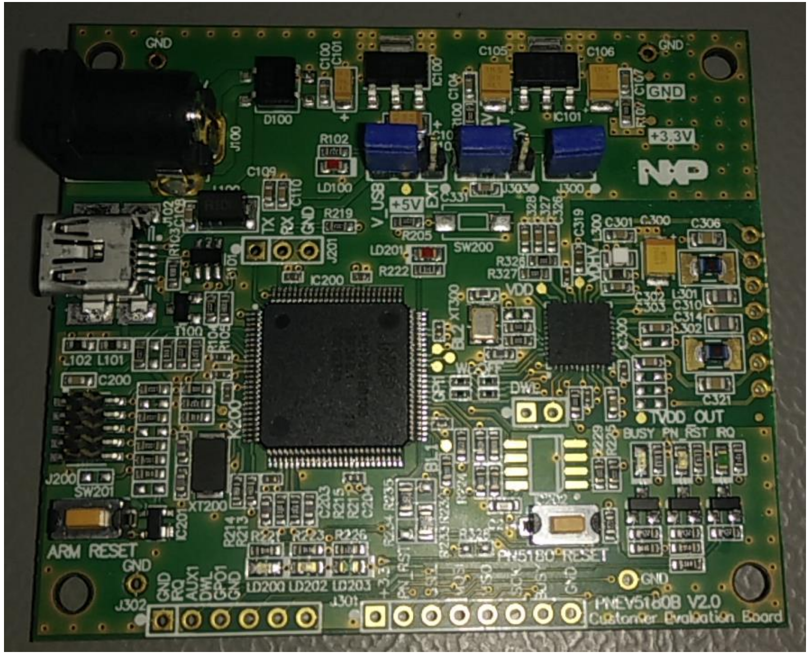
- NFC antenna section can be easily separated from the main board

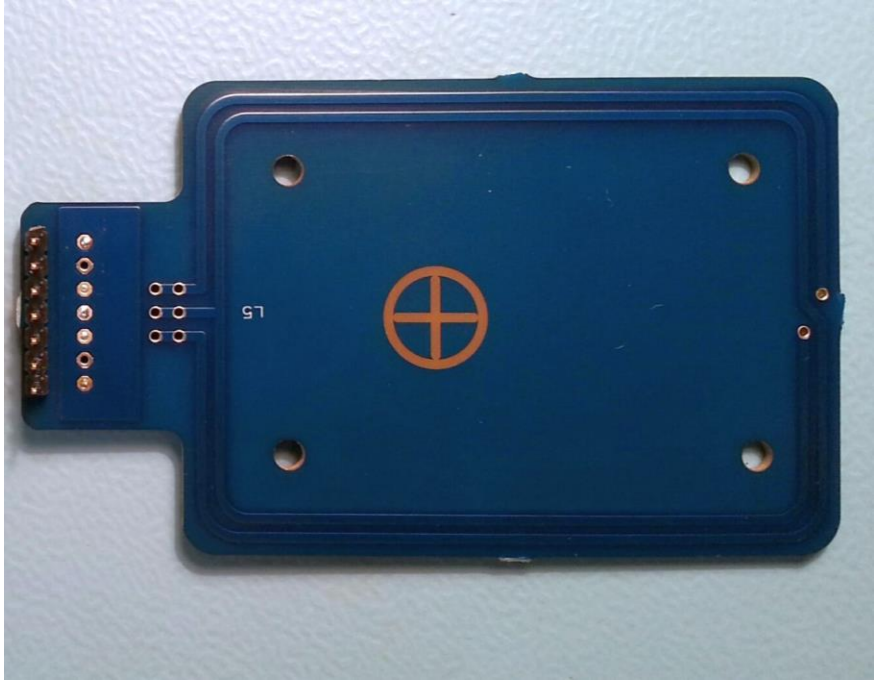




Antenna tuning with PNEV5180B board

Material used





PNEV5180B board
(included in OM25180CDK kit)

Antenna matching PCB
(included in OM25180CDK kit)

70x50mm PCB antenna
(Choose your own)

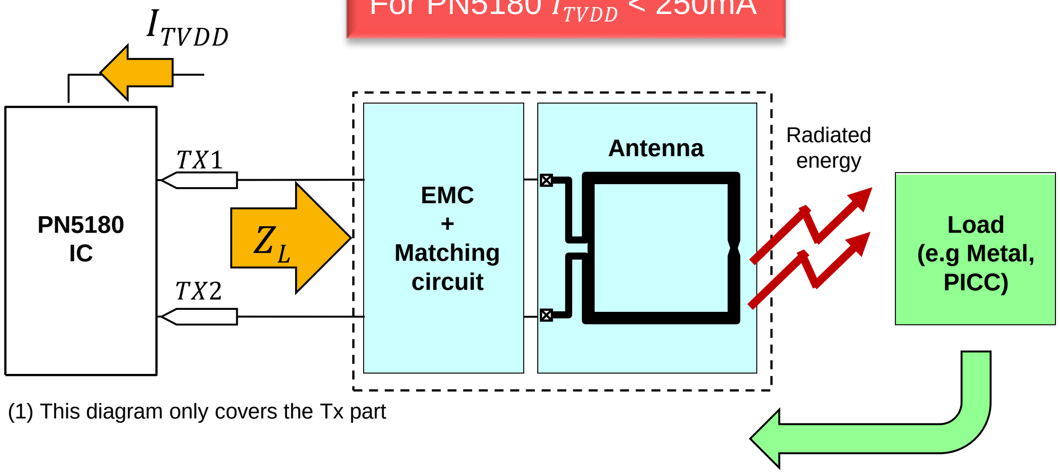
STEP 1:

DEFINE TARGET IMPEDANCE AND Q-FACTOR

Define target impedance

- We need to adjust the target impedance the NFC reader IC “sees” according to the performance we want to achieve.
  - Maximum output power
  - Minimum current consumption (battery life)
- The target impedance is chosen so that the highest possible output power does not exceed the maximum driver current (datasheet).

For PN5180 I_{TVDD} < 250mA



(1) This diagram only covers the Tx part

The load detunes the antenna

R_L = 20 ……… 80 Ω for PN5180

Maximum output power (Operating distance)

Minimum current Consumption (Battery life)

Different load detuning effect depending on “symmetric” or “asymmetric” antenna tuning

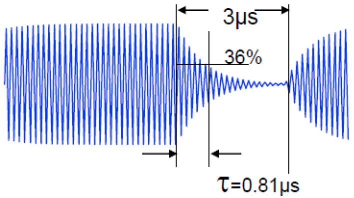
Our example:
Z = 20

Define Q-factor

- A high Q factor leads to high current in the antenna coil and thus improves the power transmission to the transponder

$$B = \frac{f}{Q}$$

- In contrast, the transmission bandwidth of the antenna is inversely proportional to the Q factor.
  - A low bandwidth, caused by an excessively high Q factor, can therefore significantly reduce the modulation sideband received from the transponder.



e.g.: ISO/IEC 14443-A @ 106Kbps

$$Q < f \cdot T$$

$$Q < 13.56MHz \cdot 3\mu s$$

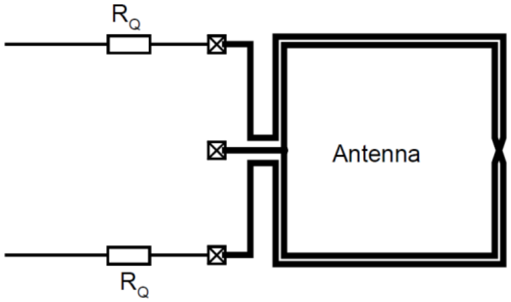
$$Q < 30$$

- The quality factor of the antenna is calculated with:

$$Q_a = \frac{\omega \cdot La}{R_a}$$

- If the calculated Q_a is higher than the target value, an external damping resistor (R_q) has to be added.
- The value of (each side of the antenna) is calculated by:

$$R_Q = 0.5\left(\frac{\omega \cdot La}{Q}\right)$$

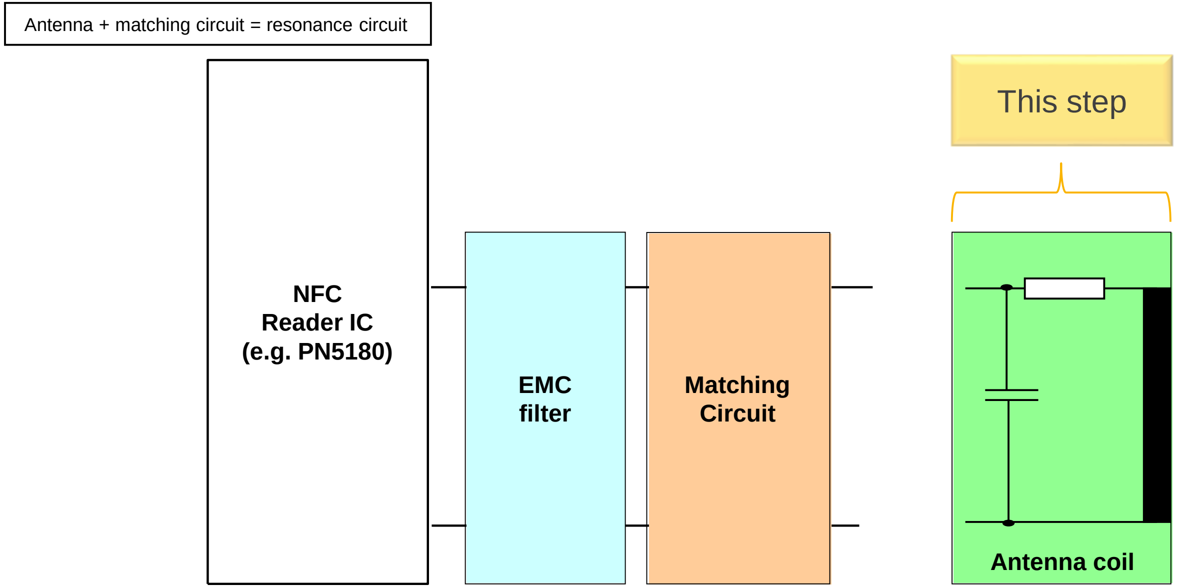


Our example!!!

Q ≈ *28*

STEP 2:
MEASURE ANTENNA COIL

Step 2: Antenna coil characterization



** This circuit only covers the TX part*

How to measure antenna coil

- The antenna loop has to be connected to an impedance or network analyzer at 13.56 MHz to measure the series equivalent components

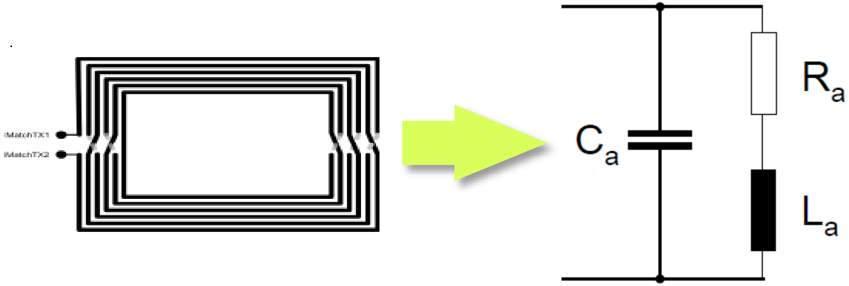


Fig. Antenna series equivalent circuit

Inductance (L): mainly defined by the number of turns of the antenna

Resistance (R): mainly defined by the diameter and length of the antenna wires

Capacitance (C): mainly defined by the distance of antenna wires from each other and number of turns

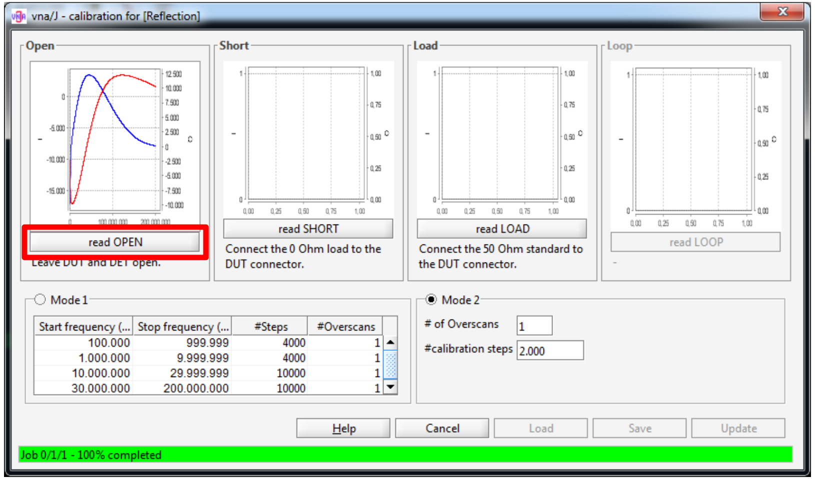
High-end network analyzer (i.e. Rohde & Schwarz ZVL)

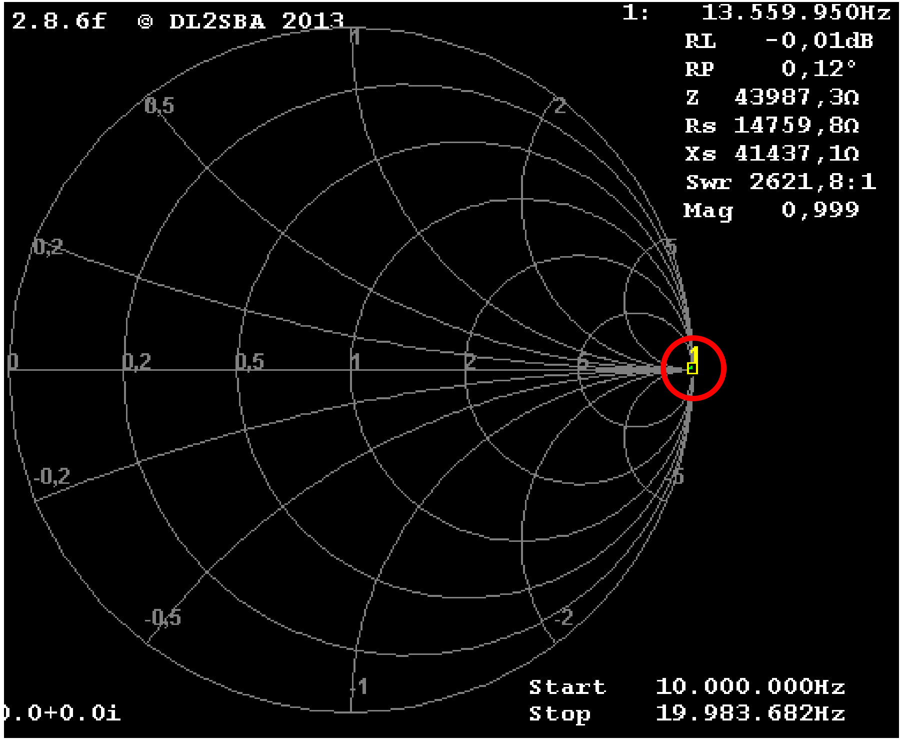
- Powerful, accurate and easy to use

Low-end network analyzer (i.e. miniVNA PRO)

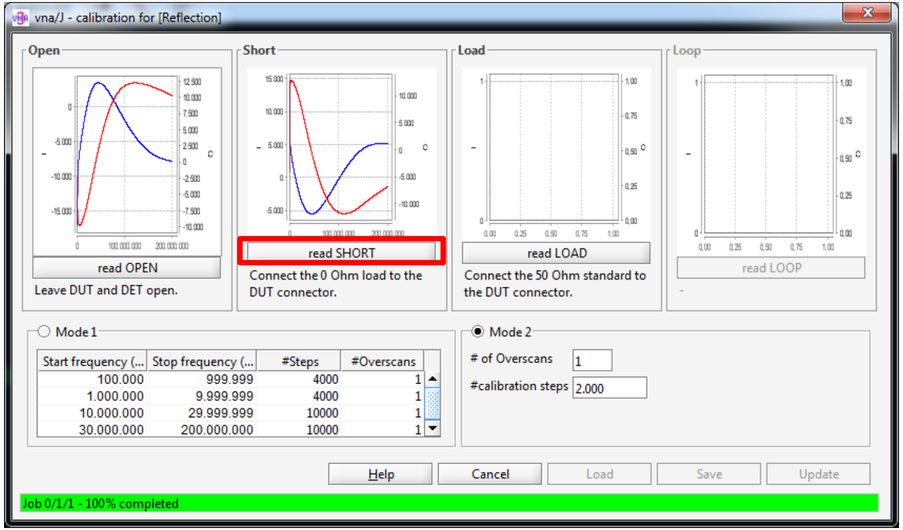
- Cheap, accurate enough and easy to use

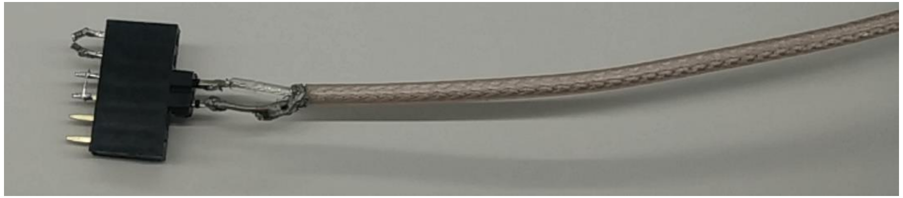
Measuring antenna coil with miniVNA Pro - Calibration (Open)

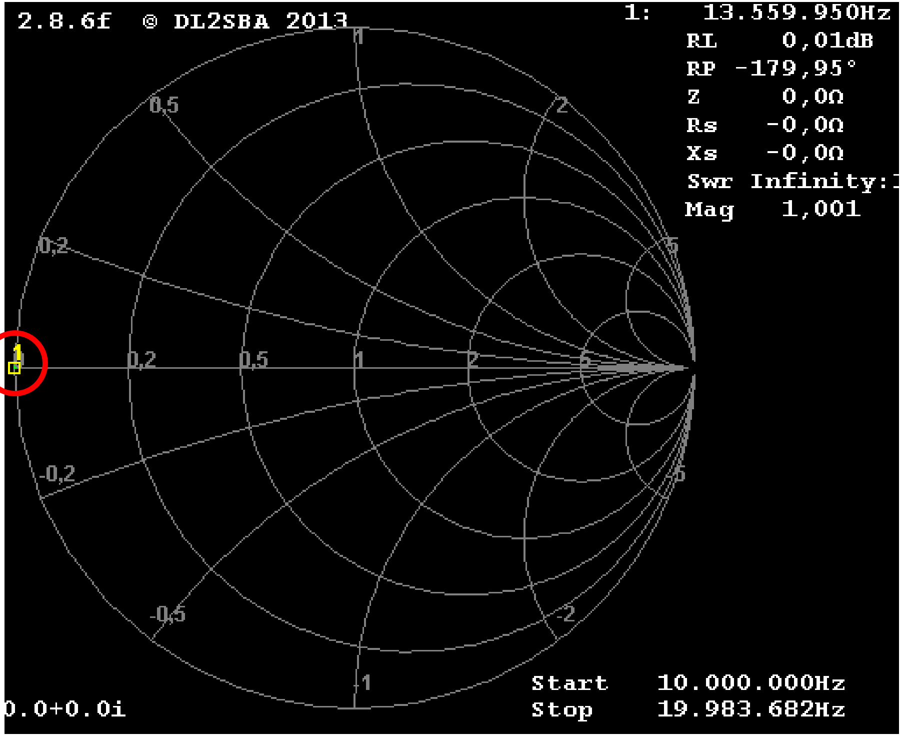




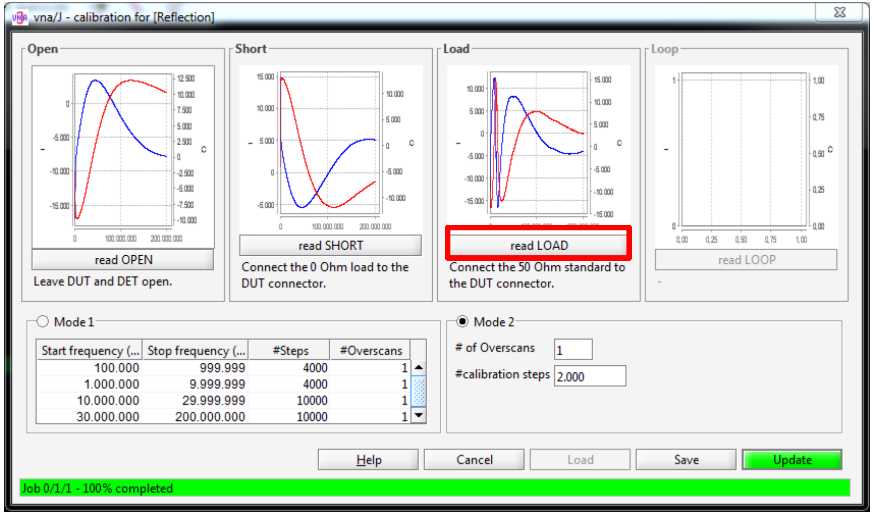
Measuring antenna coil with miniVNA Pro - Calibration (Short)

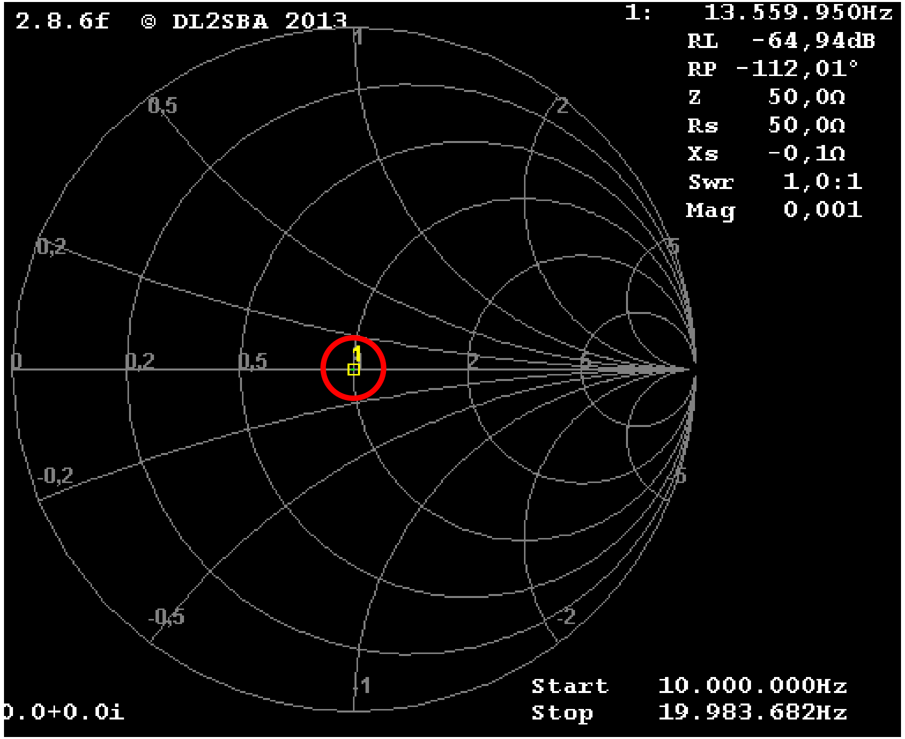






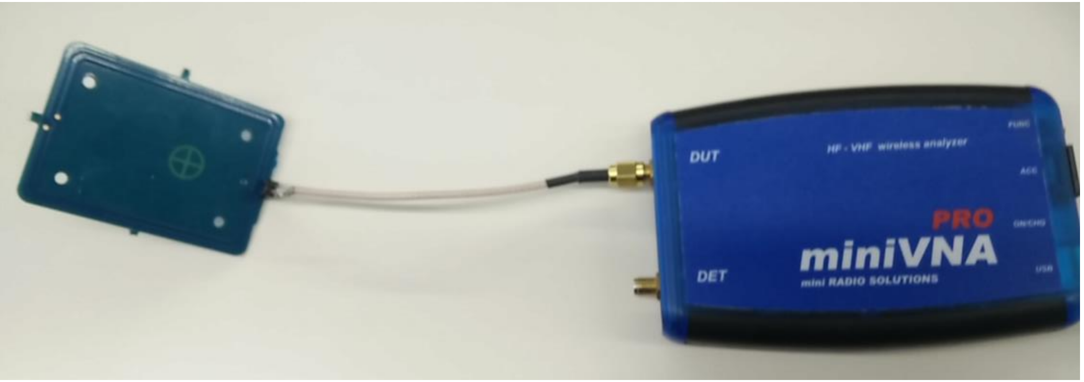
Measuring antenna coil with miniVNA Pro - Calibration (Load – 50Ohms)

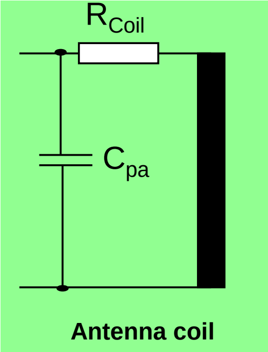




Measuring antenna coil with miniVNA Pro

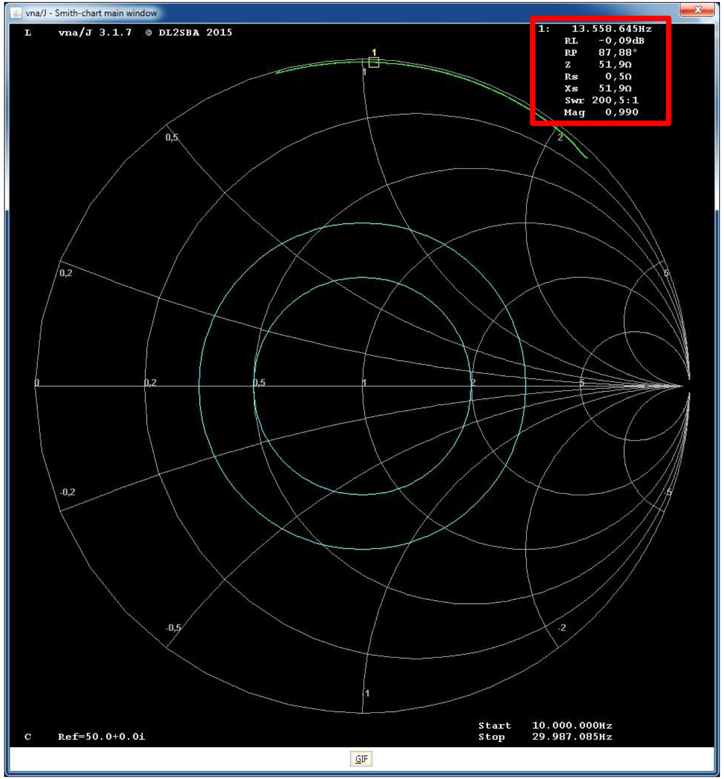
Setup





S11

Measuring antenna coil with miniVNA Pro - Results



$$L_a = \frac{X_s}{2\pi \cdot 13.56MHz}$$

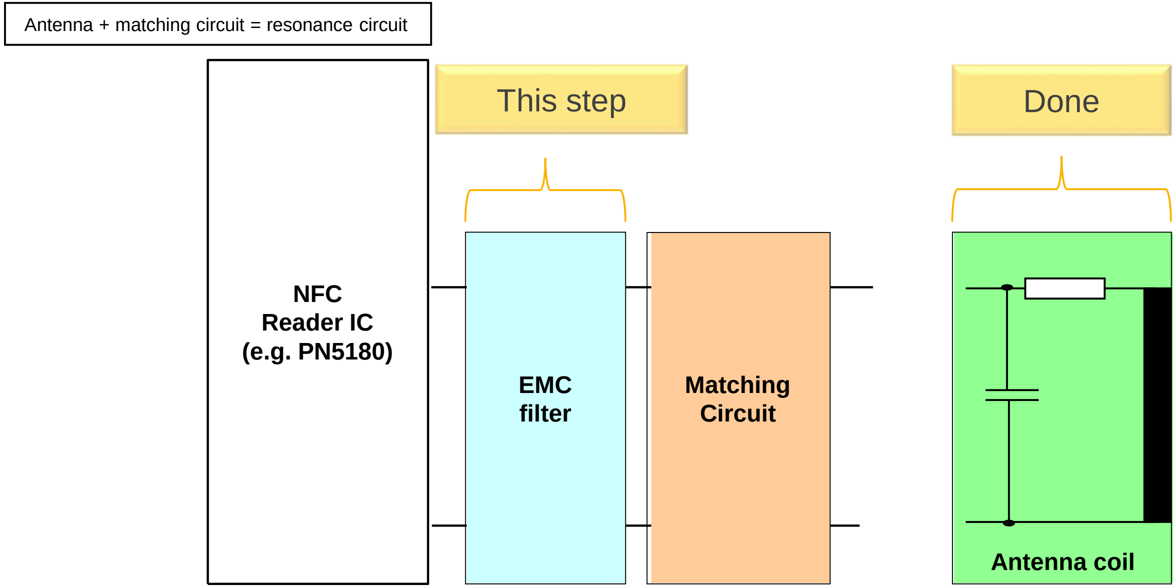
L = 608 nH — Good enough!

$R_{Coil} \approx 0.7\ \Omega$ — Not very accurate, but will be adapted later… In reality R is typically less than measured here.

$C_{pa} \approx 0{,}1pF$ — We don‘t know. Let‘s start with a good guess.

STEP 3:
EMC FILTER DESIGN

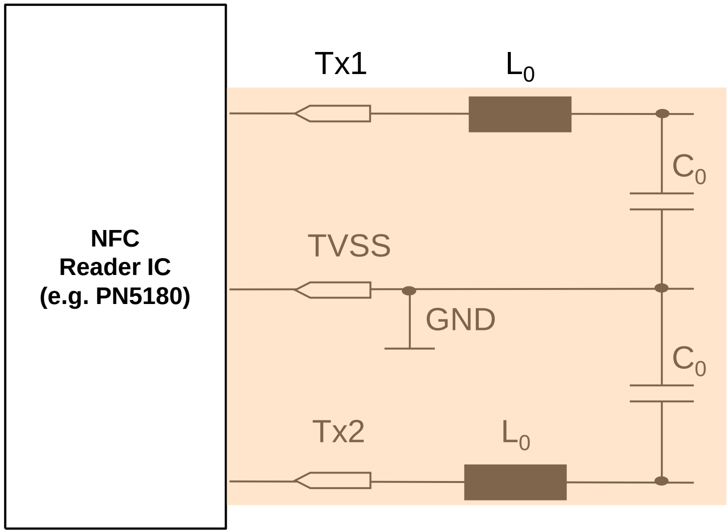
Step 3: EMC filter design



** This circuit only covers the TX part*

EMC filter design for “asymmetric” antenna tuning

- The EMC is a low pass filter reducing 2nd and higher harmonics and performs impedance transformation



EMC Filter

- A convenient cutoff frequency (fc) is between:

$$f_c = 14.5\,MHz \;\ldots\; 22\,MHz$$

- We begin specifying , this range of values has proven to be very useful in practice:

$$L_0 = 330\,nH \;\ldots\; 560\,nH$$

- With fc and $L0$, we can easily calculate $C0$:

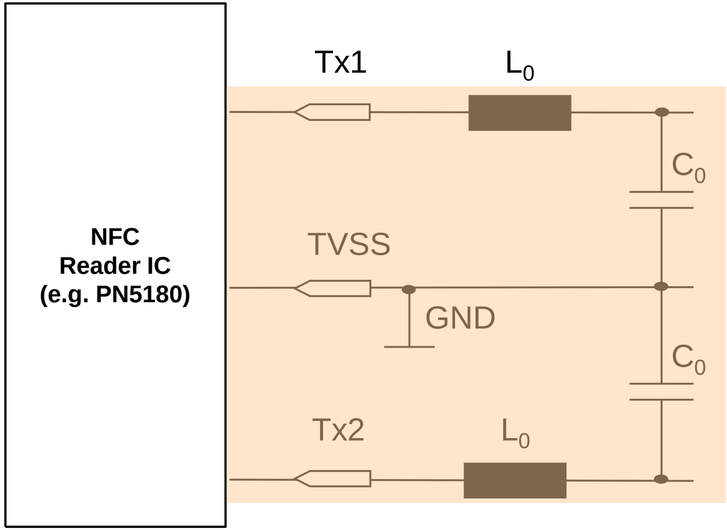
$$w_c = \frac{1}{\sqrt{C_0 \cdot L_0}} \Rightarrow C_0 = \frac{1}{(2 \cdot \pi \cdot fc)^2 \cdot L_0}$$

- Example: fc = 21 MHz and $L0$ = 470 nH:

$$C_0 = 122.2\,pF \Rightarrow \begin{array}{l} C_{01} = 68\,pF \\ C_{02} = 56\,pF \end{array}$$

EMC filter design for "symmetric" antenna tuning

- The EMC is a low pass filter reducing 2nd and higher harmonics and performs impedance transformation



EMC Filter

- A convenient cutoff frequency (fc) is lower:

$$f_c = 14.5\ MHz\ \ldots\ 14.7\ MHz$$

- We begin specifying $L0$, the value should be lower than measured La. Better performance as closer to this value.

$$L_0 \leq {}^{La}/_{2} \qquad L_0 \sim {}^{La}/_{2}$$

- With fc and $L0$, we can easily calculate $C0$:

$$w_c = \frac{1}{\sqrt{C_0 \cdot L_0}} \Rightarrow C_0 = \frac{1}{(2 \cdot \pi \cdot fc)^2 \cdot L_0}$$

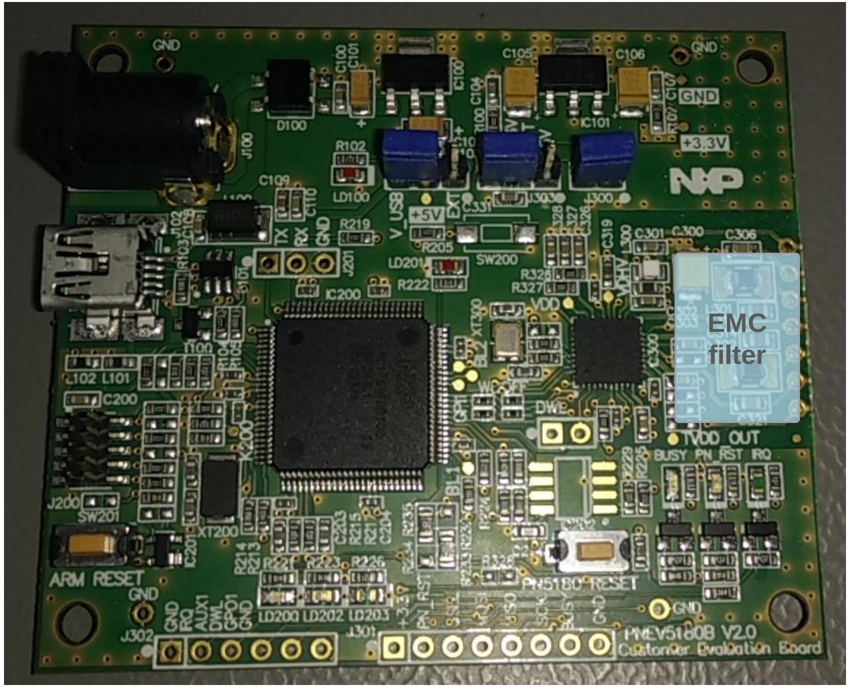
- Example: fc = 14,6 MHz and $L0$ = 470 nH:

$$C_0 = 252{,}8\ pF \Rightarrow \begin{array}{l} C_{01} = 220\ pF \\ C_{02} = 30\ pF \end{array}$$

DPC calibration and correlation test required

EMC filter design for "symmetric" antenna tuning

PNEV5180B board EMC filter

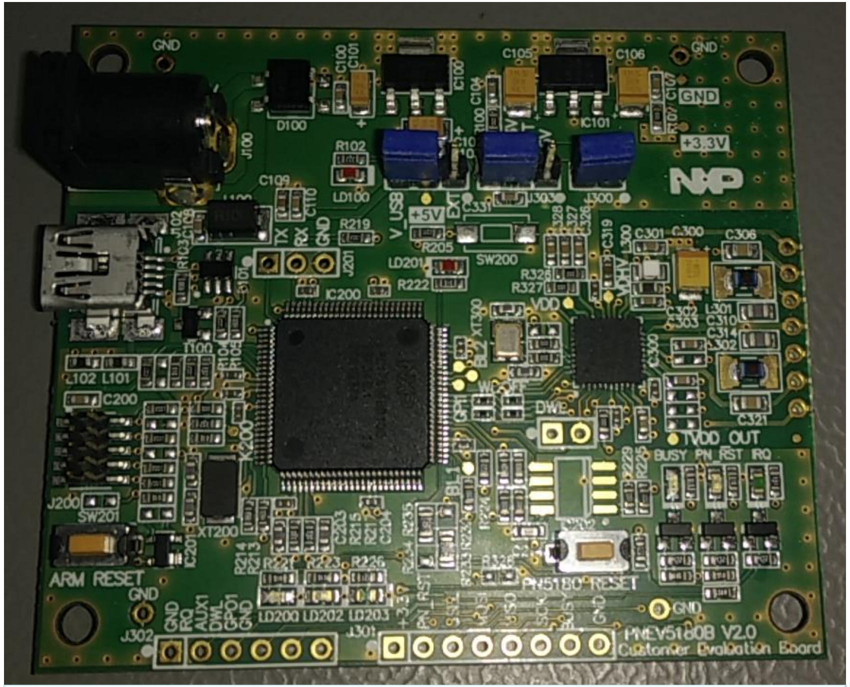


- Default PCB EMC values:
  - L_0 = 470 nH; C_0 = 220 pF; $f_{cut\text{-}off}$ = 15.65 MHz
- Symmetrical impedance rules:
  - $L_0 < \frac{L_a}{2} \Rightarrow 470\,nH < 608\,nH\,/\,2$
  - $f \sim 14{,}6 MHz \Rightarrow C_0 = 252.8\,pF$
- Changes required
  - Add a 33pF in paralel to the EMC filter

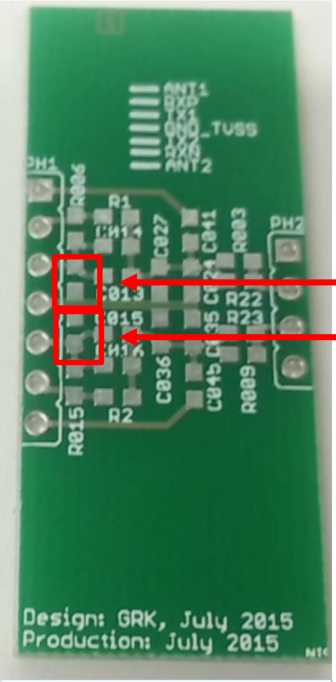
To fulfil requirements a 33pF capacitor is needed!

EMC filter design for "symmetric" antenna tuning

Capacitors assembly



PNEV5180B board (included in OM25180CDK kit)

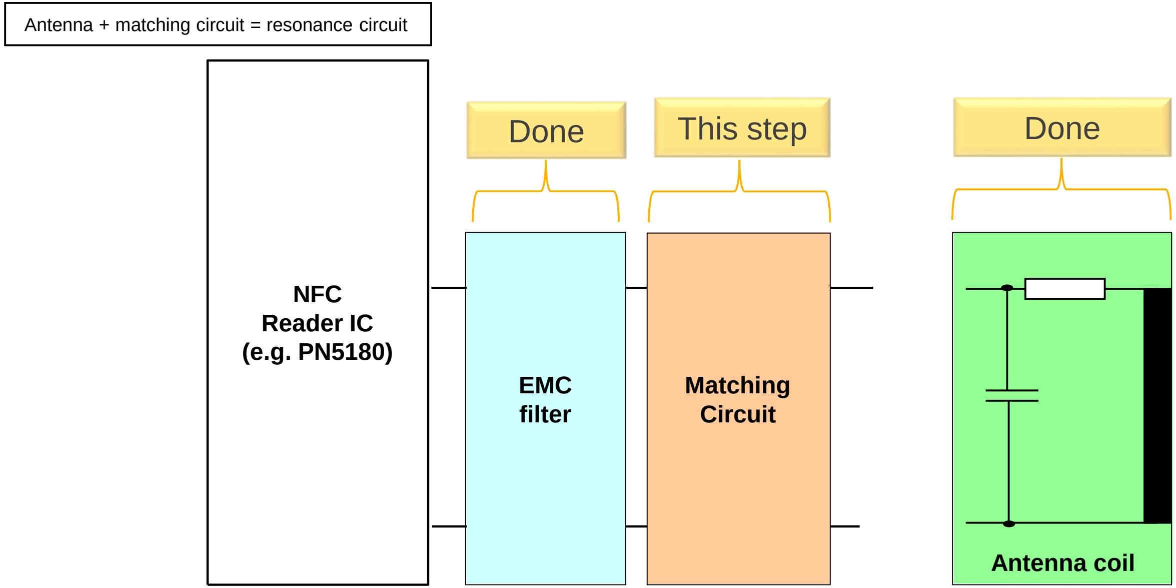


Antenna matching PCB (included in OM25180CDK kit)

Add 2 capacitors $C_0 = 33\ pF$

STEP 4:
CALCULATE MATCHING COMPONENTS

Step 4: Calculate matching components



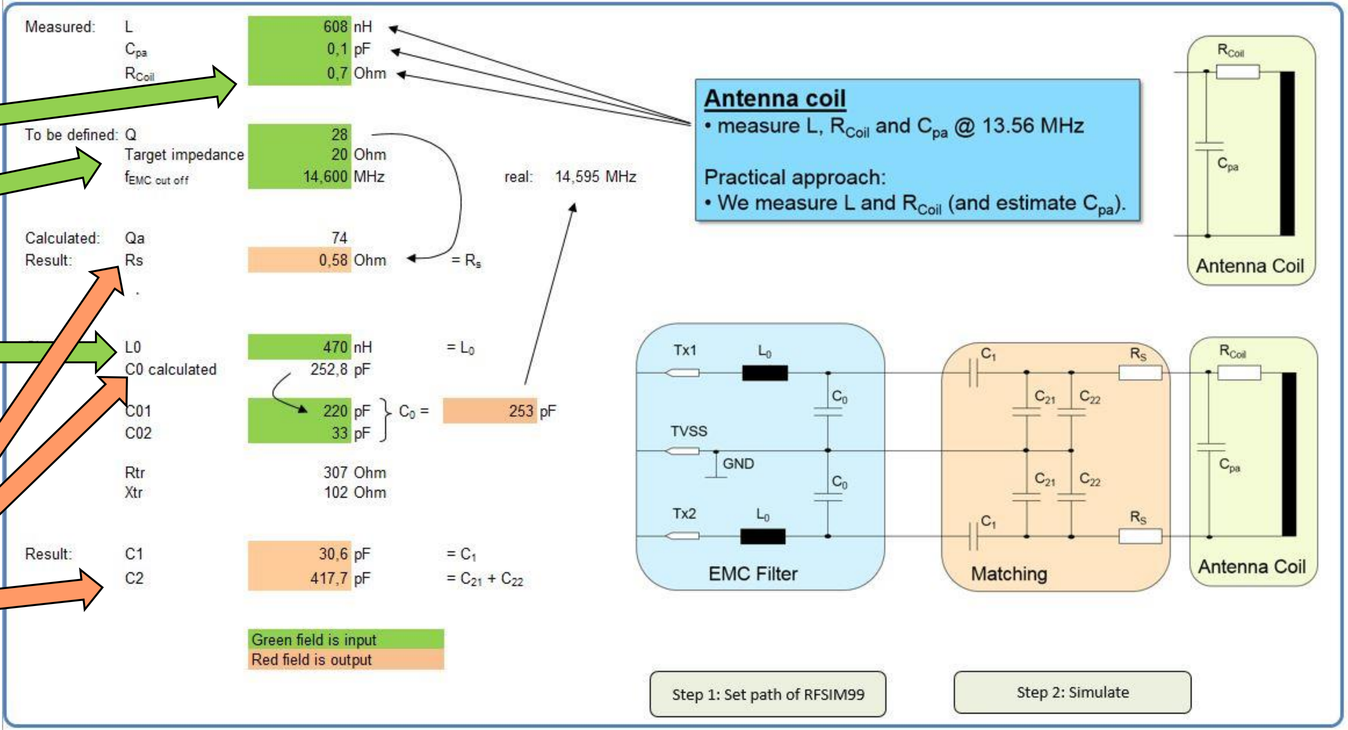
** This circuit only covers the TX part*

Calculate matching components

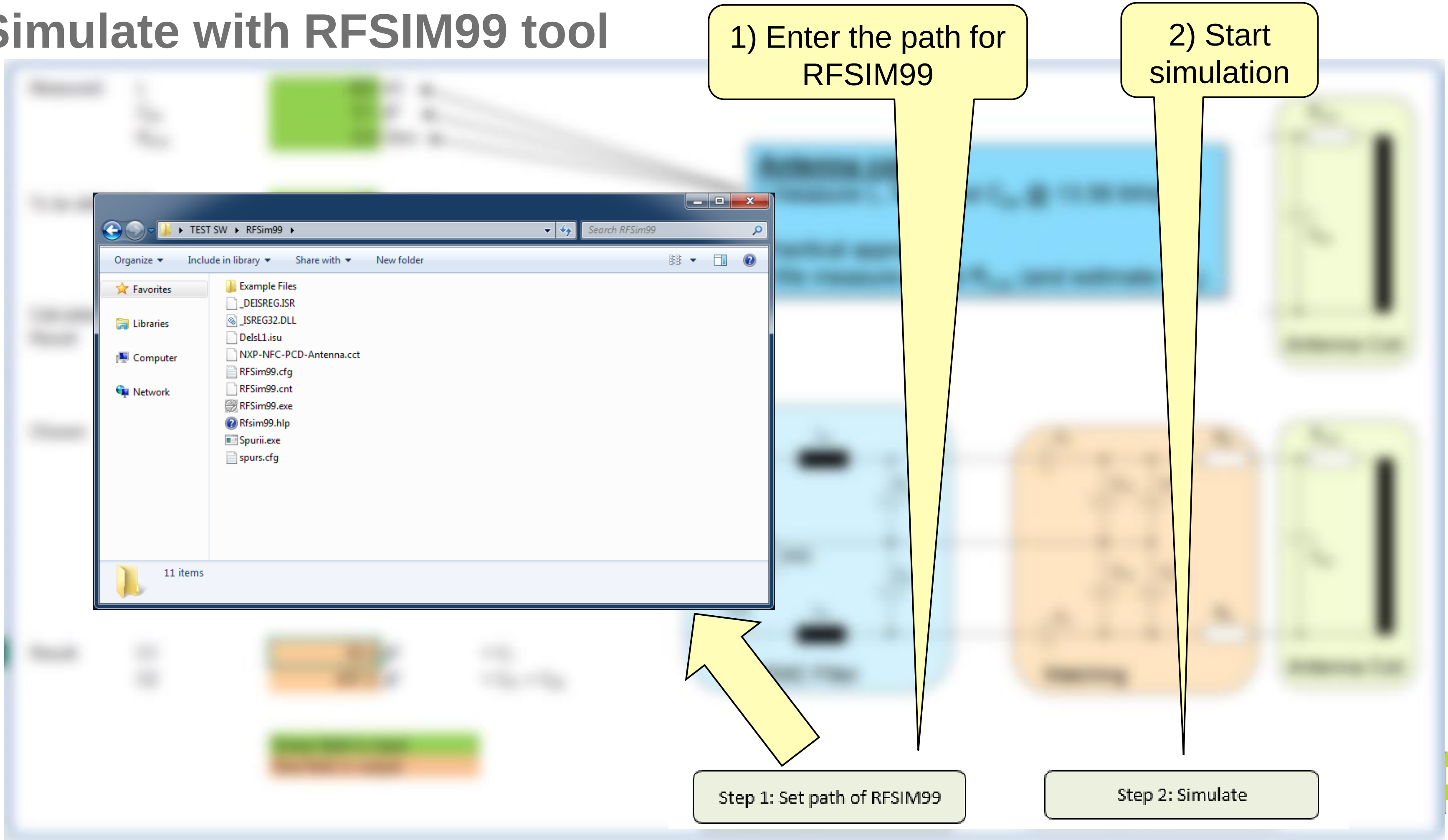
Excel sheet

- INPUT VALUES
  - Antenna coil measured / estimated values (L_a, C_a, R_a)
  - Q-factor
  - f_{EMC}
  - Target impedance (Zmatch).
  - L_0 of EMC filter

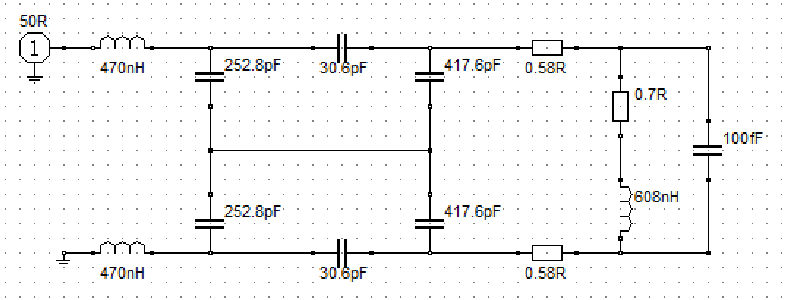
- OUTPUT VALUES
  - R_S, C_0, C_1 and C_2



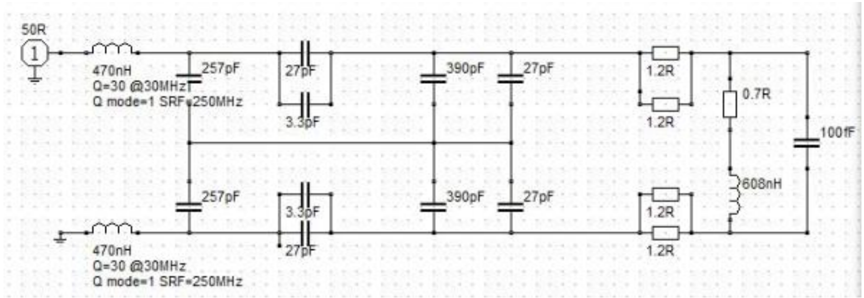
Simulate with RFSIM99 tool



Simulate with RFSIM99



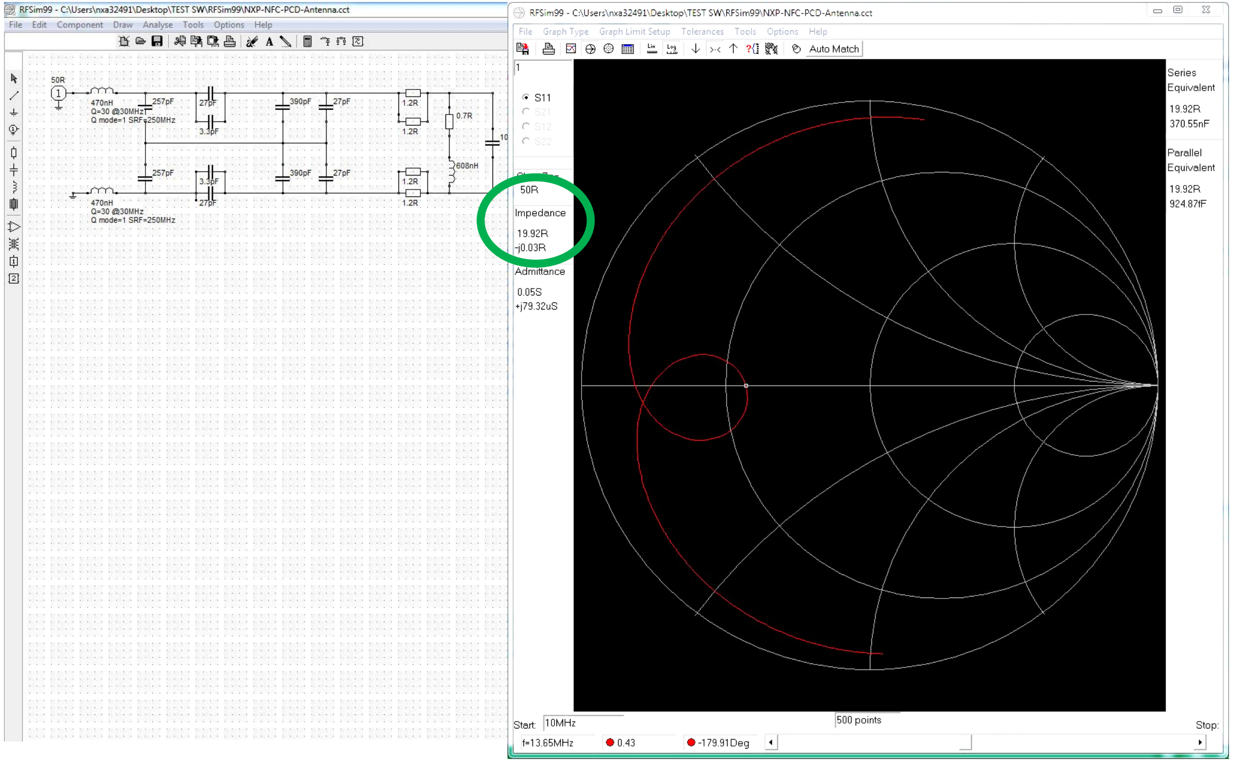
These are not real commercial values.



Add components in parallel and set actual values to be assembled

RFSim99: simple freeware simulation tool
http://www.electroschematics.com/835/rfsim99-download/

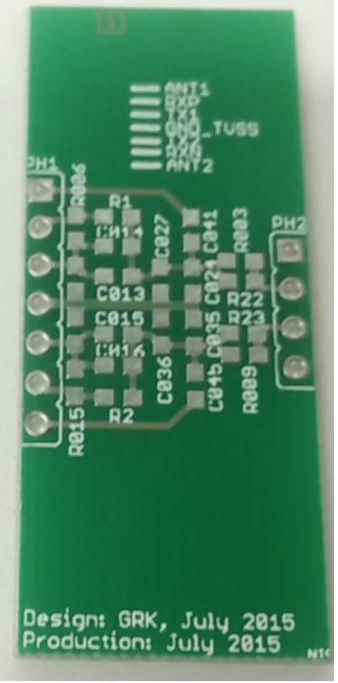
Simulate with RFSIM99

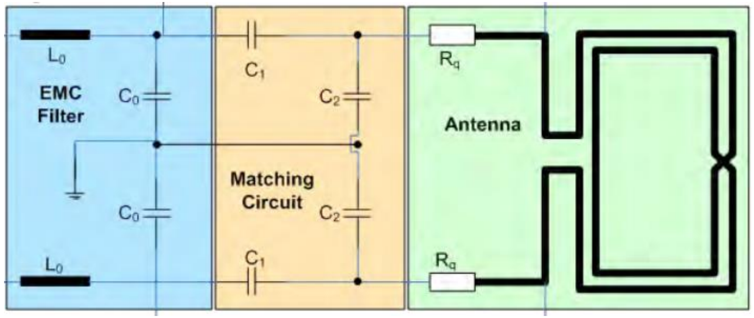


Z = 19.92 Ohm

STEP 5:
ASSEMBLY AND MEASUREMENT

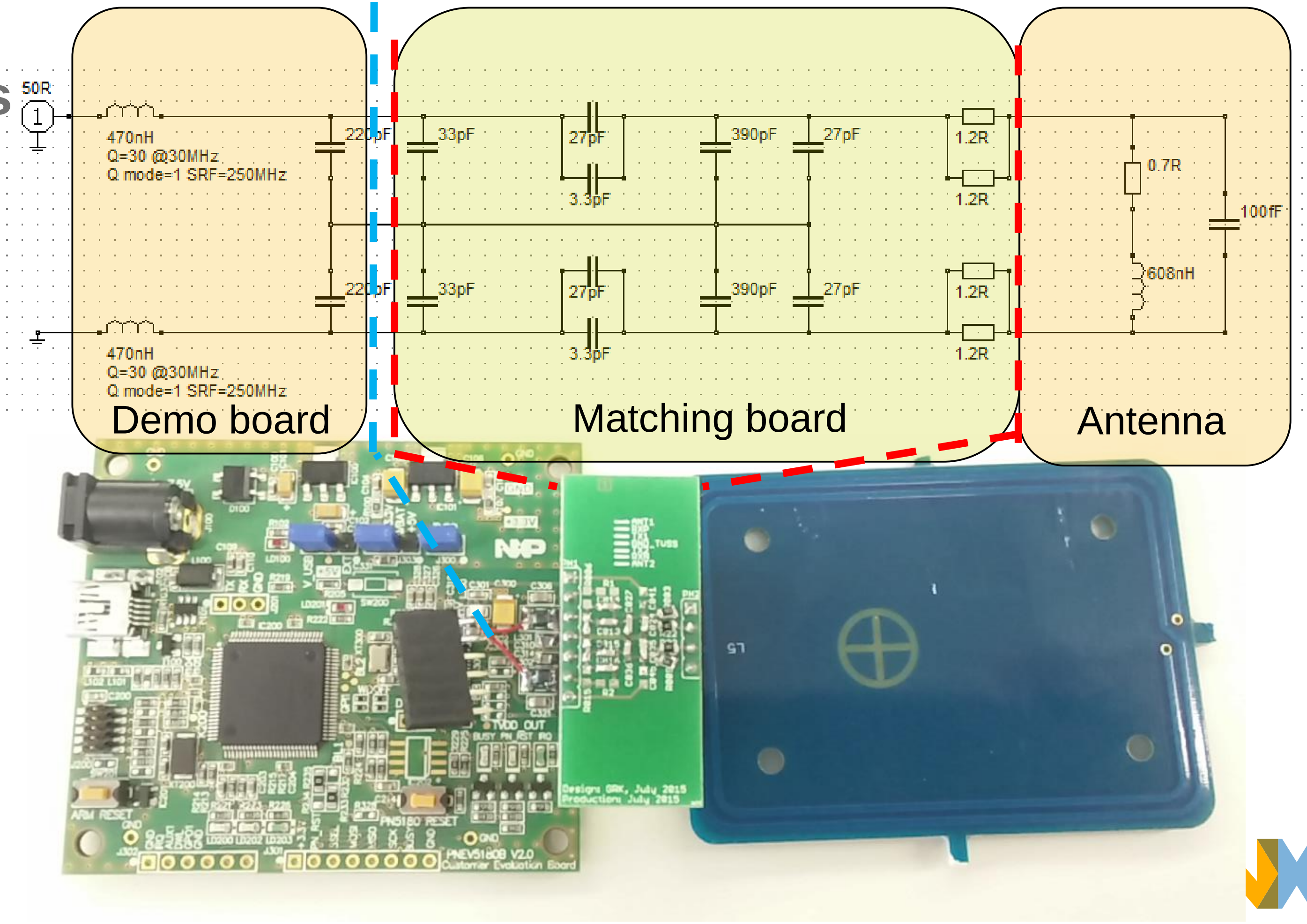
Matching components assembly





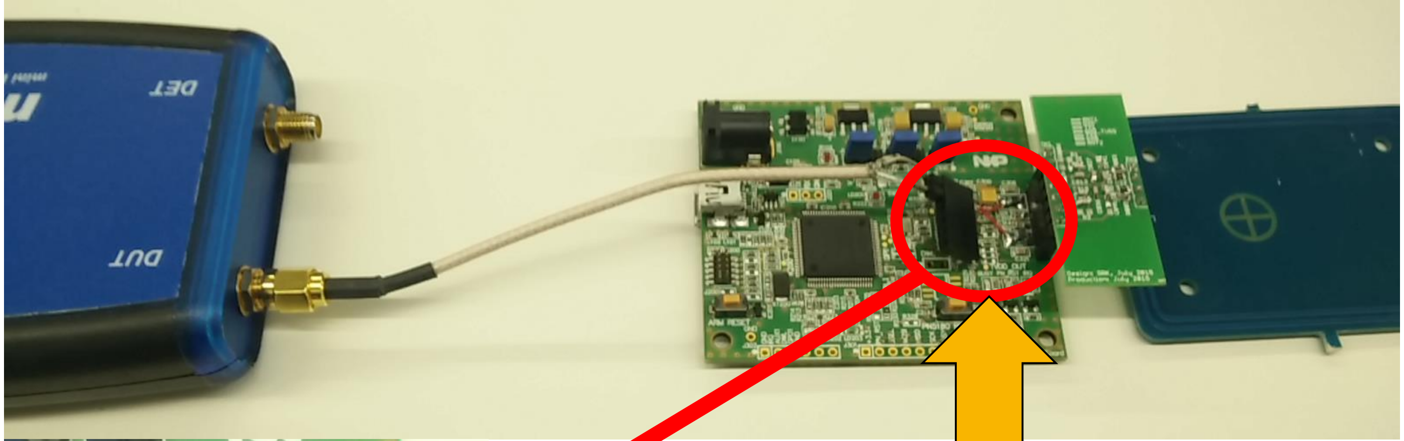
Excel file	PCB matching board
C_1	C013 // C014 C015 // C016
C_2	C027 // C024 C035 // C036
R_S	R003 // R22 R009 // R23

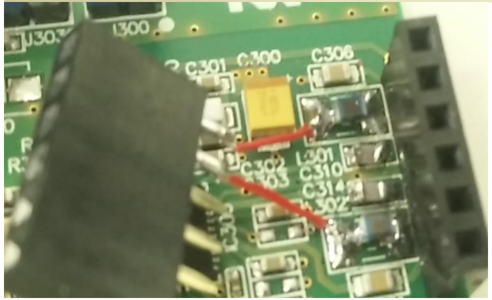
Matching components assembly



Matching components assembly

Antenna tuning measurement with miniVNA Pro

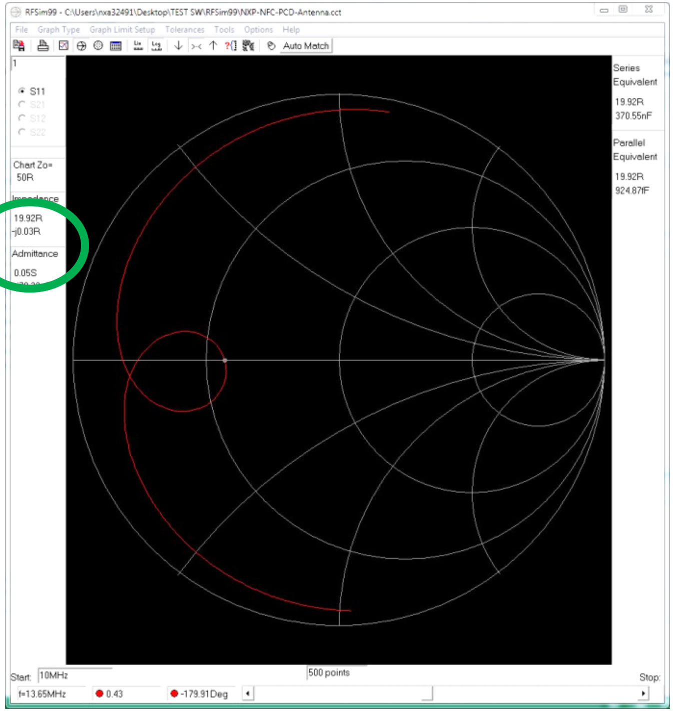




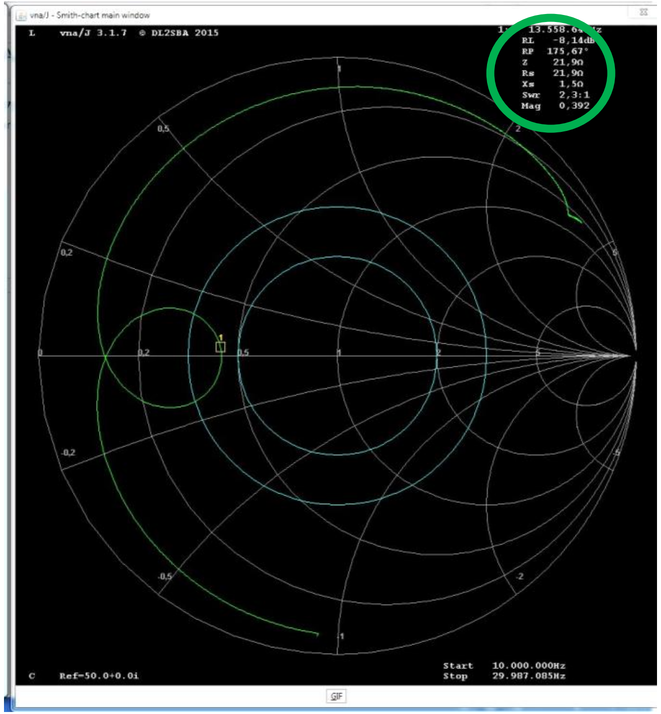
Measurement between Tx1 and Tx2

Antenna tuning measurement

Measured vs simulation



Simulated: Z = 19.92 – j0.03Ω



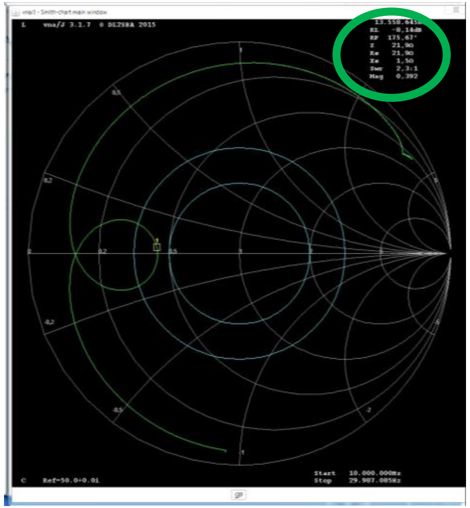
Measured: Z = 21.9 + j1.5Ω

STEP 6:

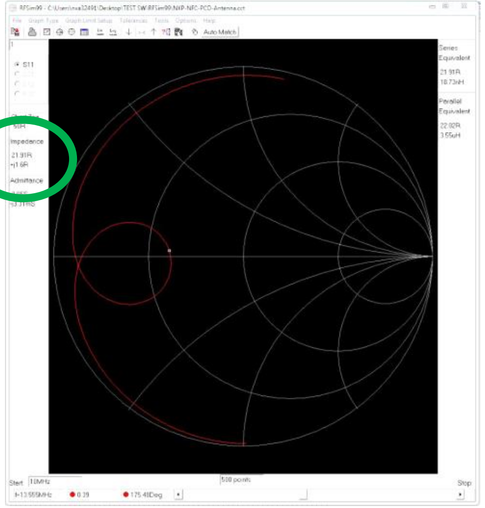
ADAPT SIMULATION

Adapt simulation

- Measured / estimated L_a, R_a and C_a antenna parameters are imprecise.
- Tune R_a and C_a parameters until the simulation looks like the reality.



Measured: Z = 21.9 + j1.5Ω

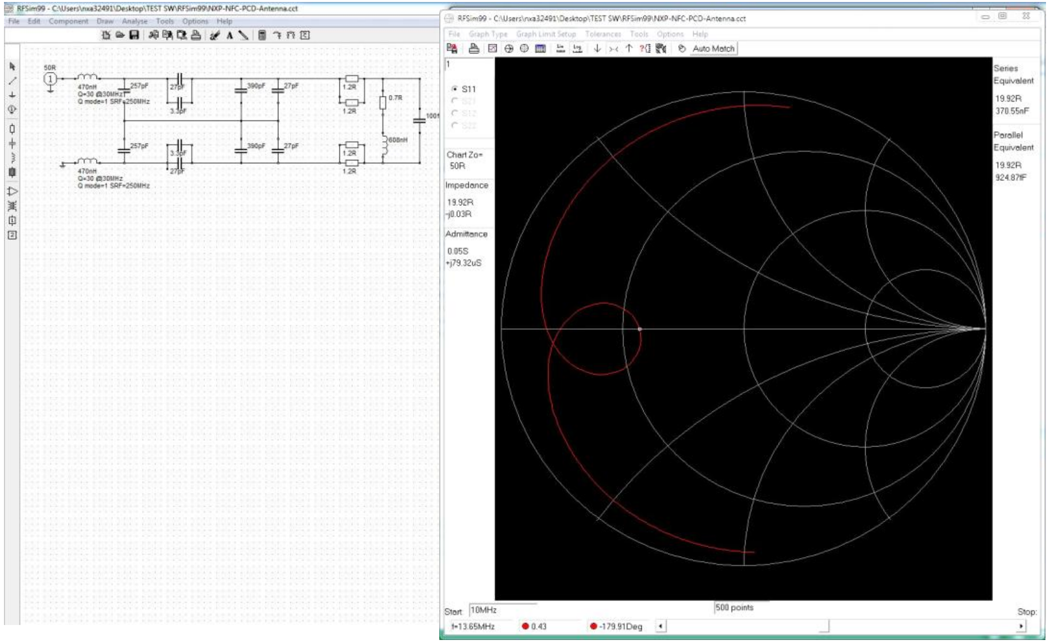


Simulation: Z = 21.91 + j1.6Ω

- $R_a = 0.7\ \Omega \quad \Rightarrow \quad R_a = 0.25\ \Omega$
- $C_a = 0.1pF \quad \Rightarrow \quad C_a = 2.3pF$

Fine tune matching components and simulate again

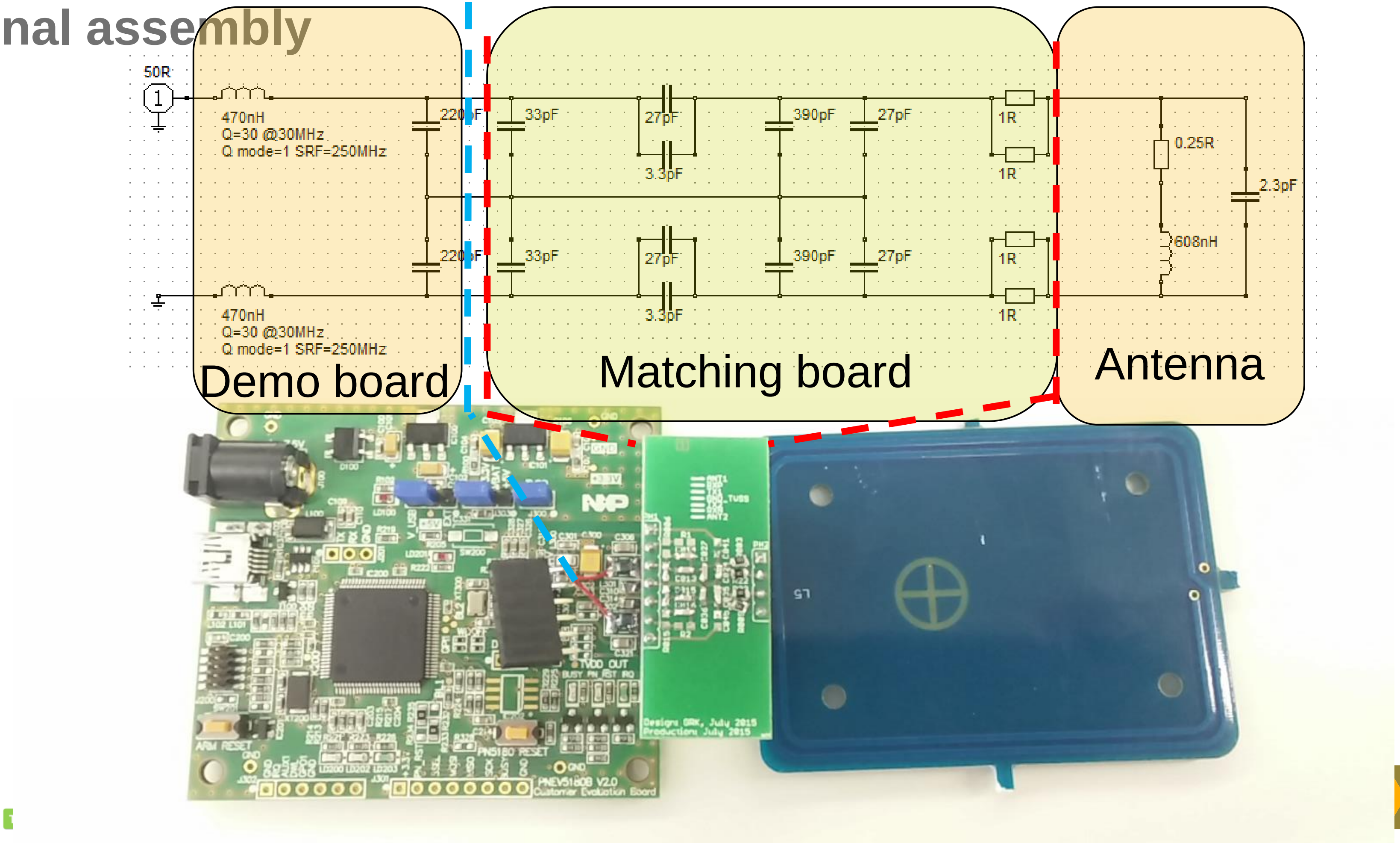
- Update C_a, L_a, R_a
- Fine tune C_1, C_2, R_s to achieve target impedance again. Use available values.



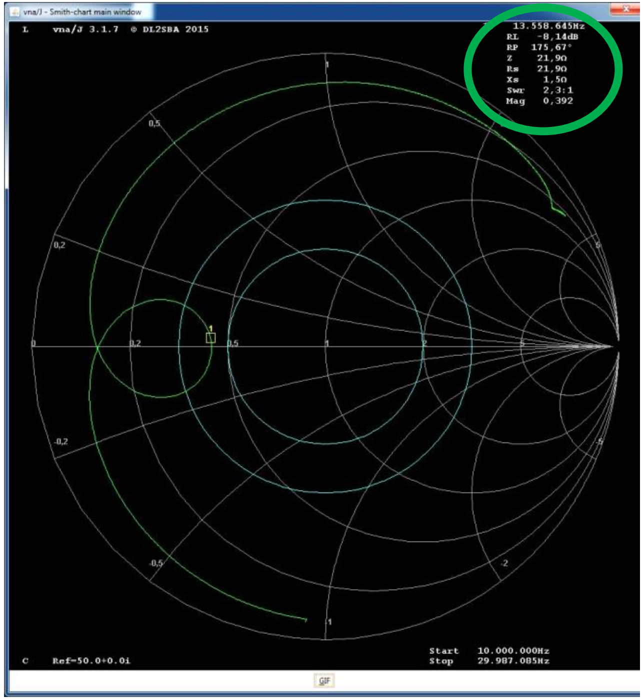
Z = 20 Ω

STEP 7:
CORRECTION AND RE-ASSEMBLY

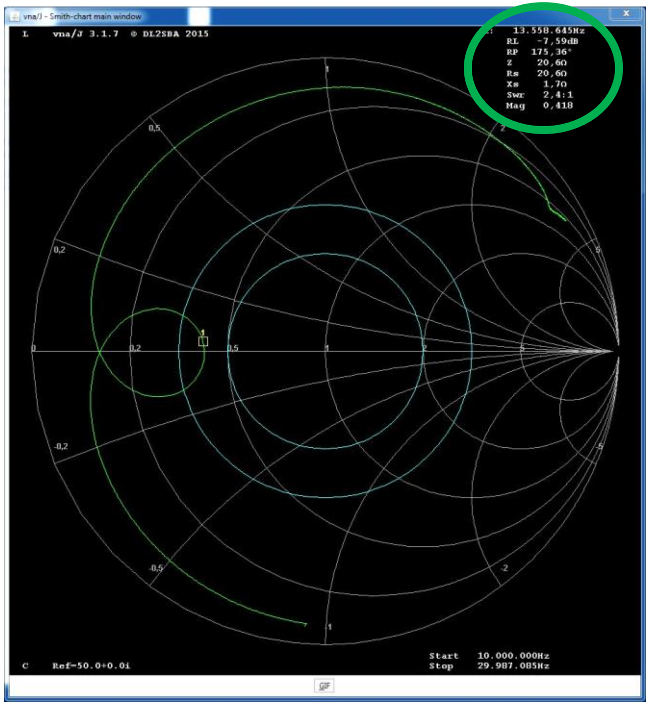
Final assembly



Final antenna tuning measurement results



First matching: Z = 21.9 + j1.5Ω



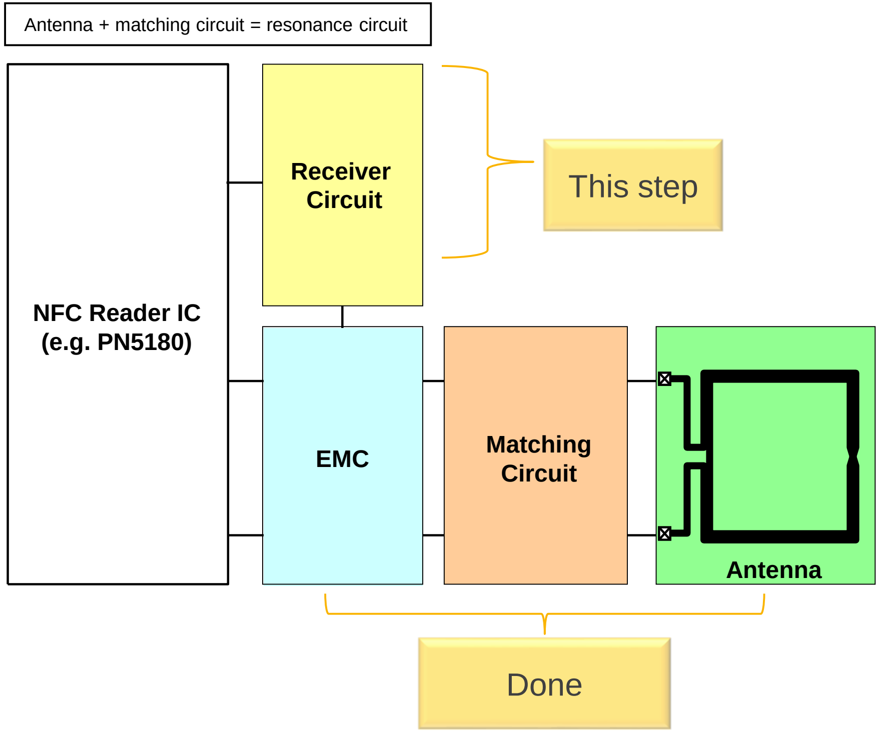
Fine tuned: Z = 20.6 + j1.5Ω

STEP 8:

RECEIVER CIRCUIT

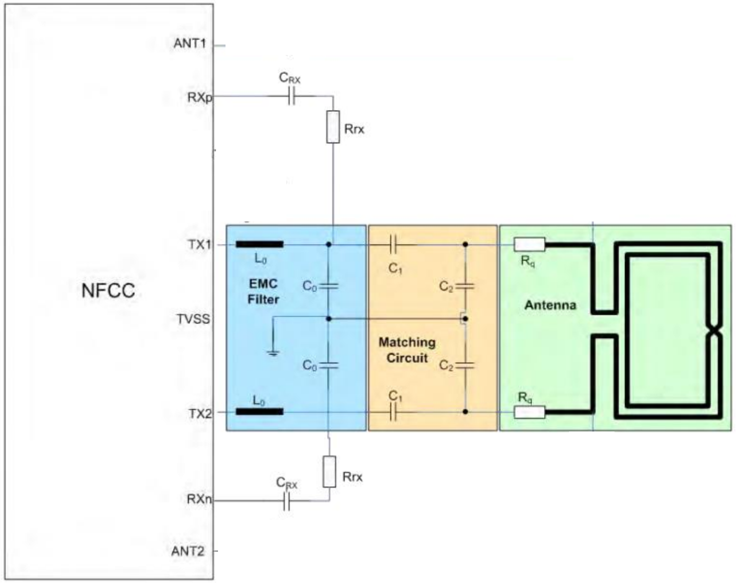
Receiver circuit

Standard values



Receiver circuit

Standard values



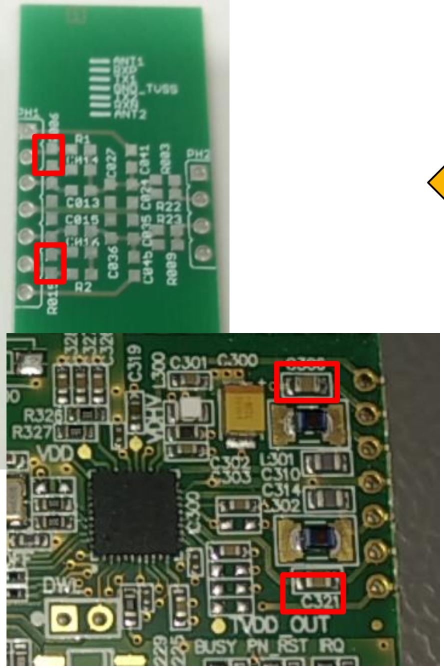
- Goal: the voltage level at RX_n and RX_p pins must be high enough to achieve a good sensitivity, but must not exceed the given limit.

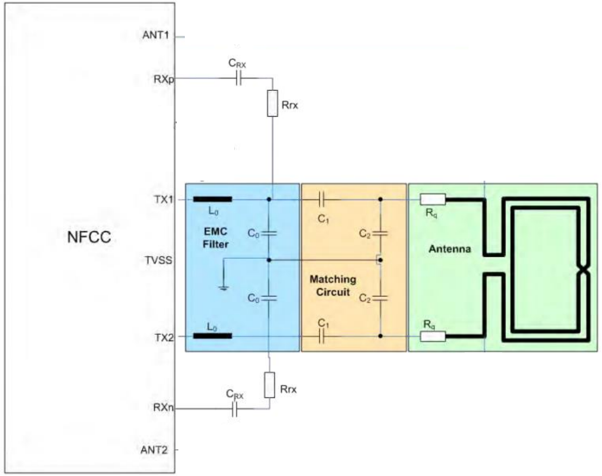
- Recommended circuit has a resistor and a capacitor in series. Typically the serial resistor R_{rx} is in the range of 1…10kΩ.

- Start with 4.7k value and adjust sensitivity reading/writing AGC_VALUE register.

Receiver circuit

Standard values



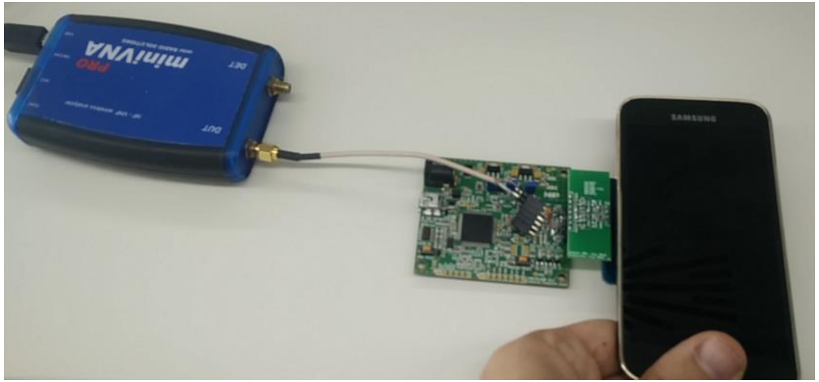


Excel file	PCB matching board	PCB demo board
Rrx	R006 R015	
Crx		C306 C321

DETUNING EFFECT
UNDER LOADING CONDITIONS

Antenna loading & detuning

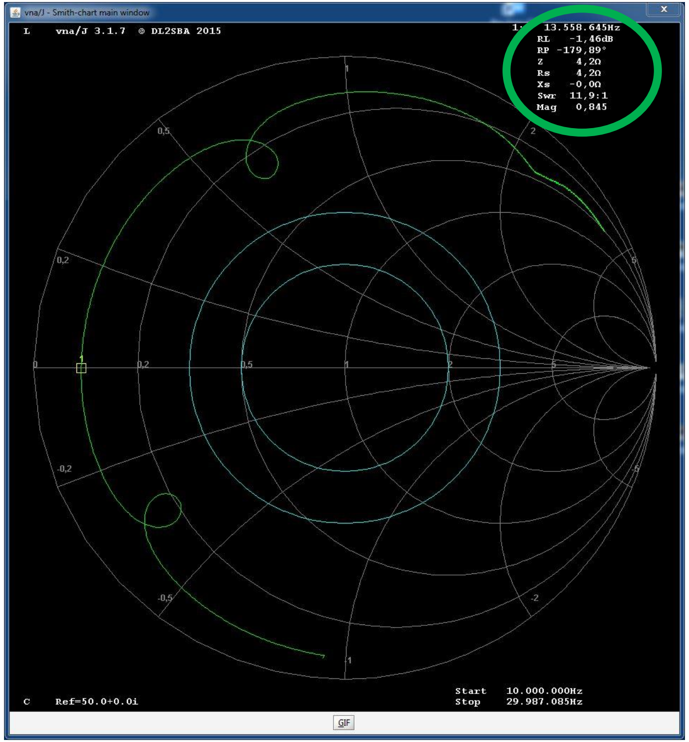
Metal (smartphone)



$Z = 4.2 + j0\ \Omega$

Due to symmetric matching, Z decreases => I_{TVDD} increases

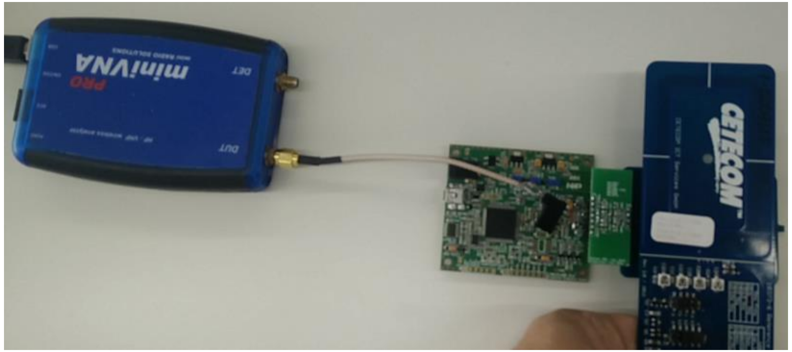
Without properly calibrated DPC the PN5180 might be killed!

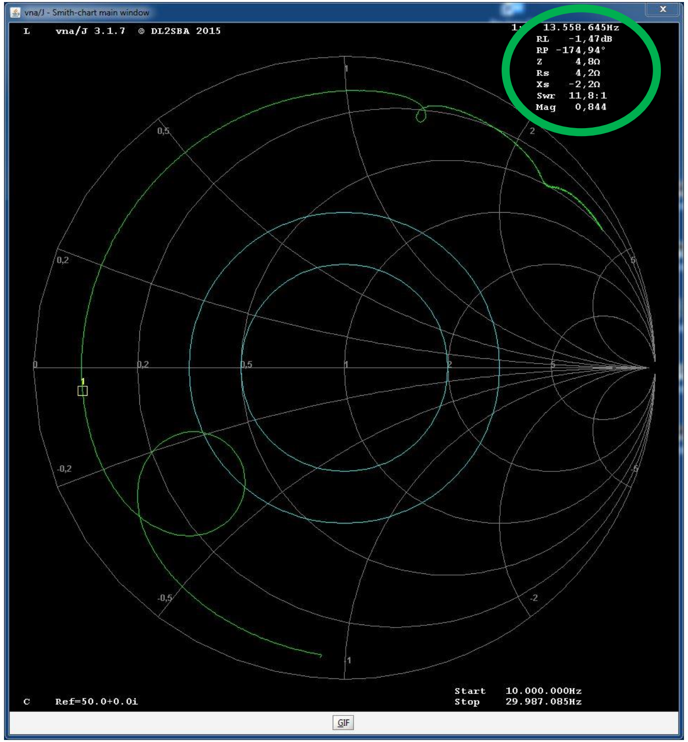


Webinar session
18/10/2016

Antenna loading & detuning

Reference PICC





$Z = 4.8 + j2.2\Omega$

Due to symmetric matching, Z decreases => I_{TVDD} increases

Without properly calibrated DPC the PN5180 might be killed!

Webinar session
18/10/2016

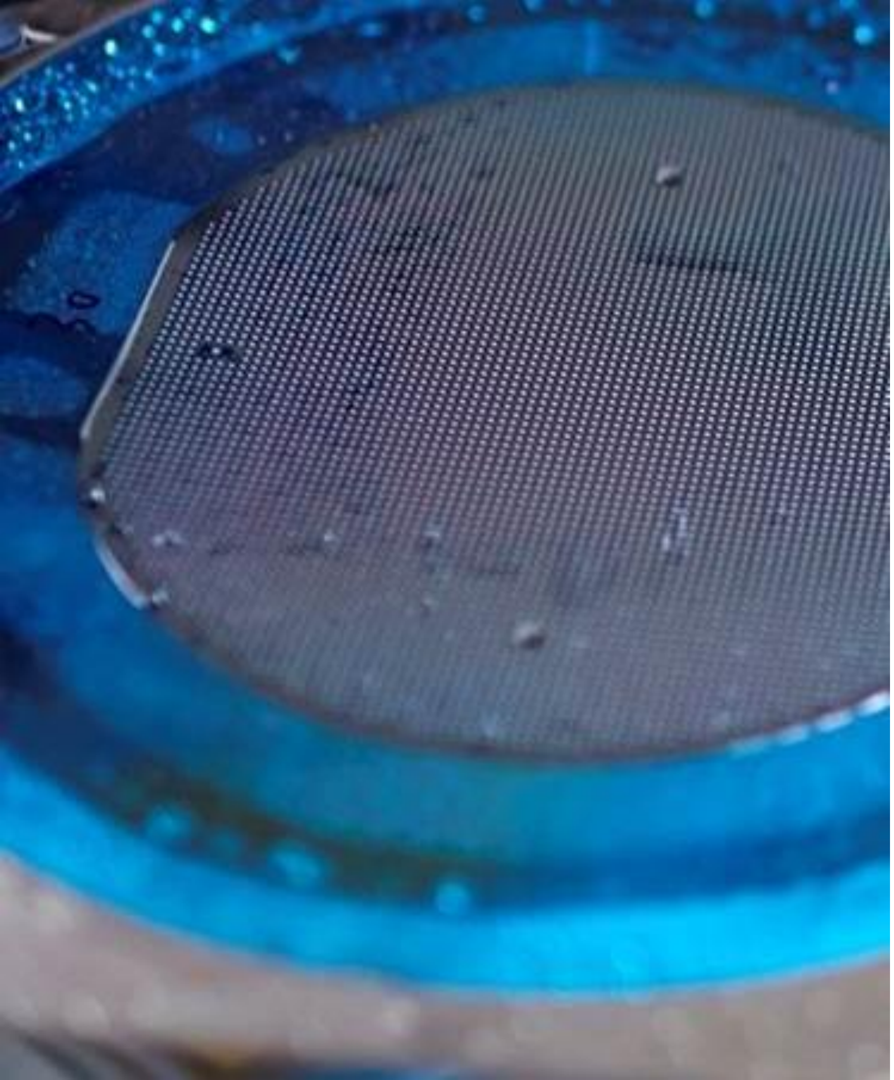
WRAP UP

Summary of NFC antenna design steps

Matching Steps:

1. Target impedance and Q-factor= 20…80 Ω (PN5180), Q<30
2. Design EMC Filter (L_0 and C_0) -> $f_{EMC} \approx$ 14.6MHz
3. Measure antenna coil (L_a, R_a and C_a)
4. Calculate start values (C_1, C_2, R_S using Excelsheet)
5. Assemble & measure
6. Adapt RFSIM99 simulation to meet reality (R_a and C_a)
7. Correct matching in simulation (C_1 and C_2)
8. Assemble & measure
9. Assemble R_X standard values

Done.



Coming sessions

Design and implement NFC applications

Session I, 7th September
Product support package for NXP NFC readers
https://attendee.gotowebinar.com/rt/2329750067403618817

Session II, 28th September
Antenna design considerations for NXP NFC reader solutions
https://attendee.gotowebinar.com/rt/282682617345186049

Session III, 18th October
The NFC Cockpit - the complete design tool for engineers
https://attendee.gotowebinar.com/rt/4665515186055692545

Session IV, 31th October
NFC Reader Library - SW support for NFC frontend solutions
https://attendee.gotowebinar.com/rt/7151741873899128067

Software development in Android and iOS
Embedded software for MCUs
JCOP, Java Card operating Systems
Hardware design and development
Digital, analog, sensor acquisition, power management
Wireless communications WiFi, ZigBee, Bluetooth, BLE
Contactless antenna RF design, evaluation and testing

MIFARE applications
End-to-end systems, readers and card-related designs
EMVco applications
Readers, cards, design for test compliancy (including PCI)
Secure Element management
GlobalPlatform compliant backend solutions
Secure services provisioning OTA, TSM services

We help companies leverage the mobile and **contactless revolution**

MobileKnowledge
Roc Boronat 117, P3M3
08018 Barcelona
(Spain)

Get in touch with us
www.themobileknowledge.com
mk@themobileknowledge.com

Partner IDH
Independent Design House

Accredited Training Partner

MOBILE WORLD CAPITAL. BARCELONA

Design and implement NFC applications

Session 2: Antenna design considerations for NXP NFC reader solutions

Jordi Jofre (Speaker)
Angela Gemio (Host)

Thank you for your kind attention!

Please remember to fill out our **evaluation survey** (pop-up)

Check your email for **material download** and on-demand **video** addresses

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www.themobileknowledge.com/content/knowledge-catalog-0