YOUR ULTIMATE GUIDE TO DESIGNING ANTENNAS FOR THE NTAG I²C *PLUS*

JORDI JOFRE
NFC EVERYWHERE
JULY 2018

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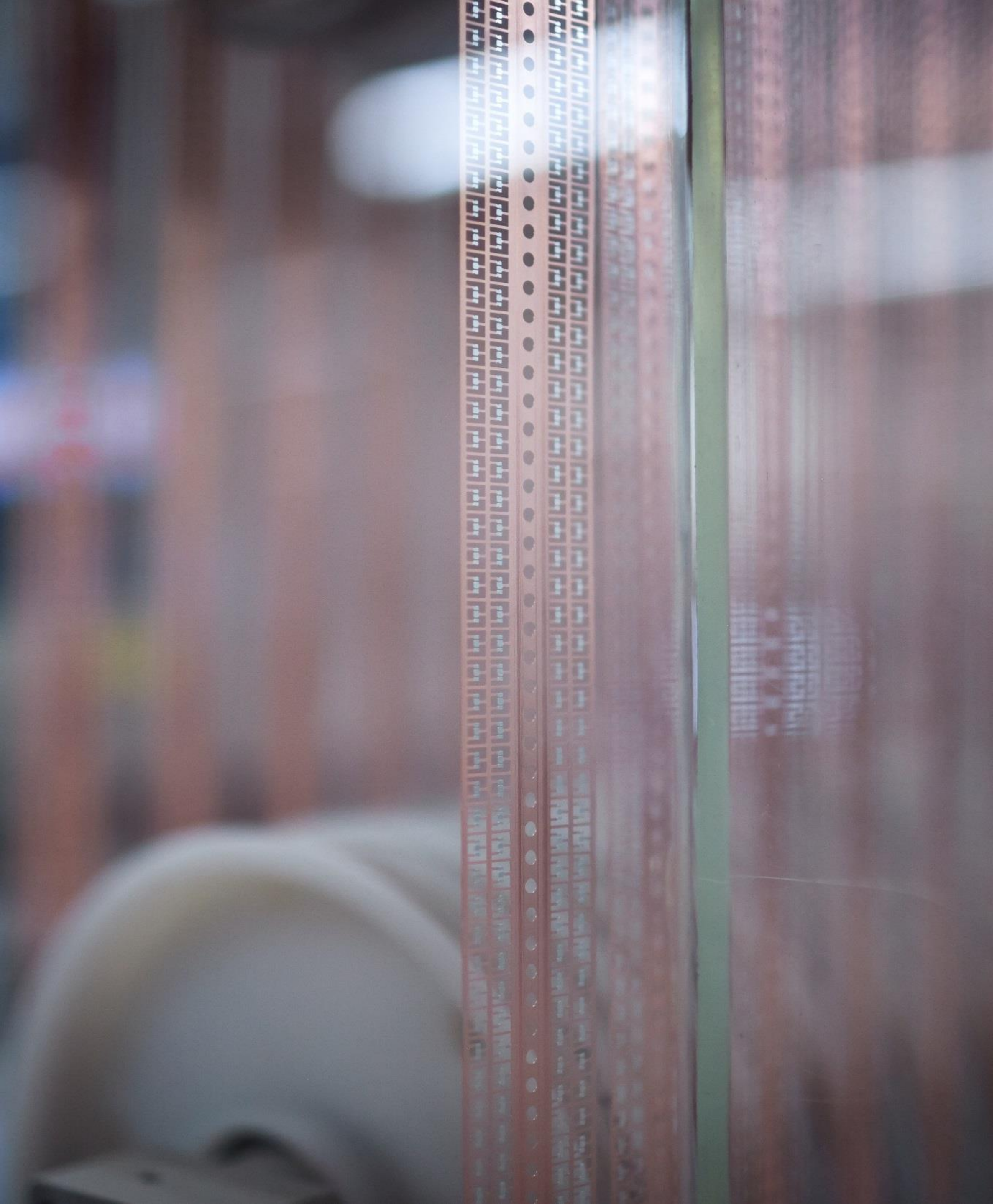
SECURE CONNECTIONS
FOR A SMARTER WORLD



Agenda

- NTAG I^2C *plus:* How it works
- NTAG I^2C *plus:* Basic antenna design theory
- NTAG I^2C *plus:* Antenna design procedure
- Example: Tuning for a 54x27mm PCB antenna

How NTAG I^2C *plus* works

NFC focus products for each application need

Readers/connected tags: for embedded electronics

Features and price

	Connected tag solutions	NFC Frontend solutions	NFC controller solutions
Specialist		High-perf full NFC with DPC **PN5180**	One chip system, programmable NFC controller with DPC **PN7462 family**
All round	Single-chip MCU with integrated NFC tag **LPC8N04**	High-perf multi-protocol reader **CLRC663 *plus***	Plug&Play NFC for Linux, Android, WinIoT **PN7150**
Entry level	**NTAG I²C *plus***	Proximity&vicinity readers **MFRC630** (ISO14443A – Reader for NTAG® and MIFARE® product families) **SLRC610** (ISO15693 / ISO18000-3M3 - Reader for ICODE® family)	

Connected tag solutions
NFC tags with non-volatile memory and host connection or integrated MCU

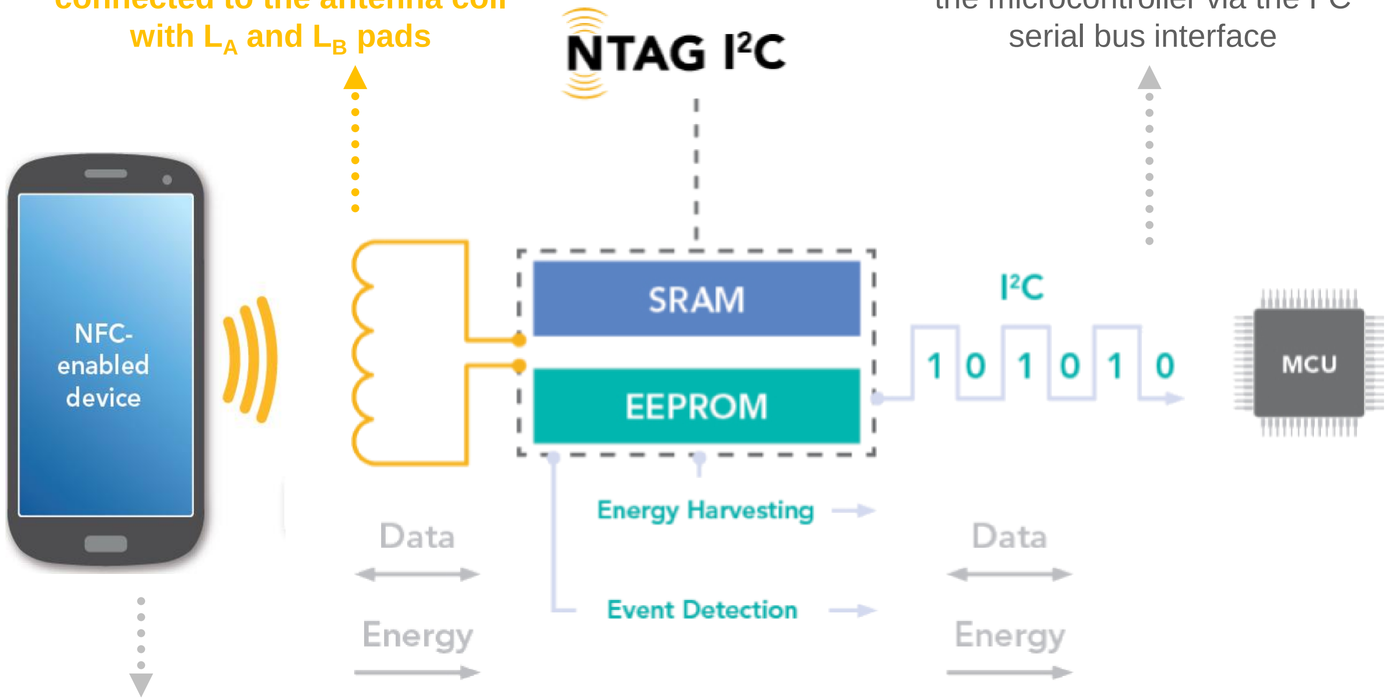
NFC Frontend solutions
NFC reader with NFC Reader SW Library

NFC controller solutions
NFC reader with integrated 32-bit Cortex MCU and either integrated firmware or freely programmable memory

How NTAG I²C *plus* works

The NTAG I²C *plus* needs to be connected to the antenna coil with L_A and L_B pads

The NTAG I²C *plus* connects to the microcontroller via the I²C serial bus interface

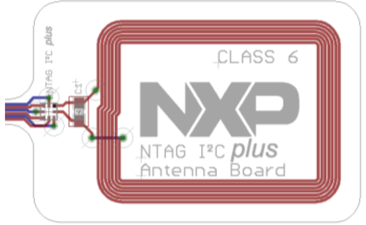


NFC-enabled mobile device connects to the MCU via the NFC interface, using the I²C as the communication conduit

- Field Detection
- Energy harvesting
- SRAM memory
- SRAM mirroring
- Pass-through mode
- Memory access management
- Originality signature

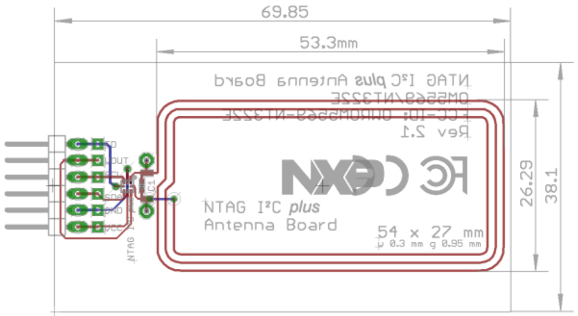
NTAG I²C *plus* support package: Antenna design files

[SW3641 - NTAG I²C *plus* flex antenna Class 6]



[SW3639 - NTAG I²C *plus* Class 4]

[AN11276 – NTAG Antenna design guide]



If you do not have constrains about the antenna size or shape:

NXP offers the designs files for the *Class 4* and *Class 6* antennas included as part of the NTAG I²C *plus* Explorer kit (OM5569)

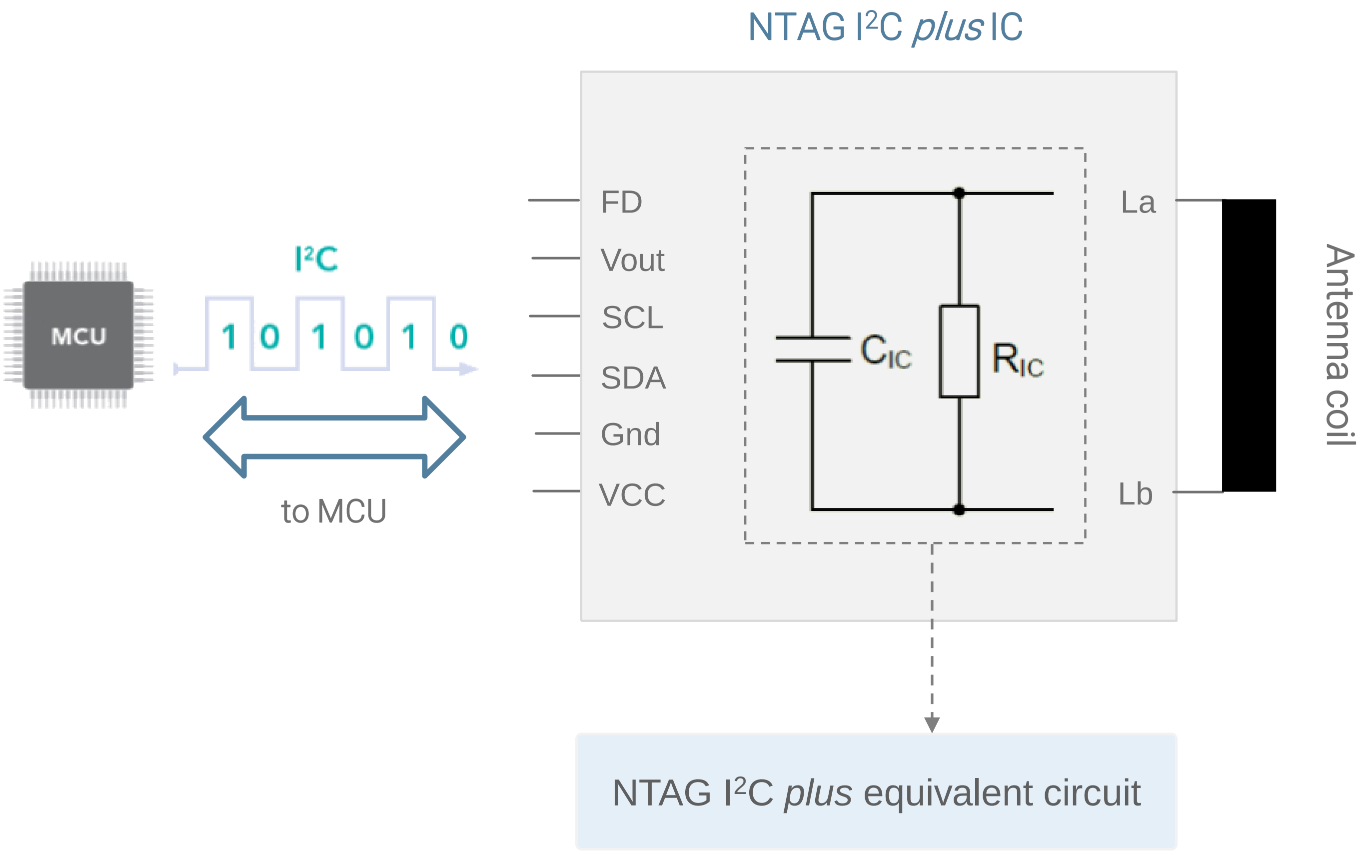
If you need your custom antenna for your design:

NXP offers an Excel-based coil calculation tool to estimate the inductance of rectangular and round antennas *

* More details in slide 18

Basic antenna theory for NTAG I²C *plus* tags

NTAG I²C *plus* electrical input capacitance



C_{IC}= NTAG I²C *plus* **input capacitance** (50pF)

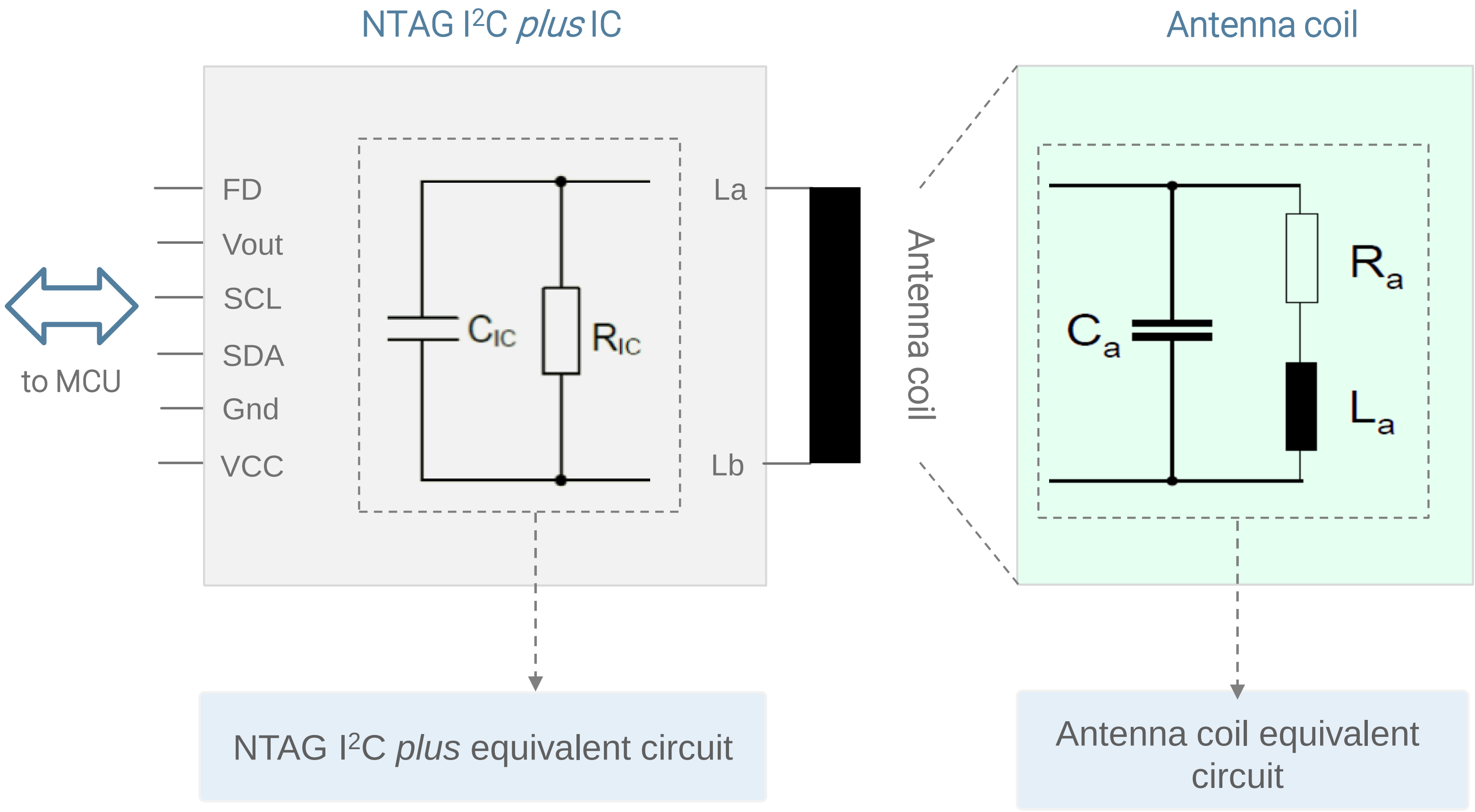
NTAG I²C *plus* IC connections

- **La, Lb =** NTAG I²C *plus* pads to be connected to the antenna

NTAG I²C *plus* IC input capacitance

- It is the most important factor for the antenna design.
- The form factor and the parameters of the antenna are affected by the input capacitance

Antenna coil electrical equivalent circuit



C_{IC}= NTAG I²C *plus* **input capacitance** (50pF)

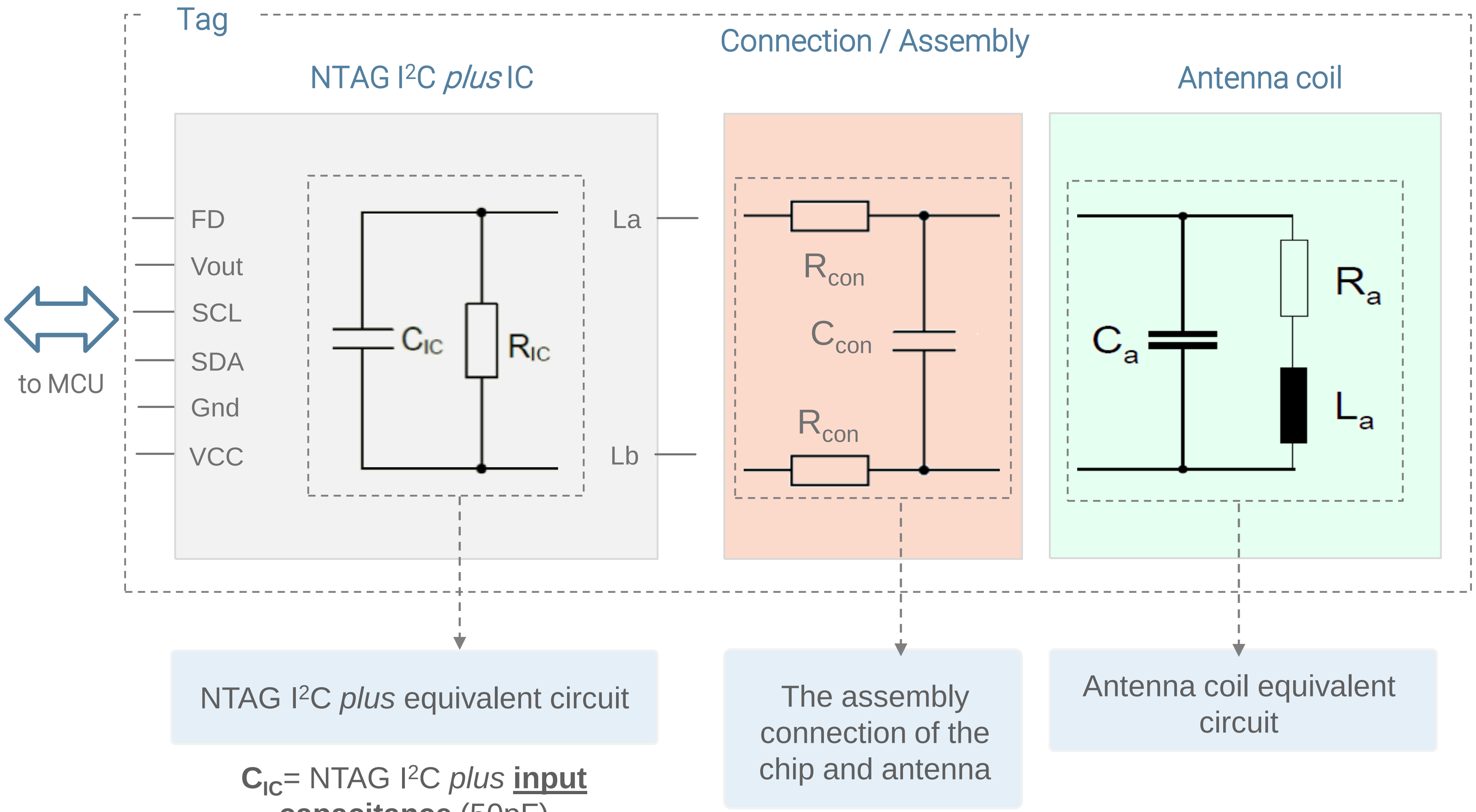
Each antenna is a resonant circuit with a specific input impedance.

This input impedance is complex and consists of an inductance, capacitance as well as some losses represented by a resistance.

The actual values depend on

- Antenna material
- Thickness of conductor
- Distance between the windings
- Number of turns
- Shielding layer
- Environment

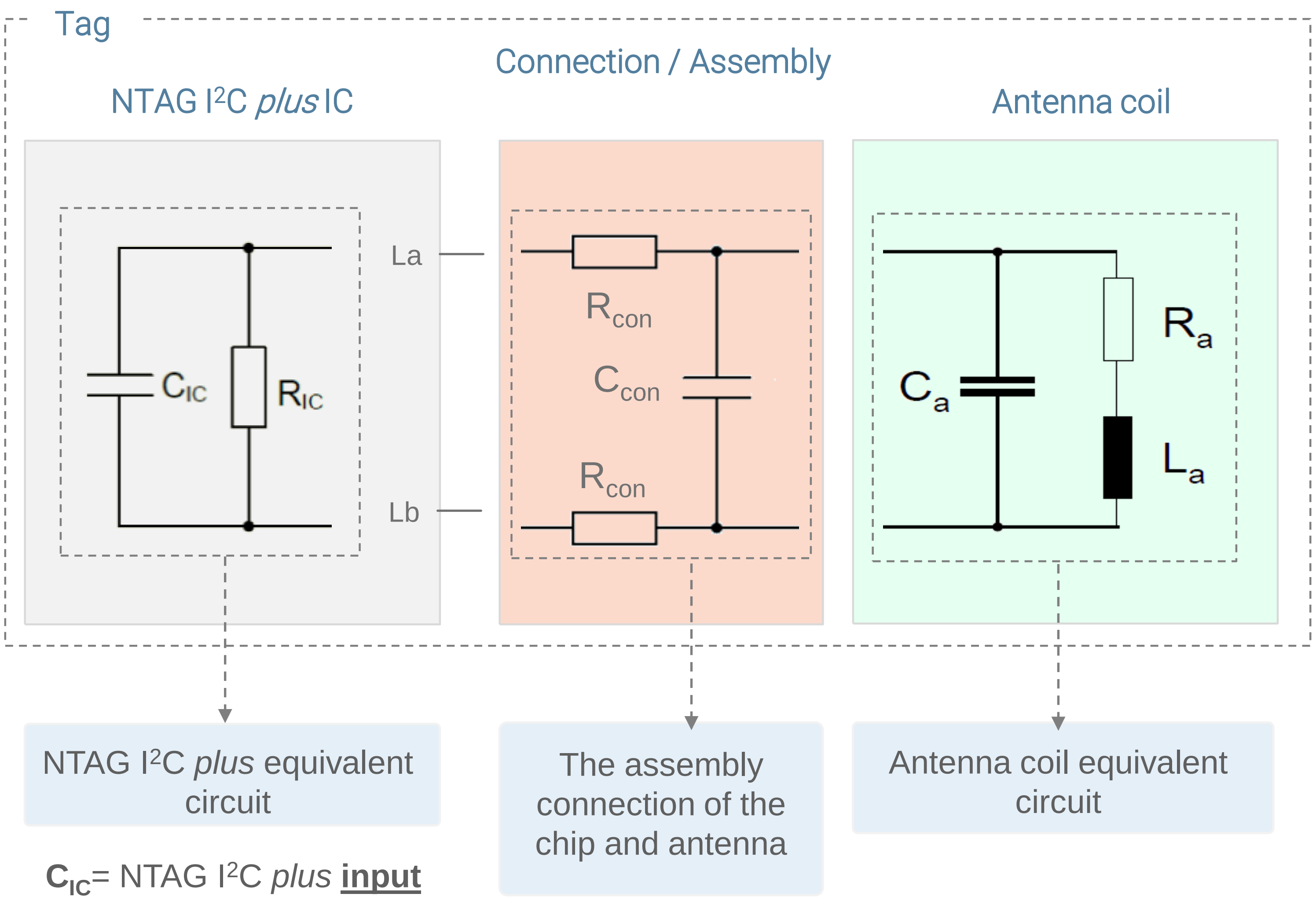
Tag with an NTAG I²C *plus* electrical equivalent circuit



C_{IC}= NTAG I²C *plus* **input capacitance** (50pF)

The NTAG I²C *plus* capacitance together with the antenna capacitance and the parasitic connection capacitance forms a resonance circuit with the inductance of the antenna.

Tag with an NTAG I²C *plus* resonance frequency and Q-factor



C_{IC}= NTAG I²C *plus* **input capacitance** (50pF)

The resonance frequency of the tag can be calculated with:

$$f_r = \frac{1}{2 \cdot \pi \cdot \sqrt{C \cdot L}}$$

The Q-factor of the tag can be calculated with:

$$Q = \frac{R}{2 \cdot \pi \cdot f \cdot L}$$

$C =$ Equivalent capacitance of the tag $(C_{IC}, Ccon, Ca)$

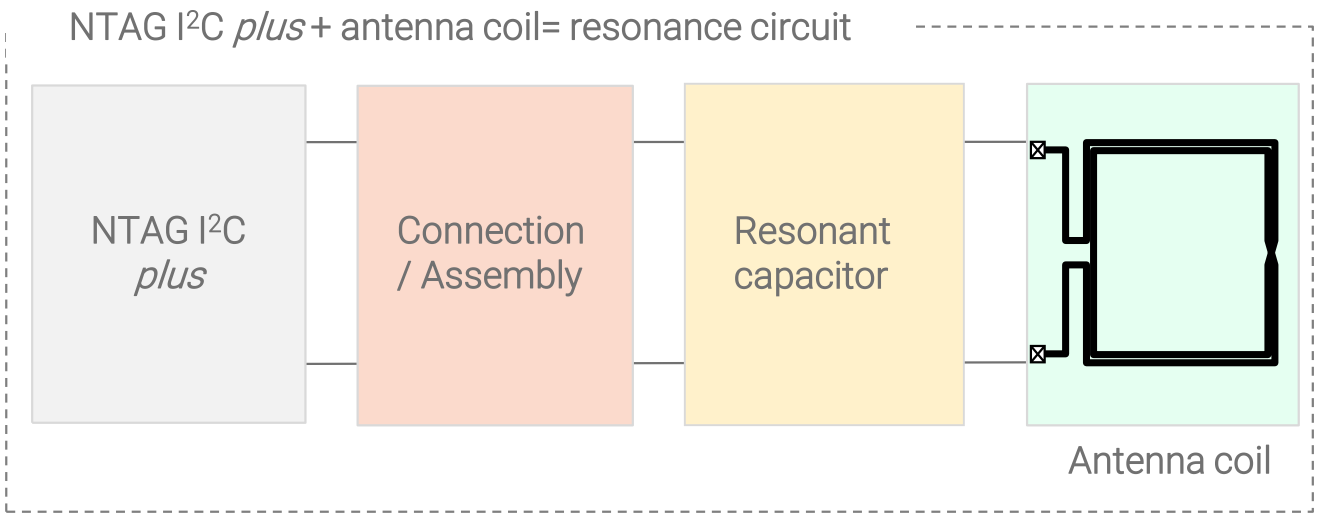
$R =$ Equivalent resistance of the tag (R_{IC}, R_a)

$L =$ Antenna coil inductance

Antenna design procedure for NTAG I^2C *plus* tags

Antenna design procedure for NTAG I^2C *plus* tags

1. **Design the antenna coil**
   Determine the size and the specs of the antenna (number of turns, track width, spacing, etc.)
2. **Measure antenna coil**
   Characterize R,L,C antenna coil parameters
3. **Calculate the resonant capacitor value**
   Determine the value of resonant capacitor to set the tag to the target resonant frequency
4. **Assemble & measure resonant frequency**
   Measure the resonant frequency and adjust the capacitor value if needed

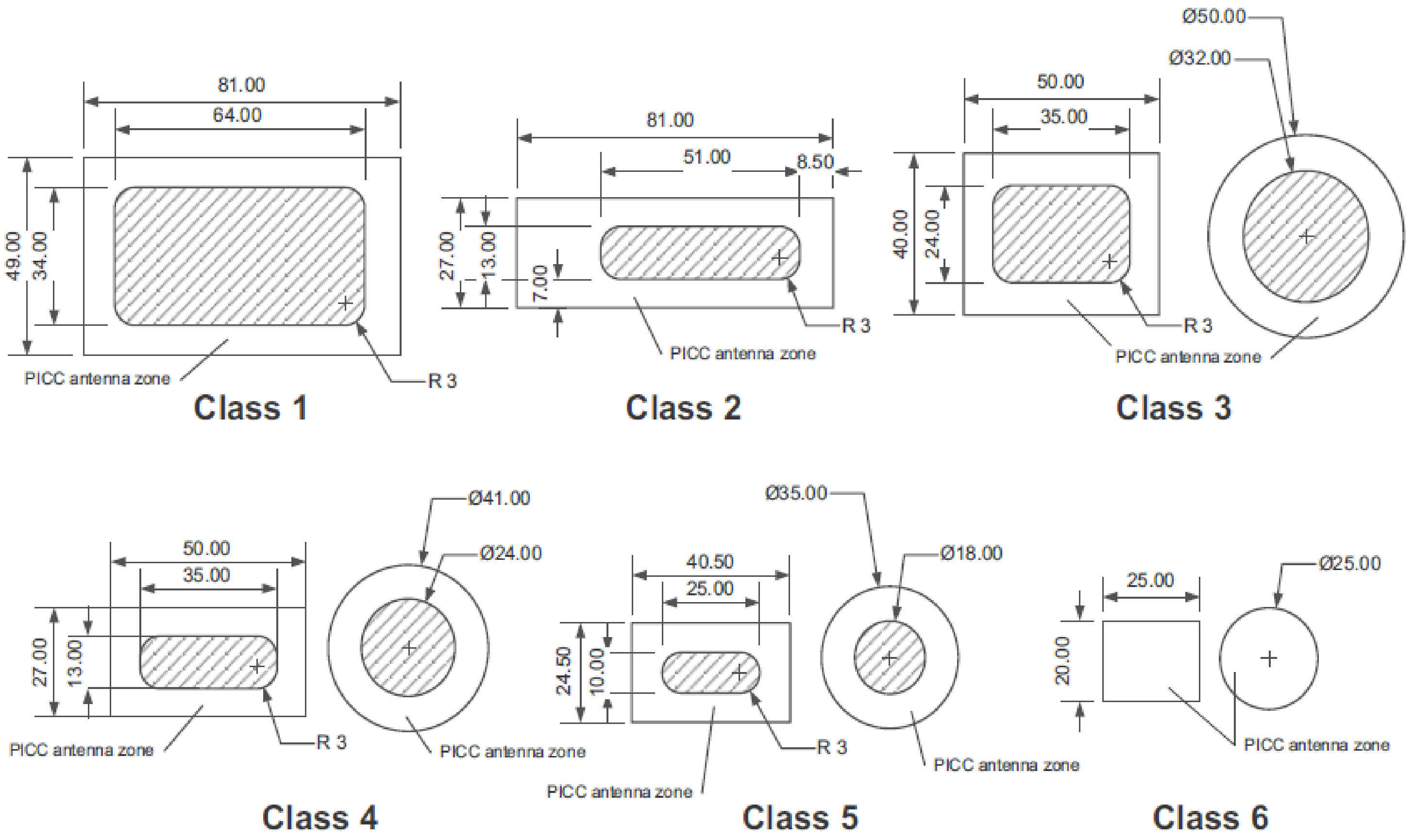


The precision of the antenna equivalent inductance computation, the length of the connection between the chip and its antenna, and the environment (metal surface, ferromagnetic material) impact the tuning frequency.

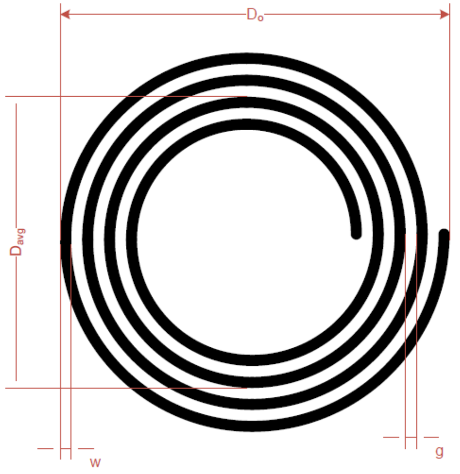
Design the antenna coil

Antenna class based on ISO/IEC14443

- ISO/IEC 14443-1 defines 6 antenna classes, also referred to in ISO/IEC 15693.
- The use of ISO/IEC14443 antenna class is **optional** but it has been established that the use of a prescribed class may enhance interoperability



Antenna parameters for rectangular and round antennas

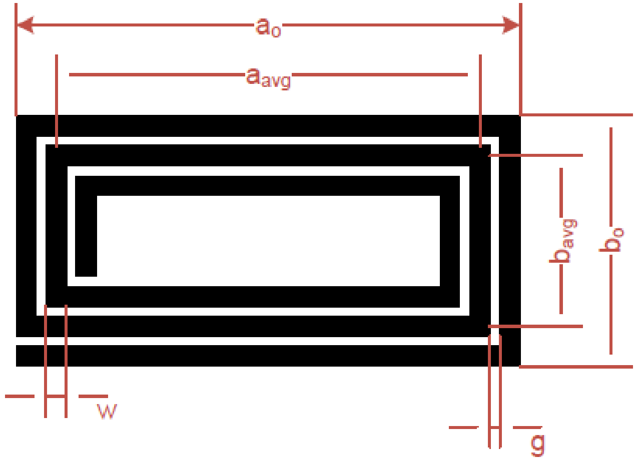


Antenna geometry

- ***D_0*** → Definition of the antenna diameter (mm)
- ***w*** → Track width in mm,
- ***g*** → Gap between tracks (mm),
- ***t*** → Track thickness
- ***N*** → Number of turns

Material properties

- ***ρ*** → Electric conductivity
- ***ε_r*** → Permittivity of card material



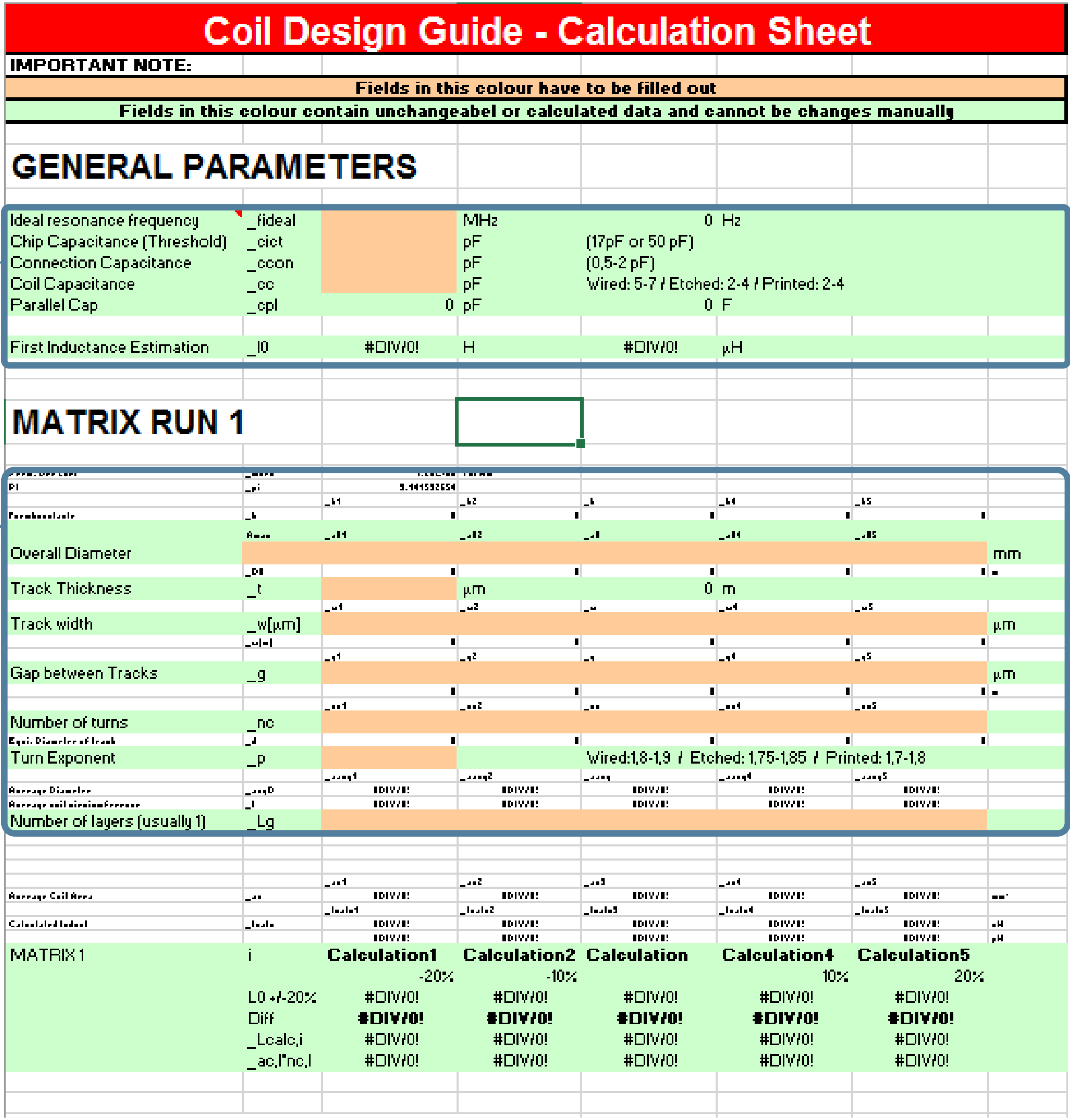
Antenna geometry

- ***a_0*** → Definition of the overall length (mm)
- ***b_0*** → Definition of the overall width (mm)
- ***w*** → Track width in mm
- ***g*** → Gap between tracks (mm)
- ***t*** → Track thickness
- ***N*** → Number of turns

Inductance of an antenna depends on the antenna dimensions and material properties

Coil design calculation sheet

- This coil design guide calculation sheet uses antenna dimensions and estimates the antenna equivalent inductance.
- The following steps are a reliable method to design and fine tune a custom antenna coil:
  - Estimation of the electrical parameters
  - Definition of the target inductance
  - Definition of the dimensions
  - Definition of the matrix run
  - Production of samples
  - Selection of the best coil parameters
  - Definition of second matrix run (if needed)

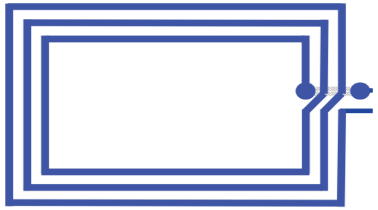


Excel calculation sheet tool included in
https://www.nxp.com/docs/en/application-note/AN11276.zip

Measure the antenna coil parameters

Measuring the antenna coil parameters

- The antenna loop has to be connected to a network analyzer to measure the antenna equivalent circuit (R_a, L_a, C_a)
- Before each measurement, the network analyzer must be calibrated (open, short and load compensation).
  - Settings: S11
  - Chart: Smith Z
  - Start frequency: 1 MHz
  - Stop frequency: Above self-resonant frequency



NTAG I²C *plus*
Antenna coil

High-end or Low-end
network analyzer
(e.g., miniVNA PRO)

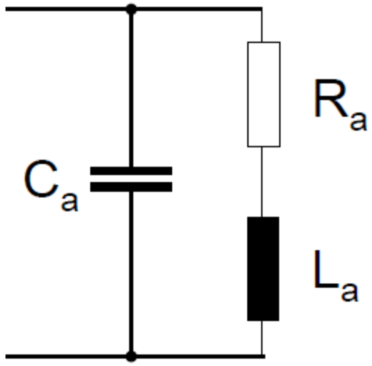
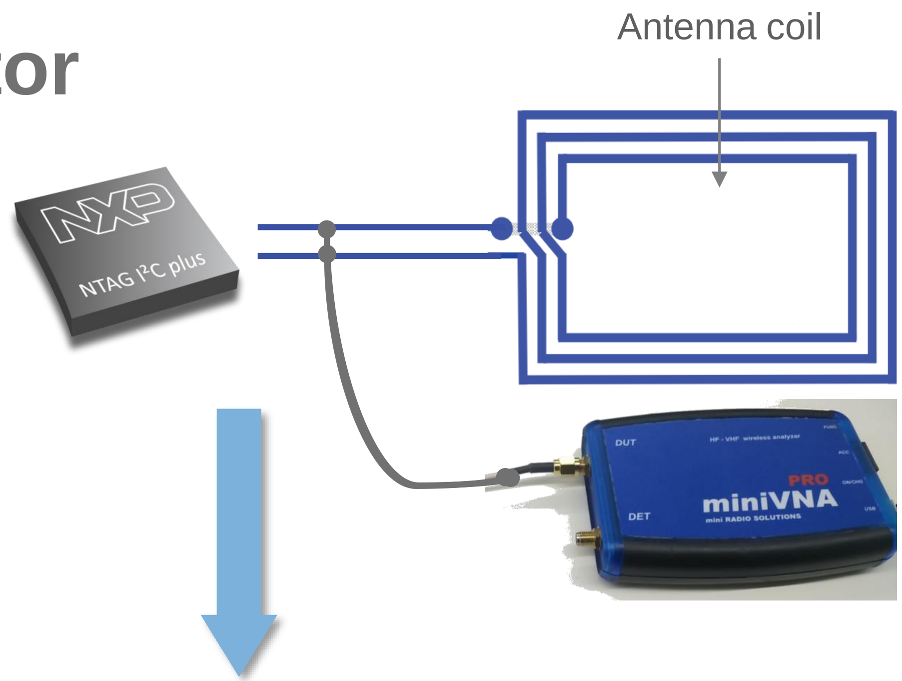


Fig. Antenna series equivalent circuit (C_a, L_a, R_a)

Note: The antenna has to be at the final mounting position to consider all parasitic effects like metal influence on quality factor, inductance and additional capacitance

Calculate the resonant capacitor value

Calculating the parallel resonance capacitor

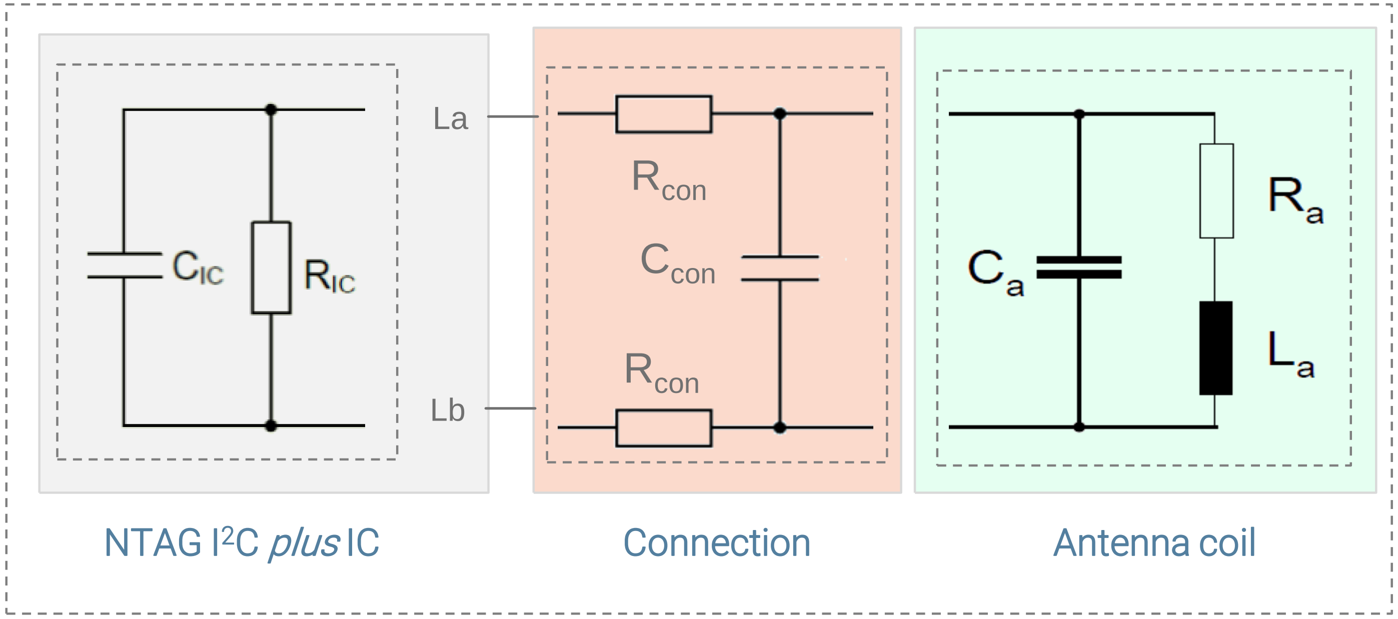


- We measure the current system resonance frequency ($f_{r\_current}$) after connecting the NTAG I²C *plus* to the antenna coil.

- If it is not $f_{r\_current} \sim 13.56MHz$, we calculate the system capacitance at the current resonance frequency with this formula:

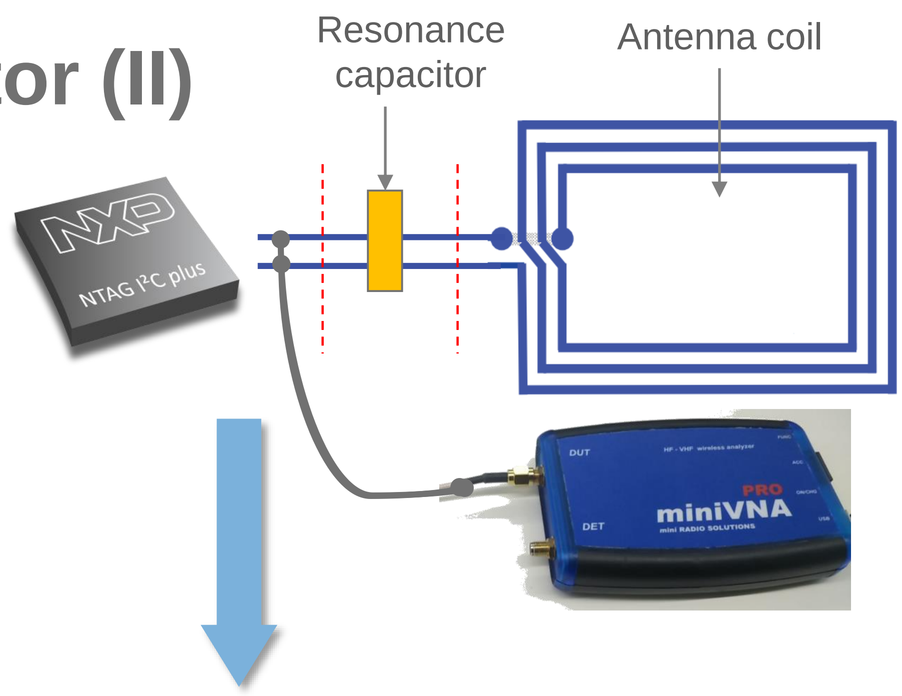
$$C_{fr\_current} = \frac{1}{(2 \cdot \pi \cdot f_{res})^2 \cdot L}$$

Note: The inductance of the system is basically the inductance of the antenna (L=La).



Training Mobile Knowledge

Calculating the parallel resonance capacitor (II)



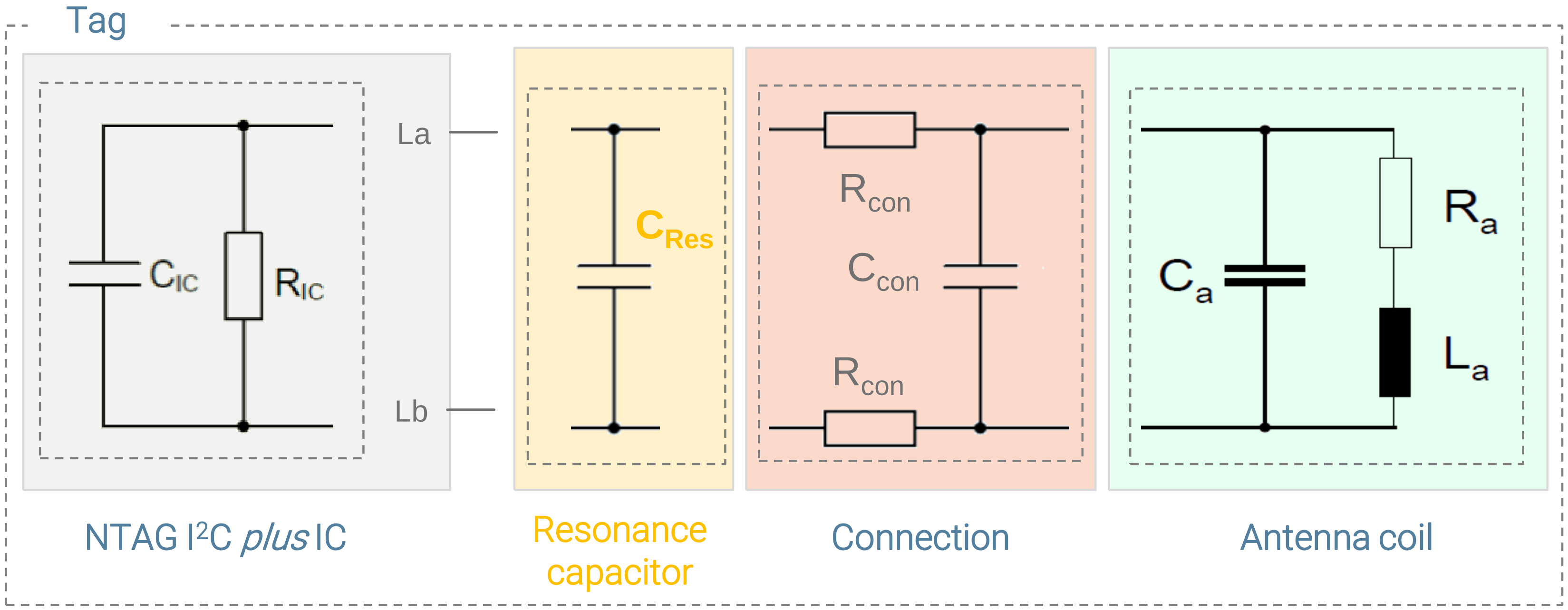
- If we fix the desired system resonance frequency (f_{r_target}), the capacitance required so that the system resonates at that target frequency can be calculated with this formula:

$$C_{target} = \frac{1}{(2 \cdot \pi \cdot f_{r\_target})^2 \cdot L}$$

- We can calculate the extra capacitance that needs to be soldered in parallel (***C_{Res}***) by:

$$C_{Res} = C_{target} - C_{fr\_current}$$

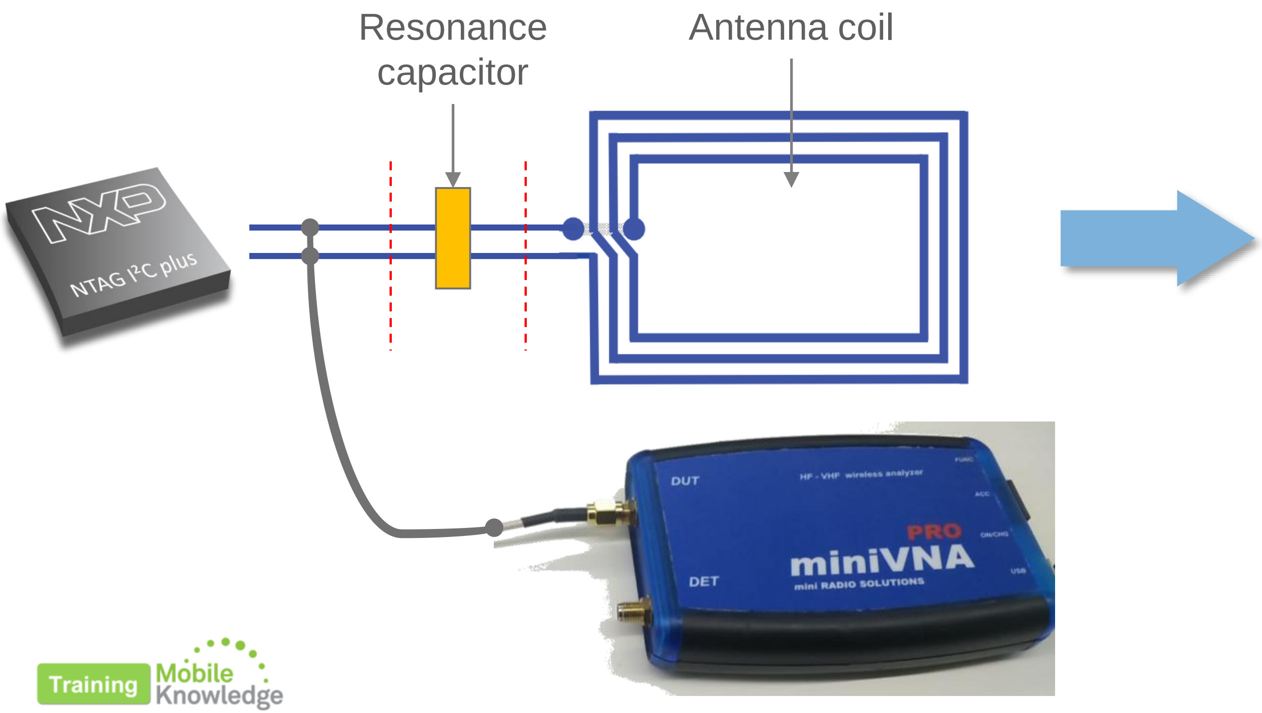
Note: For single tag operation, a tuning slightly **above 13.56 MHz** would lead to maximum read-/write distance. Due to manufacturing tolerances, a nominal frequency of **14.5 MHz** for single tag operation is recommended.



Assemble & measure resonant frequency

Assembling and measuring the tag resonant frequency

- Assemble the calculated C_{res} capacitor in your design.
- Then, measure the resonant frequency (f_{res}) at which the resistance impedance (Z) is maximum
- If the resonant frequency is not the target resonant frequency, fine tune the capacitor value. If the frequency is high, increase the capacitor value; if low, decrease it.



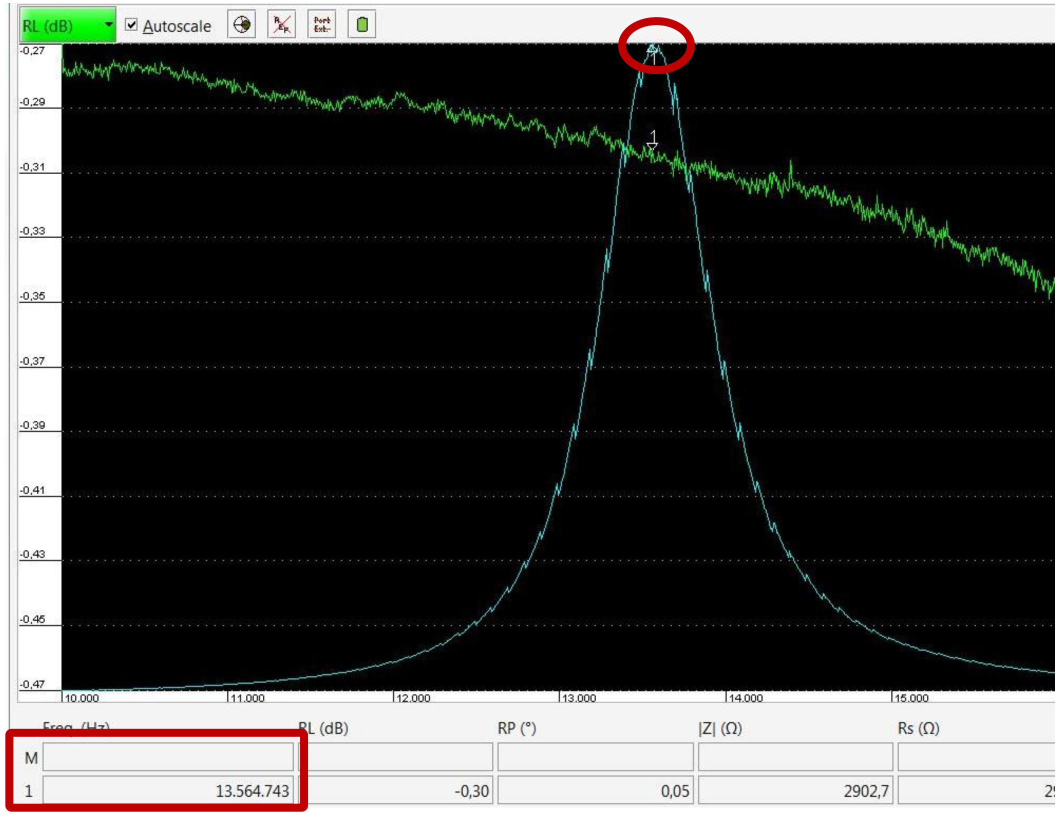


Fig. Example of a tag adjusted to f_{res} = 13.564 MHz

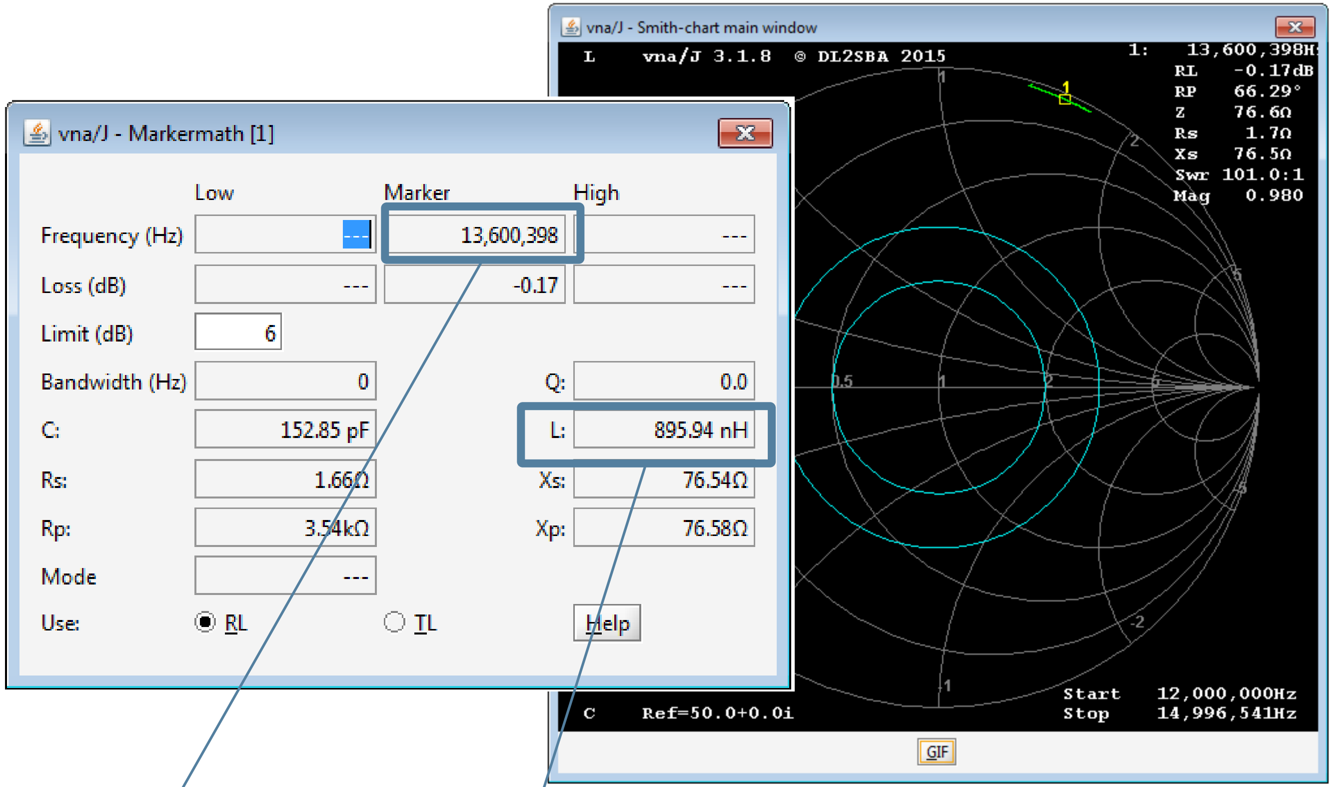
Example:

Tuning for a 54x27mm PCB antenna

Measuring the 54x27mm PCB antenna parameters

Measurement setup:

Fig 1. miniVNA PRO network analyzer connected to the 54x27mm PCB antenna connectors



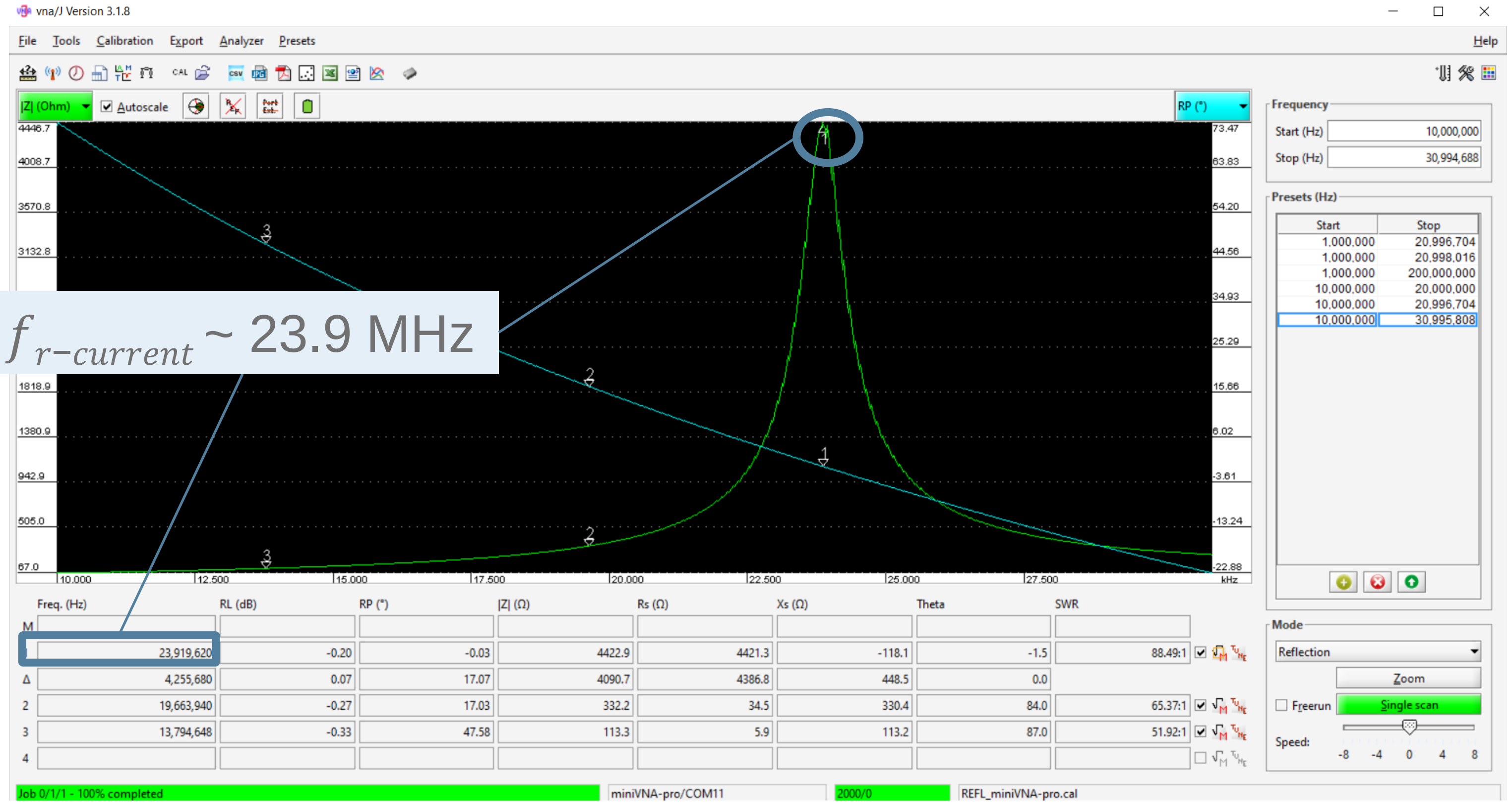
In the following steps, we will use the antenna inductance to perform the antenna tuning

f_{res} ~ 13.6 MHz L_a ~ 895 nH

Resonant capacitor value for the 54x27mm PCB antenna (I)

Measurement setup:

Fig 1. 54x27mm PCB antenna + NTAG I²C *plus* connected to miniVNA PRO



$$C_{fr\_current} = \frac{1}{(2 \cdot \pi \cdot f_{res})^2 \cdot L}$$

$$C_{fr\_current} = \frac{1}{(2 \cdot \pi \cdot 23.9MHz)^2 \cdot 895nH}$$

$$C_{fr\_current} = 49.5pF$$

Resonant capacitor value for the 54x27mm PCB antenna (I)

Target resonance frequency:

$f_{r\_target} \sim 13.6\text{MHz}$

We want to adjust our tag operation around 13.6MHz

$$C_{target} = \frac{1}{(2 \cdot \pi \cdot f_{r\_target})^2 \cdot L} \Rightarrow C_{target} = \frac{1}{(2 \cdot \pi \cdot 13.6MHz)^2 \cdot 895nH} \Rightarrow C_{target} = 153pF$$

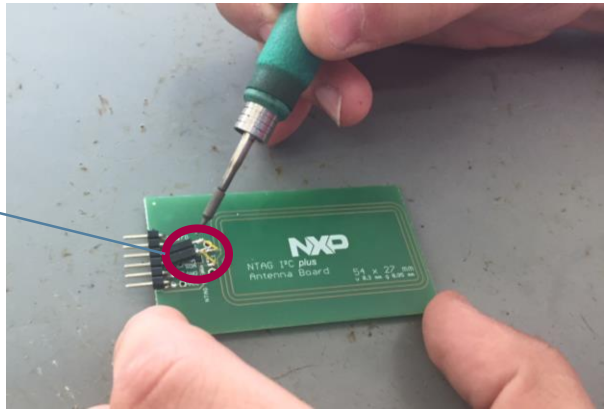
We calculate the C_{Res} :

$$C_{Res} = C_{target} - C_{fr\_current} \Rightarrow C_{Res} = 153pF \; -49pF \Rightarrow C_{Res} = 104\;pF$$

We adjust it with commercial values and we solder the C_{Res} in parallel to the antenna connectors:

$$C_{Res} \sim 104\;pF \Rightarrow C_{Res} = 100\;pF$$

We need an extra capacitance of 100pF



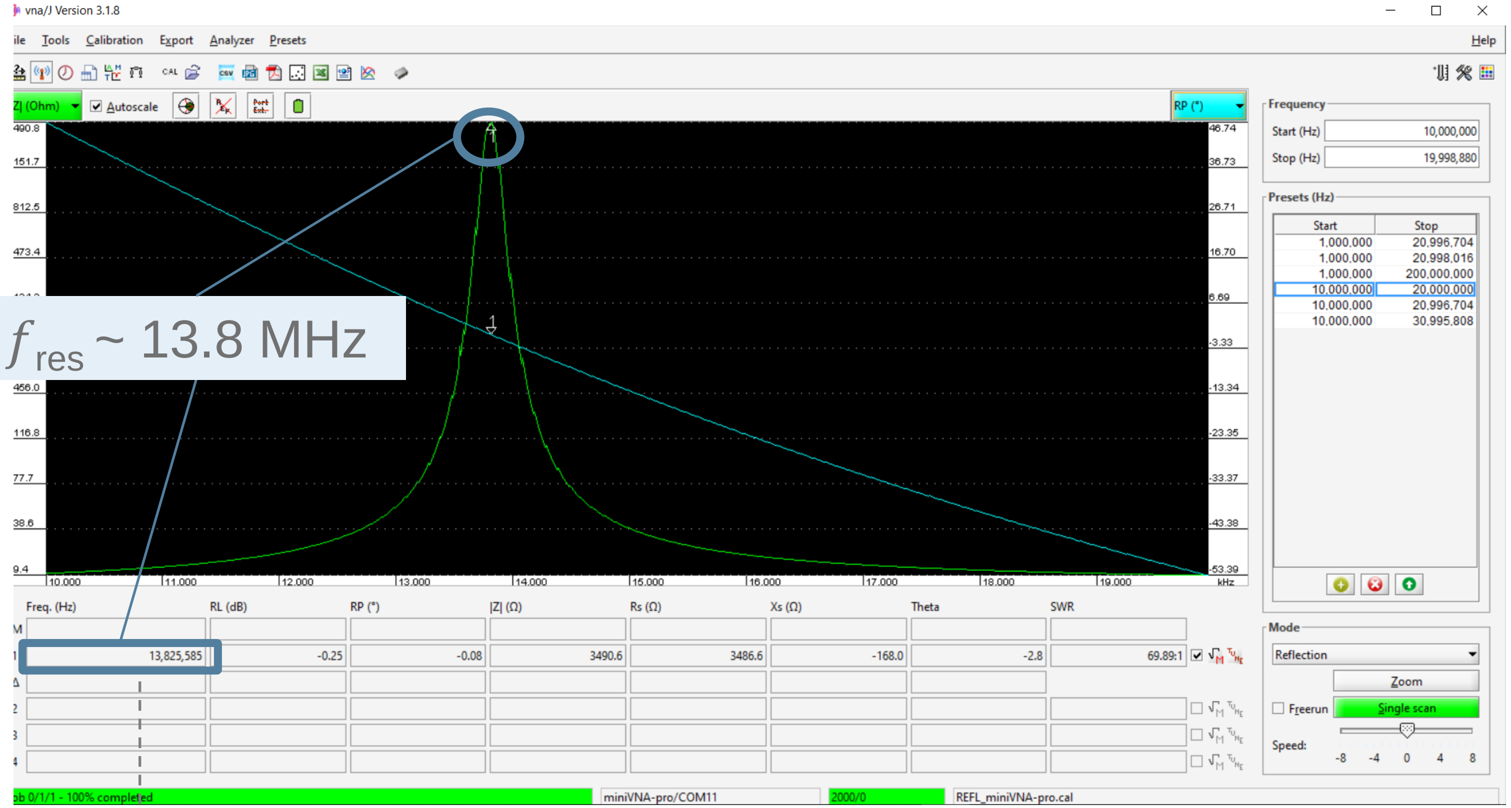
Assemble & measure resonant frequency

Measurement setup:

NTAG I²C *plus* IC

C_{Res} (100pf)

Antenna coil



f_{res} ~ 13.8 MHz

Good enough! If required, we can fine tune the capacitance until we reach the desired f_{res}

Recap and closure

Recap of the antenna tuning steps followed

1. **Design the antenna coil**
   Determine the size and the specs of the antenna (number of turns, track width, spacing, etc.)

We selected 54x27mm PCB antenna board included in OM5569-NT322E kit

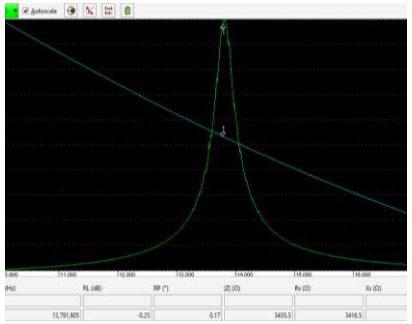
2. **Measure antenna coil**
   Characterize R,L,C antenna coil parameters

We separate the NTAG I²C *plus* from the PCB board to characterize the antenna parameters

3. **Calculate the resonant capacitor value**
   Determine the value of resonant capacitor to set the tag to the target resonant frequency

We solder an extra capacitance of 100pF

4. **Assemble & measure resonant frequency**
   Measure the resonant frequency and adjust the capacitor value if needed



This is the adjusted antenna tuning at f_{res}=13.8MHz

Further information

- NTAG I²C *plus:* http://www.nxp.com/products/:NT3H2111_2211
- NTAG antenna design guide: https://www.nxp.com/docs/en/application-note/AN11276.zip
- Get your technical NFC questions answered: https://community.nxp.com/community/identification-security/nfc
- List of Approved Engineering Consultants (AEC) for NFC: https://nxp.surl.ms/NFC_AEC

Your ultimate guide to designing antennas for the NTAG I²C *plus*

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Please check NXP and MobileKnowledge websites for **upcoming webinars** and **training sessions**

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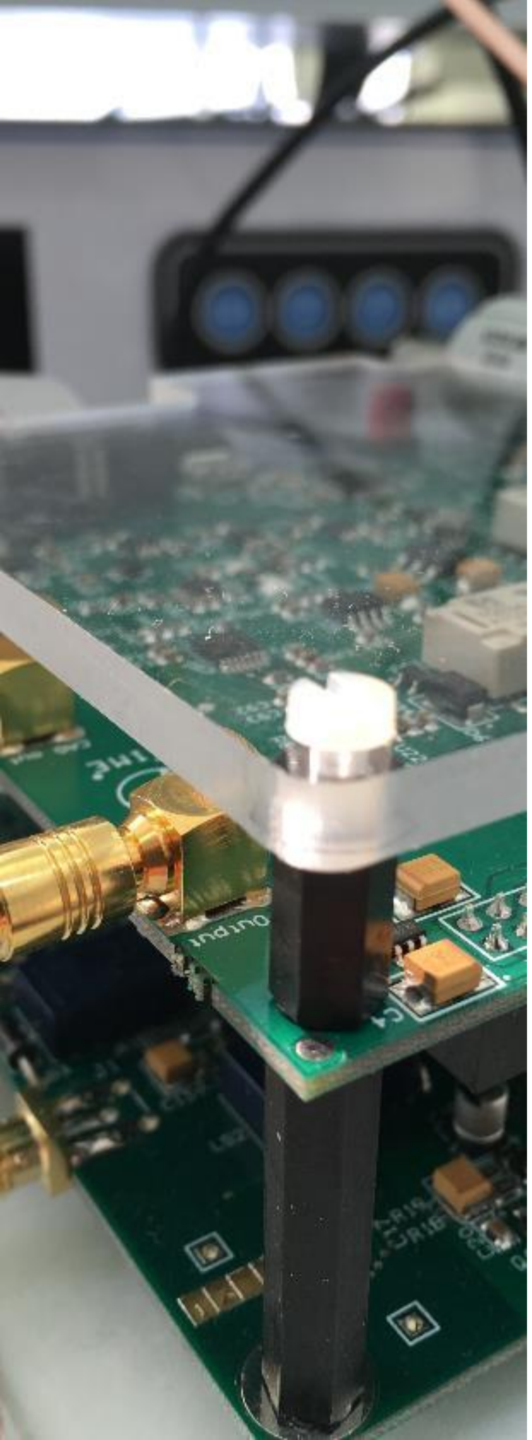

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