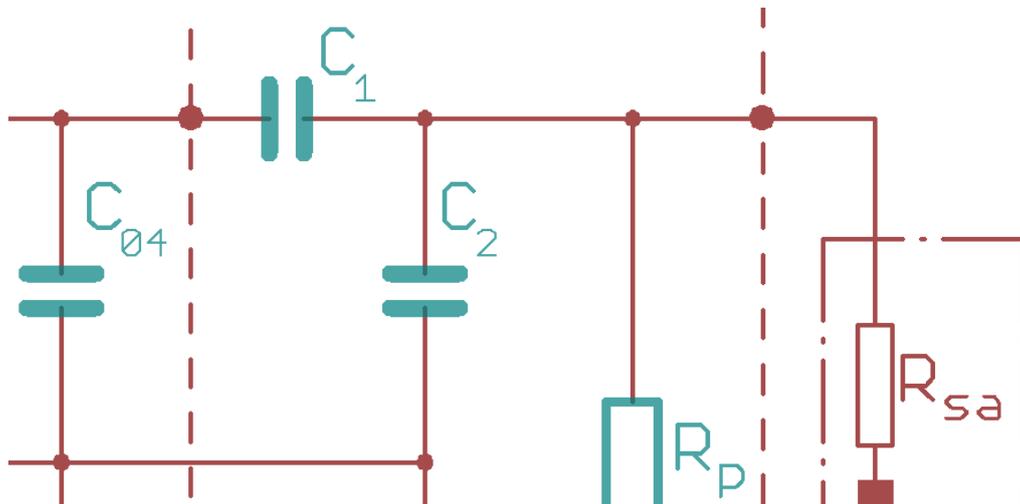


# Antenna Match Calculation Guide for TWN4 Nano Family

## Symmetrical and 50 Ohm Antenna Tuning

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# Contents

|     |   |    |
|-----|---|----|
| 1   | The Antenna . . . . .   | 3  |
| 1.1 | Calculation Tool (PCB Toolkit, loaded from <a href="http://www.saturnpcb.com">www.saturnpcb.com</a> ) . . . . . | 3  |
| 1.2 | Messure the antenna with MINI VNA . . . . .   | 4  |
| 2   | Determine the Antenna Matching Parameters . . . . .   | 6  |
| 2.1 | Antenna direct match . . . . .  | 6  |
| 2.2 | Antenna Adaption 50 Ohm . . . . .   | 8  |
| 3   | Epilogue . . . . .  | 10 |
| 4   | Disclaimer . . . . .  | 11 |

# 1 The Antenna

The optimum inductance of a HF antenna is a value around  $L = 1\mu H$  for a proper matching. But a wide range of  $0.3\mu H$  up to  $4\mu H$  still can be matched.

Small conductor tracks ( $< 0.5mm$ ) are good for small antennas. The disadvantage in this case is, that the current for a strong field is less than bigger conductor tracks (about  $1mm$ ). For small antennas you can not design big wires, because the antenna area in the middle would be smaller. So you have always to find an individual solution / compromise for your antenna.

In the following two ways are shown to determine the antenna inductance parameter. The first way is a calculation with a tool from the internet and the second way a determination with a MINI VNA equipment.

The chapter after that deals with the determination of the antenna parameters. Two ways will be introduced: The antenna direct match and the  $50R$  antenna adaption.

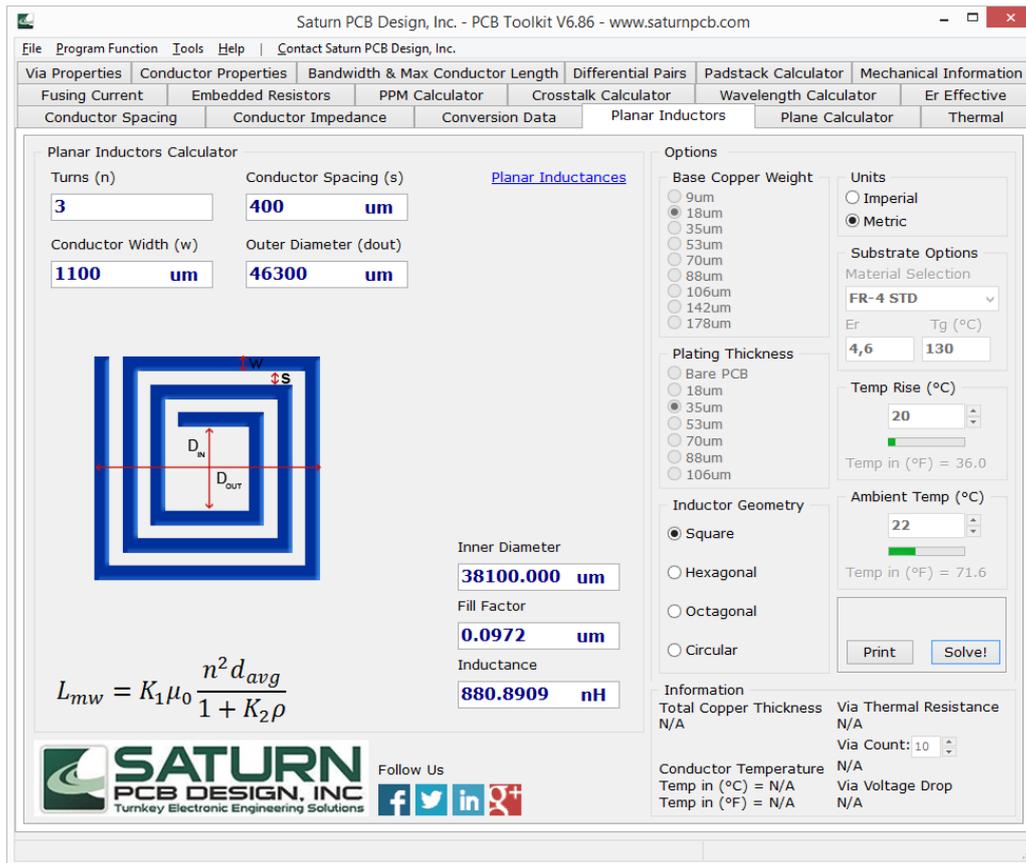
## 1.1 Calculation Tool (PCB Toolkit, loaded from [www.saturnpcb.com](http://www.saturnpcb.com))

We measure the antennae outline on the Nano Development-Board (here as example):

|                    |   |
|--------------------|---|
| Dimension:         | $45.0 * 47.6mm$                           |
| => Outer Diameter: | $(45.0 + 47.6)/2 = 46.3mm$ (Middle value) |
| Conductor Width:   | $1.1mm$                                   |
| Conductor Spacing: | $0.4mm$                                   |
| Turns:             | 3   |

Table 1.1: Measured antenna values on PCB

Install the PCB Toolkit (if not installed yet), start the tool and select the register card "Planar Inductors". Fill out the values in the upper left corner on the screen and press "**Solve!**" on the right.



|                |     |      |
|----------------|-----|------|
| Inductance $L$ | 881 | $nH$ |
|----------------|-----|------|

Table 1.2: Calculated value with the PCB tool

The inductance is a calculated value from ideal geometry (no round corners and square). The real value would be less. You can start calculation with this parameter in the next chapter!

For the coil resistor we take value  $R_{coil} = 2R$ . This is a practical start value.

## 1.2 Measure the antenna with MINI VNA

Start the MINI VNA and do calibration if not done. For measuring select a range of frequency from  $11MHz$  to  $16MHz$  (an array around  $13.56MHz$ ) and start measuring with your antenna (without any other components on the antenna and the final environmental conditions especially on metal environment or a ferrite for shielding).

Select the mouse marker at the frequency of  $13.56MHz$  and open the mathematic dialog as shown:

|                 | Minimum                             | Marke                    | Maximum      |
|-----------------|-------------------------------------|--------------------------|--------------|
| Frequenz (Hz)   |                                     | 13.563.164               | ---          |
| Dämpfung (dB)   | ---                                 | -0,36                    | ---          |
| Grenze (dB)     | 6,00                                |                          |              |
| Bandbreite (Hz) | 0                                   |                          | Q: 0,0       |
| C:              | 172,30 pF                           |                          | L: 799,16 nH |
| Rs:             | 2,98Ω                               |                          | Xs: 68,04Ω   |
| Rp:             | 1,56kΩ                              |                          | Xp: 68,17Ω   |
| Mode            | ---                                 |                          |              |
| Ben.:           | <input checked="" type="radio"/> RL | <input type="radio"/> IL | Hilfe        |

The measured values are:

|                |      |  |
|----------------|------|--|
| Inductance $L$ | 800  | $nH$   |
| $R_s$ (coil)   | 2.98 | $R$ (in praxis this value is normally smaller) |
| $C_{pa}$       | 172  | $pF$ (a calculated value from the inductance)  |

Table 1.3: Calculated values with the MINI VNA

With these values we can start matching!

## 2 Determine the Antenna Matching Parameters

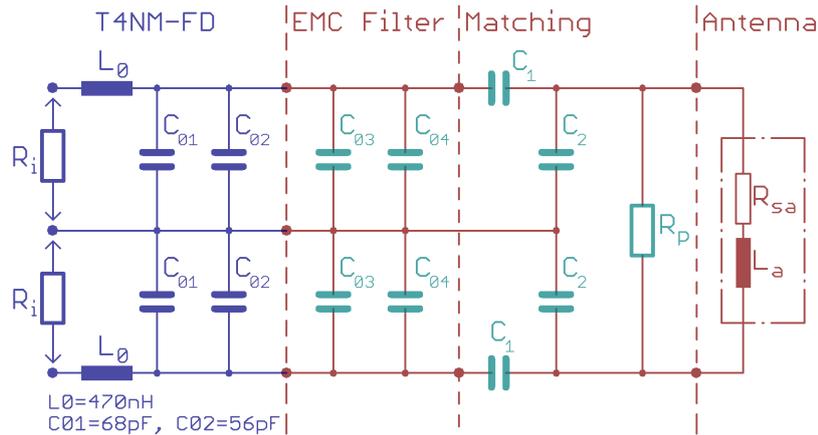
The Software **AntennaTuner.exe** calculates the matching parameters with mathematical equations - as good as the input values are given.

### 2.1 Antenna direct match

The screenshot shows the 'Antenna Tuner' software window with the 'Antenna Direct Match' tab selected. The interface is divided into several sections:

- Input Parameter:**
  - HF Frequency f: 13,56 MHz
  - Antenna Inductance La: 800 nH
  - Antenna Resistor Rsa: 2 Ohm
  - Quality Factor Q: 27
  - Target Impedance Ri: 25 Ohm
  - EMC cut off Frequency f: 14,6 MHz
- Circuit Schematic:** A diagram showing the antenna matching circuit. It includes a T4NM-FD component, an EMC Filter, a Matching section, and the Antenna. The schematic shows a series inductor  $L_{\theta}$  followed by a parallel combination of a resistor  $R_i$  and a capacitor  $C_{\theta 1}$ . This is followed by a series capacitor  $C_{\theta 2}$ , a parallel combination of a capacitor  $C_{\theta 3}$  and a capacitor  $C_{\theta 4}$ , a series capacitor  $C_1$ , a parallel combination of a resistor  $R_{p_i}$  and a capacitor  $C_2$ , and finally a series combination of a resistor  $R_{s_a}$  and an inductor  $L_a$ . Below the schematic, the calculated values are listed:  $L_{\theta} = 170 \text{ nH}$ ,  $C_{\theta 1} = 68 \text{ pF}$ , and  $C_{\theta 2} = 56 \text{ pF}$ .
- Information:**
  - Antenna Capacity Ca: 172 pF
  - EMC cut off f calc.: 14,6 MHz
  - (Resistor Rs): 0,26 Ohm
  - (Resistor Rtr): 274,8 Ohm
  - (Resistor Xtr): 43,11 Ohm
- EMC Parameter:**
  - EMC Inductance L0: 470 nH
  - Status: (empty)
  - $C_{01} + C_{02} + C_{03} + C_{04}$  (calculated): 254 pF
- EMC Chosen:**
  - Capacity C03: 120 pF
  - Capacity C04: 10 pF
- Calculated Match:**
  - Serial Capacity C1: 33 pF
  - Parallel Capacity C2: 311 pF
  - Resistor Rp: 1840 Ohm
- Calculate:** A button to perform the calculation.

The schematic in the screen of the software (register "**Antenna Direct Match**" is selected) shows the circuit diagram of the antenna direct matching (same as the Antenna-Direct-Match board on the Nano-Development-Board). Note for the Nano Module: If it is not in card mode or passive P2P target, the ANT1 and ANT2 pins do not need to be connected. If used, you wire ANT1 with  $82 \text{ pF}$  (e.g.) to the antenna connection pad and ANT2 analogous to the other:



The components  $L_0$ ,  $C_{01}$  and  $C_{02}$  on the left part "T4NM-FD" are fix placed on the Nano-Module.

The "EMC-Filter" with the capacitance  $C_{03}$  and  $C_{04}$  adjust the cut off frequency of the output circuit. This adaption is always necessary.

The "Matching" part adapts the output circuit to individual antennas.

**EMC Filter / Matching Parameters in detail:**

The **EMC filter** is a second order low pass filter and contains an inductor  $L_0$  and a capacitance  $C_0 = C_{01} || C_{02} || C_{03} || C_{04}$ . The passive components  $L_0$ ,  $C_{01}$  and  $C_{02}$  are placed on the Nano-Module.

The **Frequency  $f$  cut off** should be far above the carrier frequency and far below the second harmonic (14.5MHz to 22MHz). Take 14.5MHz to 15.5MHz for symmetrical tuning (and 17MHz to 22MHz for assymmetrical tuning).

The **Quality factor  $Q$**  depends on the overall system requirements and frame conditions. A value from 20 to 30 is recommended. The lower the  $Q$ , the better the stability and robustness of the antenna. The higher the  $Q$ , the higher the field strength.

The **Target impedance  $R_i$**  for maximum power is about 18..20R (with driver current limit 250mA). For battery powered devices take 50..80R. The higher the target impedance is, the lower the operating distance of the reader

The fix values from the Nano Module are:

$$L_0 = 470\text{nH} \text{ and } C_0' = C_{01} + C_{02} = 68\text{pF} + 56\text{pF}$$

**Note:** All the names of the capacitance and inductance are for the upper and the lower part in the plan. These parts are mirrored and have analogue the same values!

|  |       |     |
|--|-------|-----|
| HF Frequency $f$                           | 13.56 | MHz |
| Antenna Inductance $L_a$                   | 800   | nH  |
| Antenna Resistor $R_{sa}$                  | 2     | R   |
| Quality Factor $Q$                         | 27    |     |
| Target Impedance $R_i$                     | 25    | R   |
| EMC cut off frequency $f_{\text{cut off}}$ | 14.6  | MHz |

Table 2.1: Input Parameter for the calculation tool

Fill in the parameters into the entry fields of the software.

**Note for other hardware:** The value for the inductance is given as  $470\mu H$  (fix on the Nano Module). For other reader circuits you can change this value. The values  $C01 = 68pF$  and  $C02 = 56pF$  are fix deposited in the software. For adaption of the capacitance  $C03$  and  $C04$  change the values as long as you get the calculation EMC cut off frequency round  $14.6MHz$ . Note, that the EMC capacitance is always the sum of  $C01$ ,  $C02$ ,  $C03$  and  $C04$ .

The matched parameters are shown, if you press the button "**Calculate**". For safety check the calculated EMC frequency. With these calculated values you can test your antenna match.

## 2.2 Antenna Adaption 50 Ohm

Select the register card "**Antenna Adaption 50 Ohm**".

The screenshot shows the 'Antenna Tuner' software window with the 'Antenna Adaption 50 Ohm' register card selected. The interface is divided into several sections:

- Input Parameter:**
  - HF Frequency f: 13.56 MHz
  - Antenna Inductance La: 800 nH
  - Antenna Resistor Rsa: 3 Ohm
  - Quality Factor Q: 20
  - Antenna Adaptation Ri: 50 Ohm
- Information:**
  - Antenna Inductance Ca: 172.2 pF
  - Resistor Rsa+Rs: 6.4 Ohm
- Calculated Match:**
  - Resistor Rs (Variant 1): 3.4 Ohm
  - Resistor Rp (Variant 2): 2563 Ohm
  - Serial Capacity C1: 62 pF
  - Parallel Capacity C2: 111 pF

Two circuit diagrams are shown on the right side of the interface:

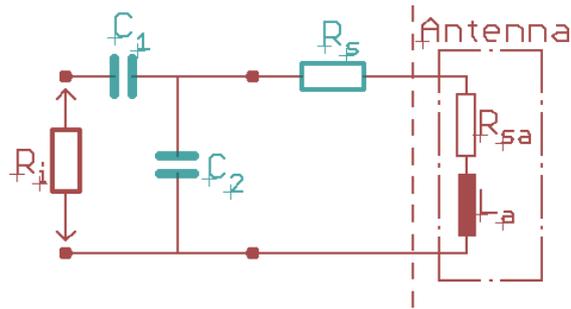
- Variant 1 with Q-Adaption serial:** A circuit diagram showing a series combination of a capacitor  $C_1$ , a resistor  $R_s$ , and an antenna. A parallel combination of a resistor  $R_i$  and a capacitor  $C_2$  is connected across the input terminals.
- Variant 2 with Q-Adaption parallel:** A circuit diagram showing a parallel combination of a capacitor  $C_1$  and a resistor  $R_p$  connected across the input terminals. A series combination of a resistor  $R_s$  and an antenna is connected to the output terminals.

A 'Calculate' button is located at the bottom right of the interface.

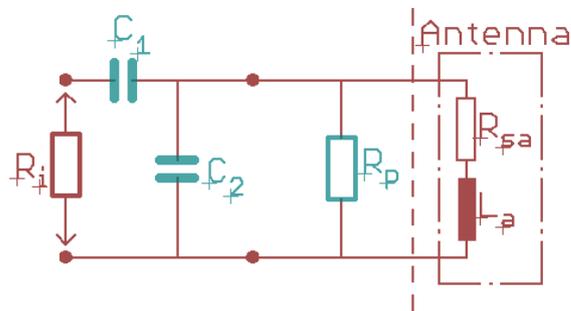
This antenna adaption is for reader with  $R_i = 50R$  HF output.

There are two variants, the serial and the parallel variant to adapt the antenna to the reader. The requirement for the calculation tool is a "ideal" reader output  $50R$ . The imaginary part is in this case zero.

Variant 1 with Q-Adaption serial



Variant 2 with Q-Adaption parallel



Fill in the parameters into the entry fields of the software.

|                           |       |                                      |
|---------------------------|-------|--------------------------------------|
| HF Frequency $f$          | 13.56 | $MHz$                                |
| Antenna Inductance $L_a$  | 800   | $nH$                                 |
| Antenna Resistor $R_{sa}$ | 3     | $R$                                  |
| Quality Factor $Q$        | 20    | (f.e. good stability and robustness) |
| Target Impedance $R_i$    | 50    | $R$                                  |

Table 2.2: Input Parameter

After you have filled in the parameters in the software, press button "**Calculate**" on the screen.

Start with the calculated capacitance values on your circuit and omitt the resistor first. If the matching is good, then equip it.

## 3 Epilogue

The measured antenna values with the VNA or the calculated values with the tool in the web are start values for your antenna adaption to reader output. The whole calculation is a good starting point. In praxis you test the field strength with cards or token. But not the maximal *reading* value is the best adaption! Important is a good *reading, authentication and writing* distance for cards and token.

*Dynamic Power Control (DPC):* The Dynamic Power Control - enabled on the Nano Module NIFARE NFC - adapts the output power dynamically. The result is a good reader performance!

*Asymmetrical tuning of the antenna:* The antenna adaption is indeed easier, but has some disadvantages regarding the pulse shapes and receiver performance. The standard "asymmetrical" antenna tuning requires the DPC to be disabled. Elatec does not support this feature for now.

## 4 Disclaimer

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