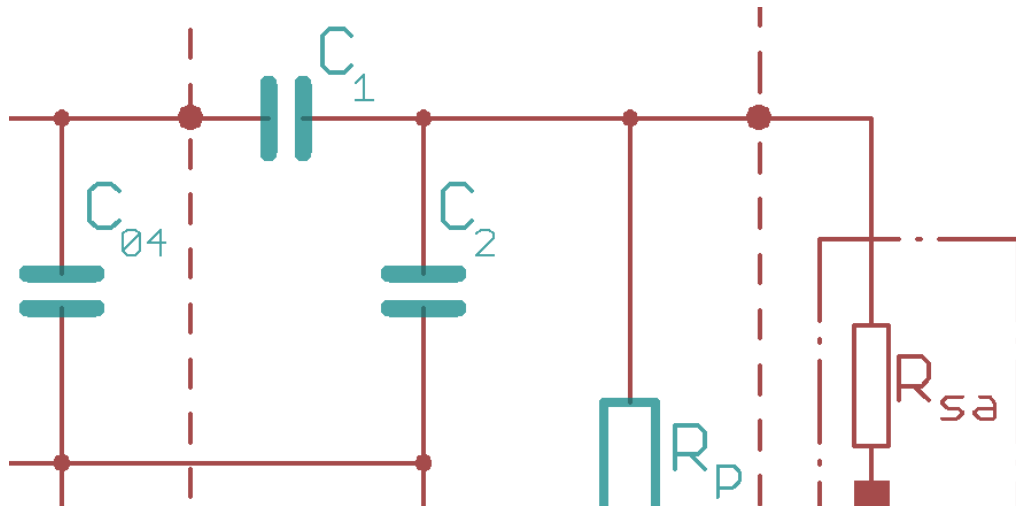


# Antenna Match Calculation Guide for TWN4 Nano Family

## Symmetrical and 50 Ohm Antenna Tuning

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ELATEC GmbH

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# 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  $50\Omega$  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):

|                    |   |
|--------------------|---|
| Dimmension:        | $45.0 * 47.6mm$                           |
| => 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.

Planar Inductors Calculator

Turns (n): 3

Conductor Spacing (s): 400 um

Conductor Width (w): 1100 um

Outer Diameter (dout): 46300 um

Inner Diameter: 38100.000 um

Fill Factor: 0.0972 um

Inductance: 880.8909 nH

Formula:  $L_{mw} = K_1 \mu_0 \frac{n^2 d_{avg}}{1 + K_2 \rho}$

Options:

- Base Copper Weight: 18um
- Plating Thickness: 35um
- Inductor Geometry: Square
- Units: Metric
- Substrate Options: FR-4 STD
- Er: 4.6
- Tg (°C): 130
- Temp Rise (°C): 20
- Temp in (°F): 36.0
- Ambient Temp (°C): 22
- Temp in (°F): 71.6

Information:

- Total Copper Thickness: N/A
- Via Thermal Resistance: N/A
- Via Count: 10
- Conductor Temperature: N/A
- Via Voltage Drop: N/A

|                |     |      |
|----------------|-----|------|
| 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

**Antenna Tuner V1.01**

Antenna Adaption 50 Ohm **Antenna Direct Match**

**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  |

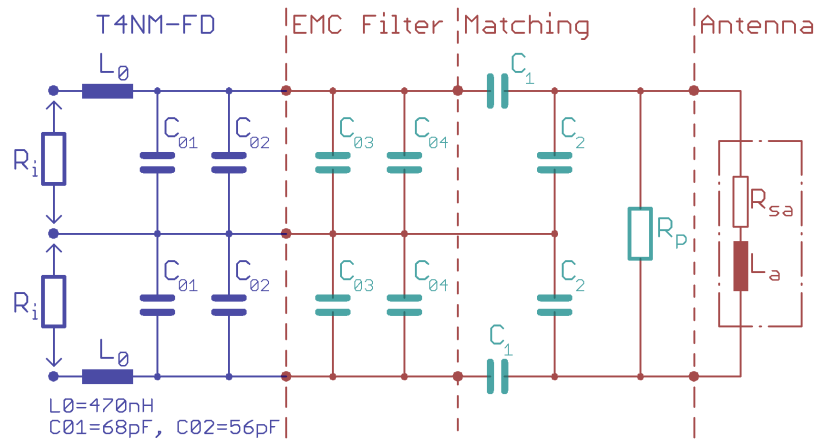
Status:

**Calculate**

**Variant 1 with Q-Adaption serial**

**Variant 2 with Q-Adaption parallel**

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:

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

**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 $f_{cut\ off}$ | 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"**.

**Antenna Tuner V1.01**

Antenna Adaption 50 Ohm | Antenna Direct Match

**Input Parameter:**

|                       |       |     |                         |      |     |
|-----------------------|-------|-----|-------------------------|------|-----|
| HF Frequency f        | 13,56 | MHz | Quality Factor Q        | 27   |     |
| Antenna Inductance La | 800   | nH  | Target Impedance Ri     | 25   | Ohm |
| Antenna Resistor Rsa  | 2     | Ohm | EMC cut off Frequency f | 14,6 | MHz |

**Circuit Diagram:** The diagram shows a matching network between a reader (left) and an antenna (right). The reader side has a series inductor  $L_0$  and a parallel resistor  $R_i$ . The matching network consists of a series capacitor  $C_1$  and a parallel capacitor  $C_2$ . The antenna side has a parallel resistor  $R_{sa}$  and a series inductor  $L_a$ . The EMC filter section includes a series capacitor  $C_3$  and a parallel capacitor  $C_4$ . The diagram is labeled with components: T4NM-FD, EMC Filter, Matching, and Antenna.

**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: |
| C01+C02+C03+C04 (calculated) | 254 | pF |         |

**EMC Chosen:**

|              |     |    |
|--------------|-----|----|
| Capacity C03 | 120 | pF |
| Capacity C04 | 10  | pF |

**Calculated Match:**

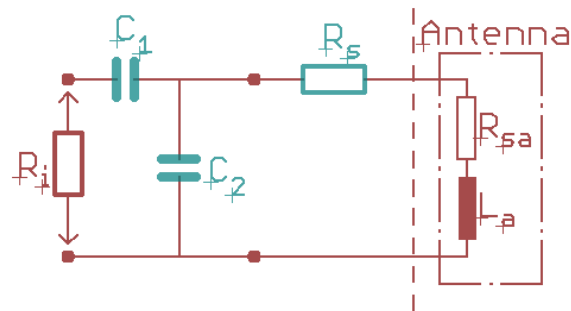
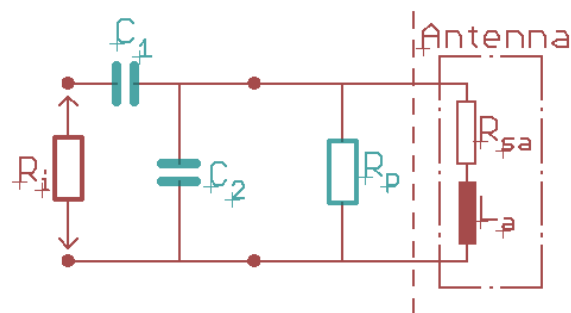
|                      |      |     |
|----------------------|------|-----|
| Serial Capacity C1   | 33   | pF  |
| Parallel Capacity C2 | 311  | pF  |
| Resistor Rp          | 1840 | Ohm |

**Calculate**

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 serialVariant 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 omit 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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