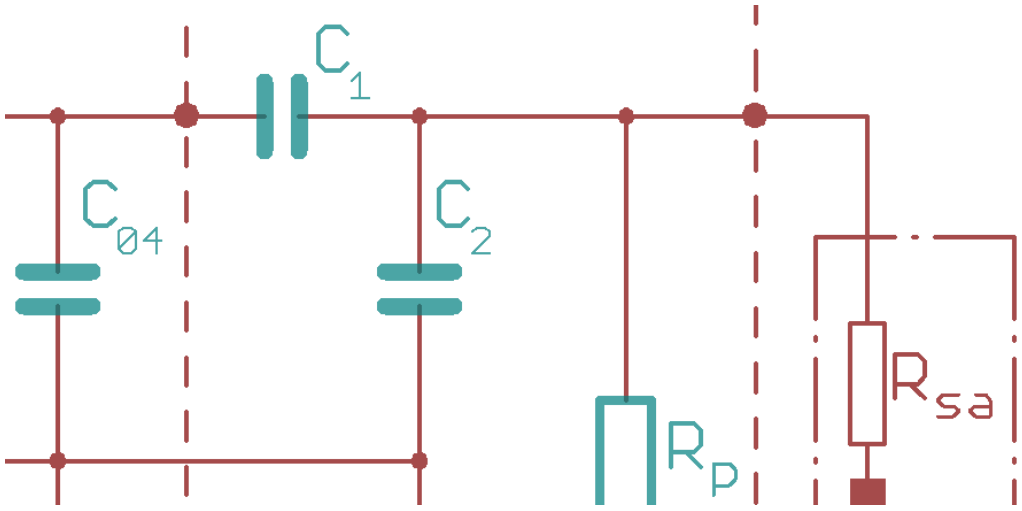
Antenna Match Calculation Guide for TWN4 Nano Family

Symmetrical and 50 Ohm Antenna Tuning

DocRev9, November 7, 2022



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 $50R$ antenna adaption.

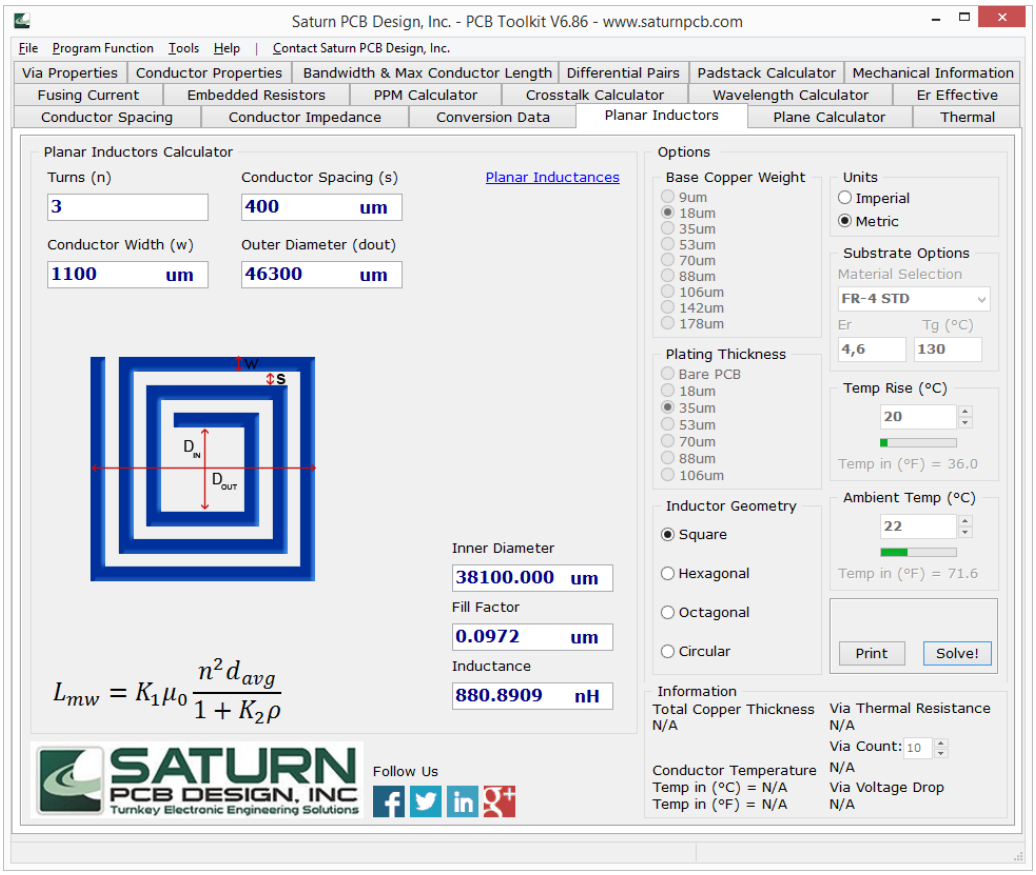
1.1 Calculation Tool (PCB Toolkit, loaded from www.saturnpcb.com)

We measure the antenne 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.



Inductance L	881	nH

Table 1.2: Calculated value with the PCB tool

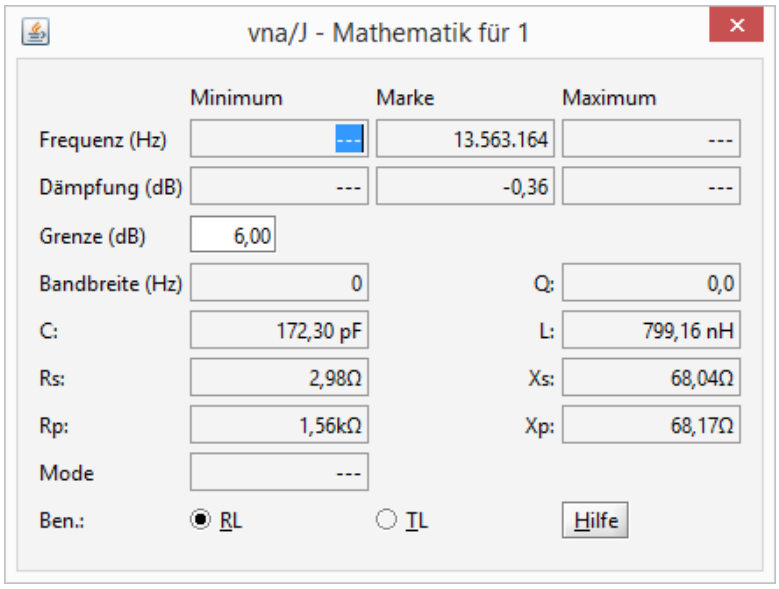
The inductance is a calculated value from ideal geometry (no round corners and square). The real value would be less. You can start calculation with this parameter in the next chapter!

For the coil resistor we take value *Rcoil* = $2R$. This is a practical start value.

1.2 Messure 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:



The measured values are:

Inductance L	800	nH
Rs (coil)	2.98	R (in praxis this value is normally smaller)
Cpa	172	pF (a calculated value from the inductance)

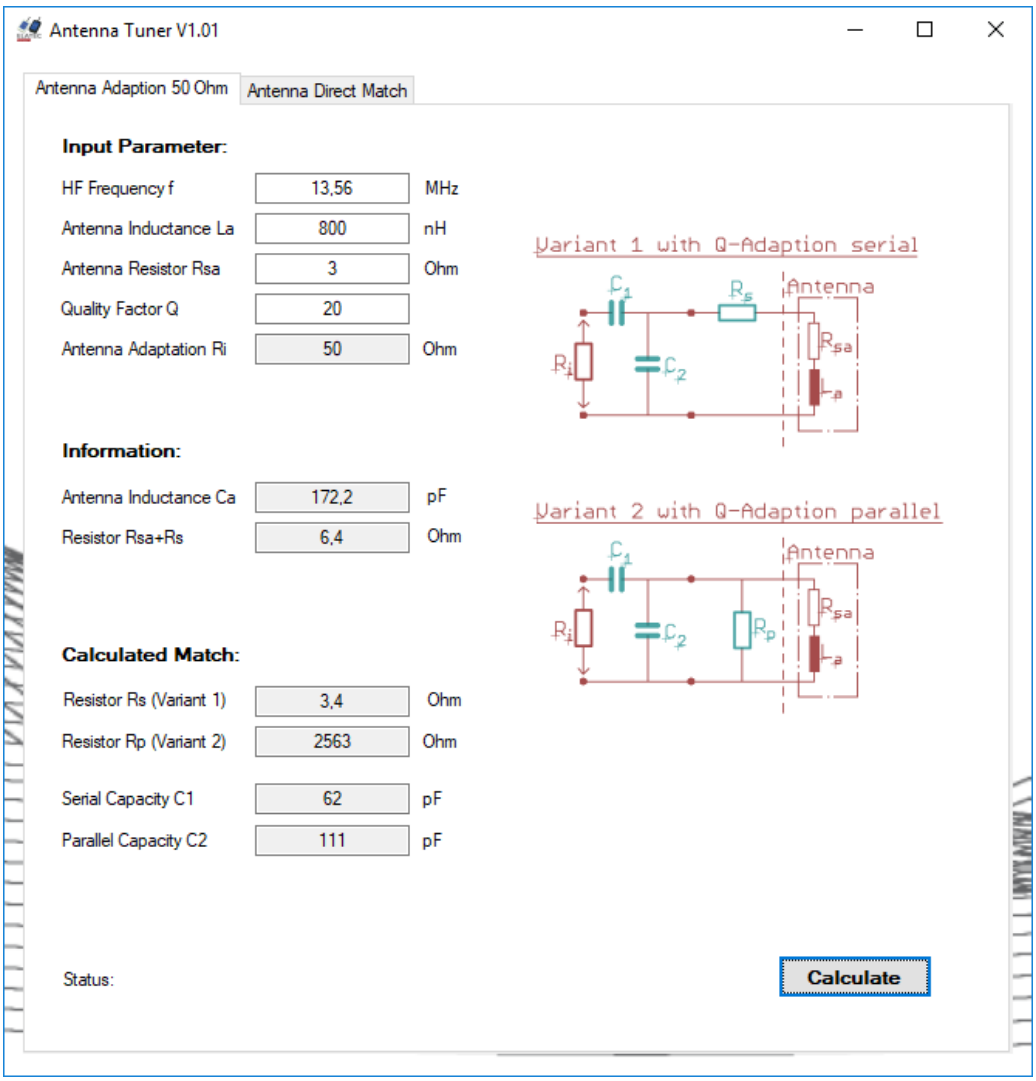
Table 1.3: Calculated values with the MINI VNA

With these values we can start matching!

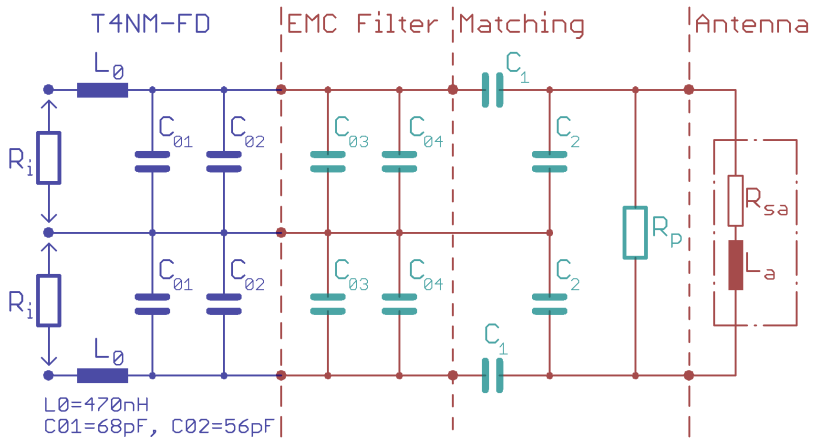
2 Determine the Antenna Matching Parameters

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 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 $82pF$ (e.g.) to the antenna connection pad and ANT2 analogous to the other:



The components $L0$, $C01$ and $C02$ on the left part "T4NM-FD" are fix placed on the Nano-Module.

The **"EMC-Filter"** with the capacitance $C03$ and $C04$ 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 $L0$ and a capacitance $C0 = C01||C02||C03||C04$. The passive components $L0$, $C01$ and $C02$ 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** Ri 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:

$L0 = 470nH$ and $C0' = C01 + C02 = 68pF + 56pF$

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 La	800	nH
Antenna Resistor Rsa	2	R
Quality Factor Q	27	
Target Impedance Ri	25	R
EMC cut off frequency $f$cut off	14.6	MHz

Table 2.1: Input Parameter for the calculation tool

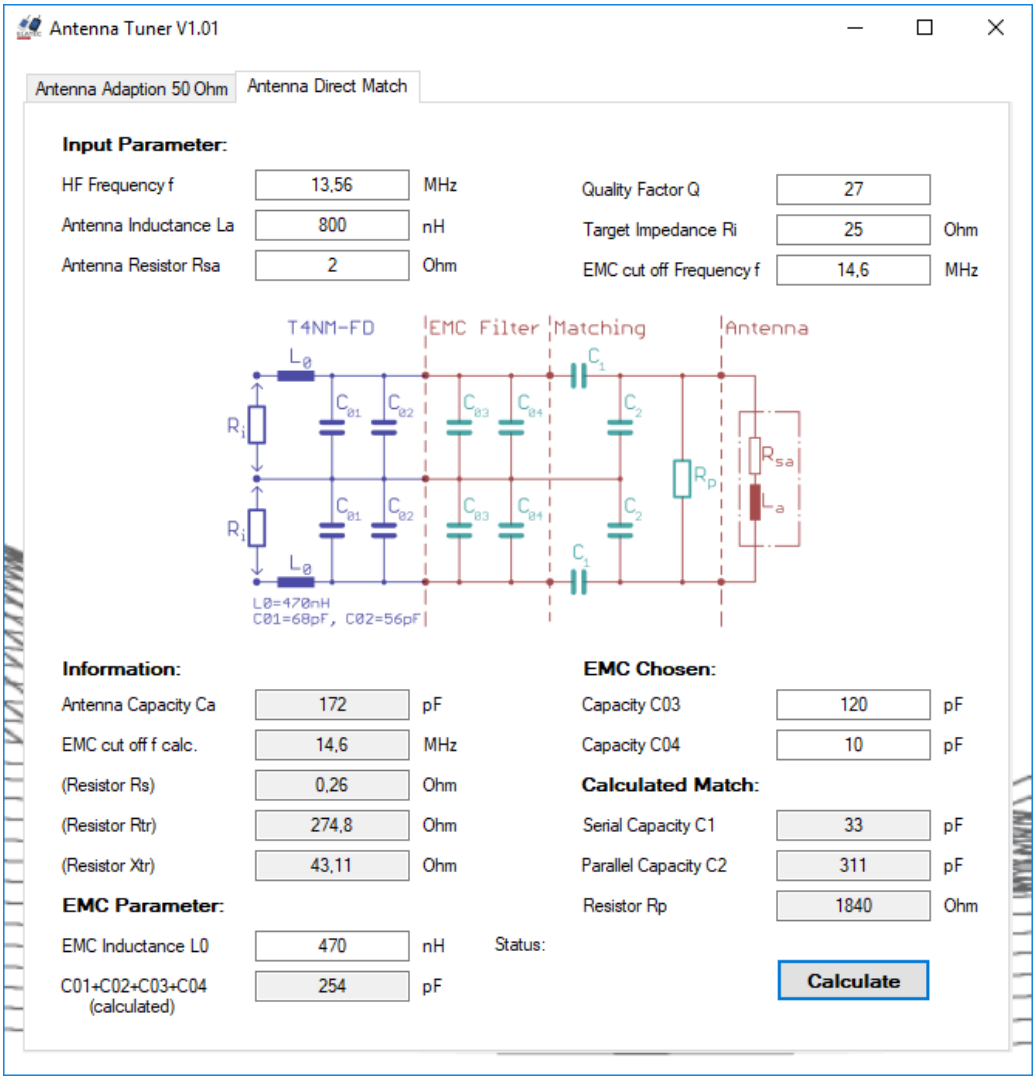
Fill in the parameters into the entry fields of the software.

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 calulation 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.

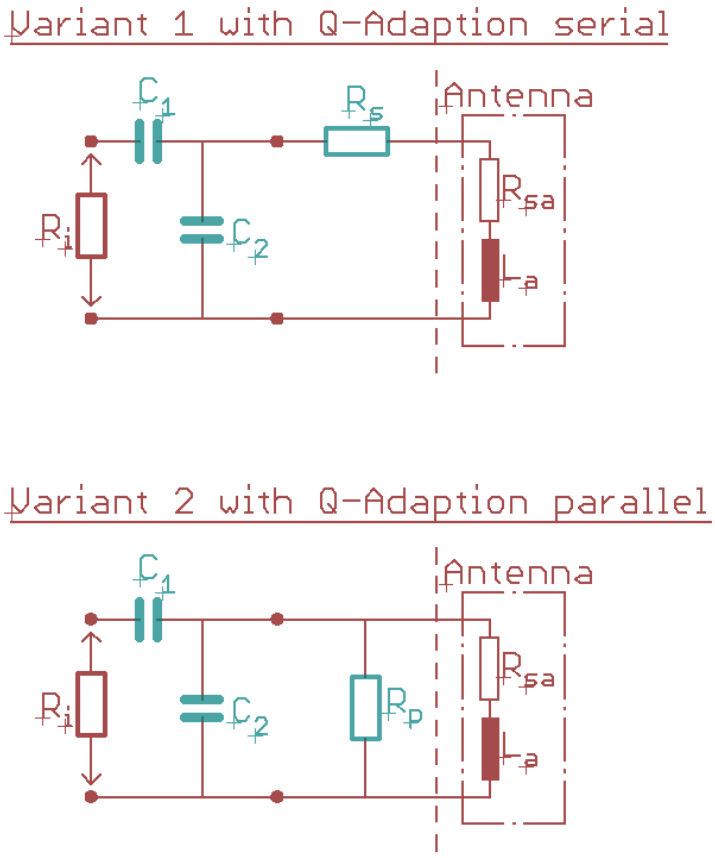
2.2 Antenna Adaption 50 Ohm

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



This antenna adaption is for reader with $Ri = 50R$ 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.



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

HF Frequency f	13.56	MHz
Antenna Inductance La	800	nH
Antenna Resitor Rsa	3	R
Quality Factor Q	20	(f.e. good stability and robustness)
Target Impedance Ri	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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