nRF52832 NFC Antenna Tuning

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White Paper

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Contents

Revision history

Date	Version	Description
April 2018	1.2	Update to the chip configuration process in Configuring the chip on page 11
August 2017	1.1	Added information on overcoupling to the chapter Choice of antenna on page 5
October 2016	1.0	First release

1 Introduction

This white paper describes how the nRF52832 NFC (Near Field Communication) antenna can be tuned.

A typical NFC system consists of two devices, an active and a passive device. The active device has a power source and induces a magnetic field with a coil inductor antenna. When the passive device is placed in this magnetic field, the varying magnetic field will induce current (power) in the passive device. The induced power in the passive device is used to retrieve and transmit data back to the active device.

An active device can also be called a poller, and a passive device can also be called a listener or a tag. The nRF52832 SoC is an NFC tag device.

2 NFC antenna

An NFC antenna is a coil inductor, and together with capacitors to ground, they form a parallel resonant LC tank. A maximized power transfer takes place when the active and the passive device antenna have the same resonance frequency. Since the active device operates at 13.56 MHz, the passive device antenna should also resonate at that frequency. In addition to the resonance frequency, the antenna's physical size and shape also matters. Two similar shaped antennas will result in more power transfer than two very different antennas.

The antenna and the parallel capacitors form an LC tank circuit (see Figure 1: NFC tag antenna with capacitors (LC-circuit) connected to NFC1 and NFC2 on page 5). The goal of the tuning is to find the optimal value of the parallel capacitors, C_{tune1} and C_{tune2}, so that the resonance frequency of the LC-circuit is at 13.56 MHz.

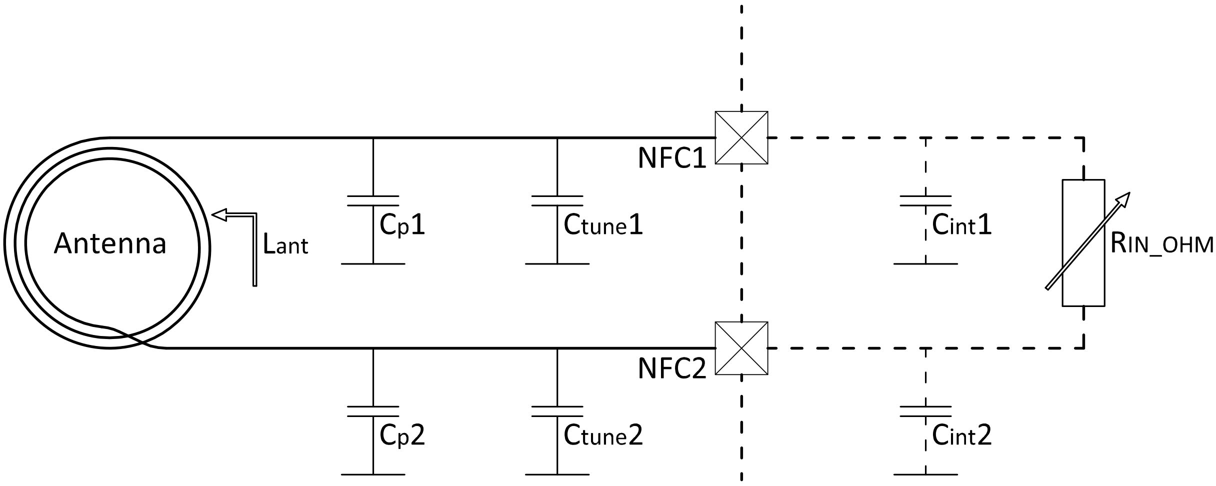

Figure 1: NFC tag antenna with capacitors (LC-circuit) connected to NFC1 and NFC2

2.1 Choice of antenna

Maximum power transfer occurs when the NFC tag antenna and the NFC poller antenna have the same shape and size.

To achieve the best performance, the choice of NFC tag antenna should be based on the application and the typical poller NFC antenna for that application. It could be a good idea to test the NFC tag with many NFC pollers.

Overcoupling is a physical effect in NFC which degrades performance. This occurs when the Poller and the Listener antenna have identical geometry and are aligned and placed at near zero distance. In some NFC products this problem is avoided due to the thickness of the casing that separates the antennas. Other NFC products use an asymmetrical antenna shape to ensure that when two identical devices are put together there is not a perfect overlap.

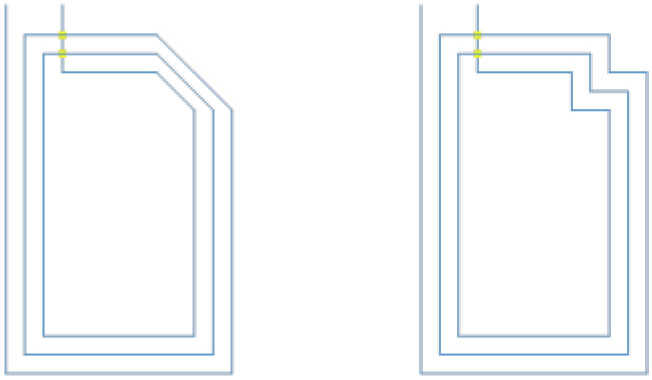

Figure 2: Asymmetrical antenna shape

The overcoupling effect should be taken into account when developing a product for certification. The NFC Forum has announced an initiative called the Tag Certification Program that is meant to establish a standard for NFC tag technology. Overcoupling can degrade performance or even lead to failing test cases when the antenna of the device matches the geometry of the Reference Poller antennas used during certification. A small difference in aspect ratio or in a single dimension is usually enough. You should avoid the following antenna geometries in a product.

- Reference Poller antenna 1: rectangular antenna of 46 by 32 mm
- Reference Poller antenna 2: rectangular antenna of 25 by 20 mm

3 Estimating values

Before starting to tune, you must estimate an approximate value for the capacitors C_{tune1} and C_{tune2}.

Coming up with an estimation is important especially when using the method described in Varying the frequency on page 9, because this method uses the estimated value to find the correct value of C_{tune1} and C_{tune2}.

Important: C_{tune1} and C_{tune2} must have the same value.

Complete the following steps to estimate the value of the capacitors, C_{tune1} and C_{tune2}:

1. Find an approximate inductance (L_{ant}) of the NFC tag antenna using an appropriate method:
   - Find the value in the antenna datasheet.
   - Calculate the inductance based on the antenna dimensions.
2. Calculate the value of the parallel capacitors, based on the inductance of the NFC antenna.

   C_{tune1} and C_{tune2} must have the same value, the internal capacitance C_{int} is approximately 4 pF, and L_{ant} is the inductance of the NFC antenna.

   Use the below formula to calculate the value of the parallel capacitors.

$$f = \frac{1}{2\pi \cdot \sqrt{LC}} \rightarrow find\ C$$

$$C'_{tune} = \frac{1}{(2\pi \cdot 13.56\ MHz)^2 \cdot L_{ant}}\ where\ C'_{tune} = \frac{1}{2} \cdot (C_p + C_{int} + C_{tune})$$

$$and\ C_{tune1} = C_{tune2} = C_{tune} \qquad C_{p1} = C_{p2} = C_p \qquad C_{int1} = C_{int2} = C_{int}$$

$$C_{tune} = \frac{2}{(2\pi \cdot 13.56\ MHz)^2 \cdot L_{ant}} - C_p - C_{int}, \qquad C_{int} \approx 4\ pF$$

Figure 3: Resonance frequency for an LC-circuit

4 Tuning methods

There are different methods for tuning. For example, you can use a network analyzer or vary the frequency.

Using an **Network analyzer** is the preferred method because there are less sources of error, and the network analyzer gives actual results: For a given measurement, the network analyzer shows the resonance frequency for the tag antenna. See Network analyzer on page 8.

The method **Varying the frequency** uses an oscilloscope to measure the maximum voltage swing. This method has more sources of errors and gives relative results. The maximum voltage swing among the results is what is of interest, one measurement only will not give much value. See Varying the frequency on page 9.

For the final results, it will not matter which method was used as long as the NFC tag antenna resonates at 13.56 MHz after tuning.

4.1 Network analyzer

The network analyzer (S11, dB magnitude) measures the return loss in the coil antenna over a frequency span to find the optimal value of the parallel capacitors.

The frequency that results in a dip is the resonance frequency of the NFC tag antenna. When using this method, the nRF52832 chip does not need to be powered. However, if the nRF52832 SoC is powered, R_{IN} has to be set to a fixed value. See Configuring the chip on page 11 for more details.

The required equipment for this method is:

- Network analyzer with minimum one port. The frequency range needs to cover 13.56 MHz.
- Coil antenna, for example, a metal wire in a coil.
- NFC tag antenna connected to the board with the nRF52832 SoC.

Complete the following steps to tune the antenna with the network analyzer method:

1. Connect the coil antenna to a network analyzer and the NFC tag antenna to the nRF52832 device.

   The network analyzer should power the coil antenna slightly, with for example -10 dBm.

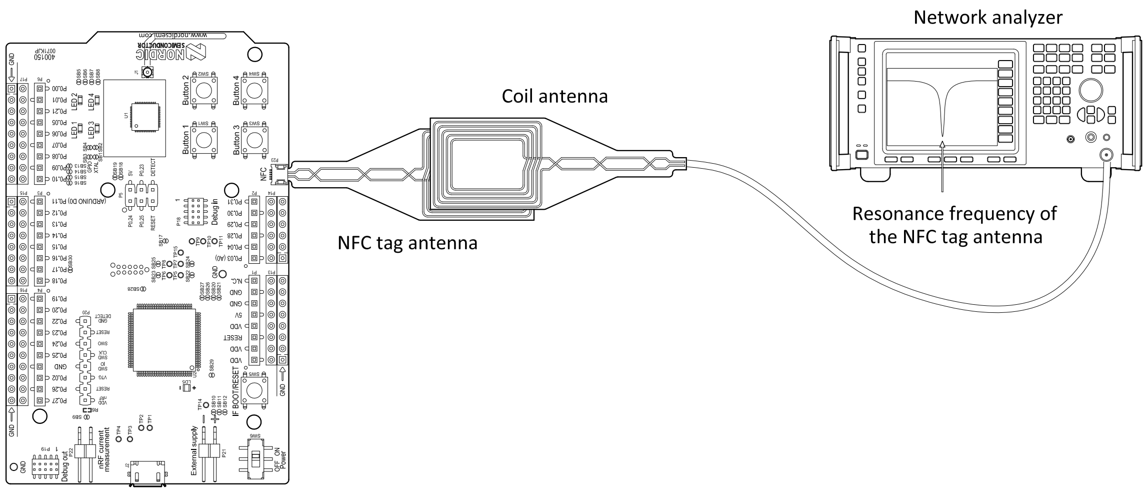

Figure 4: Setup for the network analyzer method

2. The distance between the NFC tag antenna and the coil antenna should be within the following limits:

- Lower limit: A too short distance between the two antennas will pull the resonance frequency down. The distance should therefore not be shorter than approximately 1 cm.
- Upper limit: The longer the distance between the antennas is, the weaker the loss dip in the network analyzer will be. To measure the resonance frequency, the loss dip must be visible.

3. Measure the return loss in the coil antenna over a frequency span, for example 10–15 MHz. The resonance frequency of the NFC tag antenna is the frequency that results in a dip. Change the value of C_{tune1} and C_{tune2} to make it resonate on 13.56 MHz:

- If the resonant frequency is lower than 13.56 MHz, the value of C_{tune1} and C_{tune2} should be decreased.
- If the resonant frequency is higher than 13.56 MHz, the value of C_{tune1} and C_{tune2} should be increased.

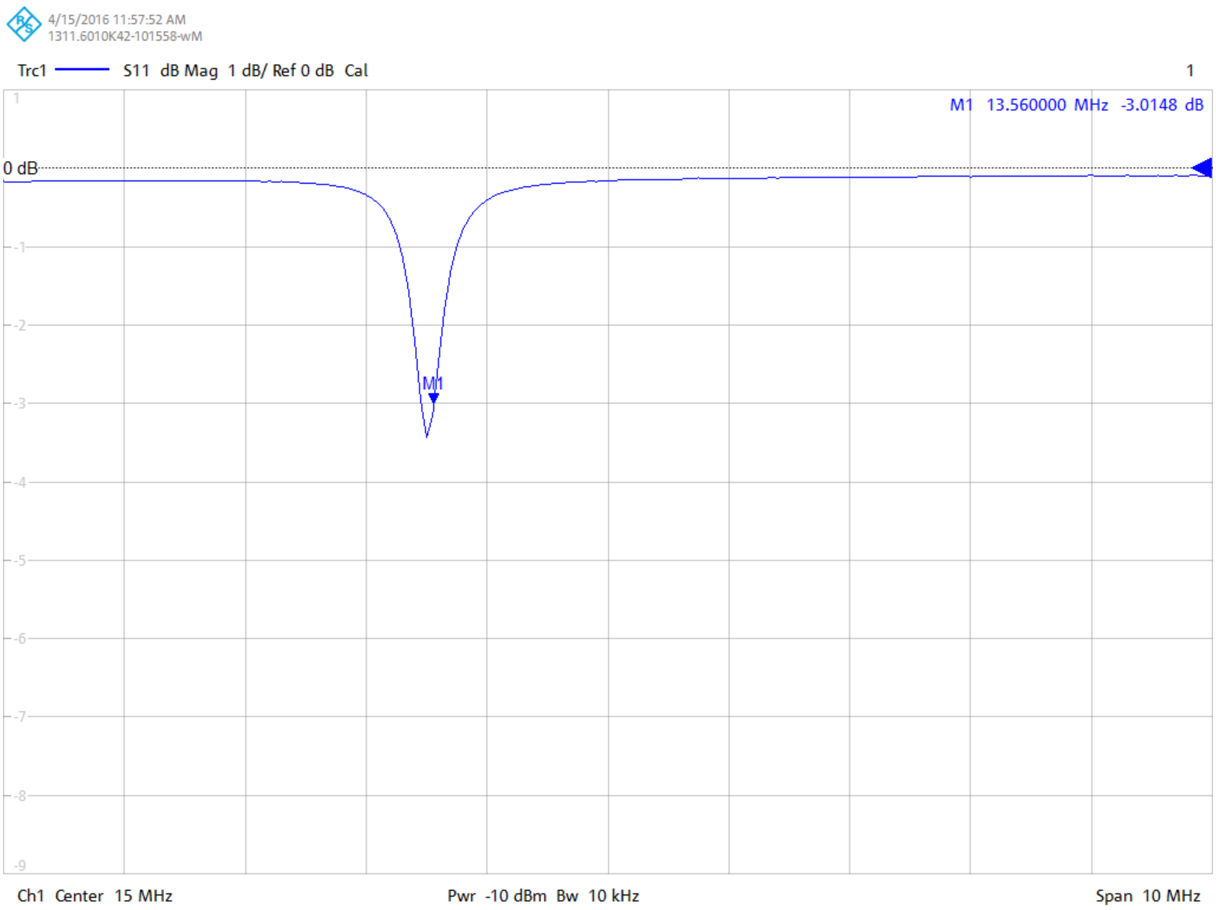

Figure 5: Example reading from network analyzer

Important: The dip at approximately 13.56 MHz shows that the resonance frequency of the NFC tag is almost at 13.56 MHz.

4.2 Varying the frequency

Measure the voltage swing of a set of capacitors and find out which one is closest to a resonance frequency of 13.56 MHz.

For a given value of C_{tune1}, C_{tune2}, and R_{IN_OHM}, vary the frequency of the poller antenna using a signal generator (13-14 MHz) and measure the maximum voltage swing between the pins NFC1 and NFC2 using an oscilloscope in differential mode. Measure the voltage swing of a set of C_{tune} values. The value of C_{tune1}

and C_{tune2} that results in the highest voltage swing at 13.56 MHz, will be best value among the tested ones for that antenna. The value of C_{tune1} and C_{tune2} with the highest voltage swing will be the value that results in an LC circuit with resonance frequency closest to 13.56 MHz, among the tested values.

The required equipment for this method is:

- Signal generator that can generate signals up to at least 14 MHz.
- NFC antenna with resonant frequency of 13.56 MHz (the poller antenna in Figure 6: Setup for the method of varying the frequency on page 10).
- Oscilloscope
- Active probes

  Active probes are required to minimize the capacitance between the NFC antenna and the oscilloscope. The reason that active probes are required is that they have much less capacitance than passive probes.

Complete the following steps to tune the antenna with the method of varying the frequency:

1. Calculate an approximate value for C_{tune1} and C_{tune2}, like described in Estimating values on page 7.
2. Create a good setup for the poller and tag antennas that will make the distance and relative placement between the antennas constant for all measurements. Any change in distance and placement will lead to inaccurate measurements.

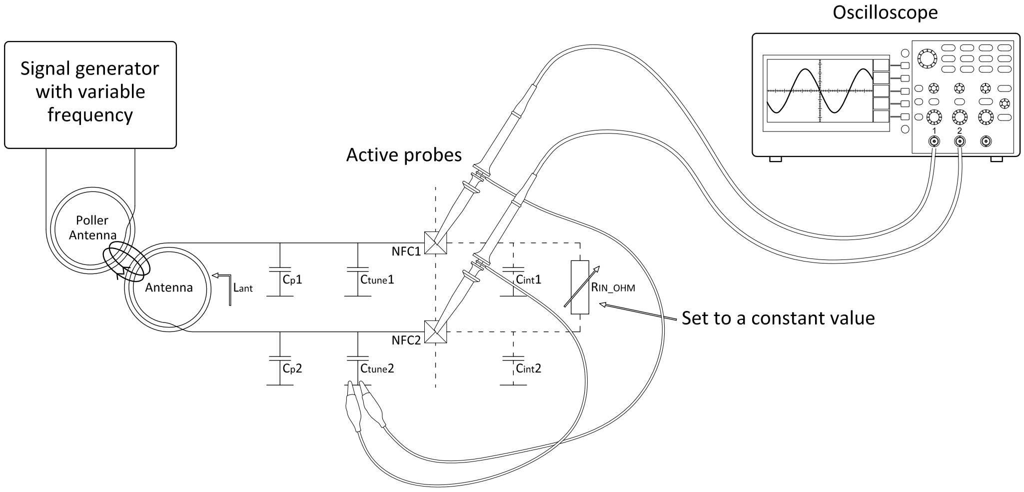

Figure 6: Setup for the method of varying the frequency

> **Important:** In order to obtain accurate and useful results, the distance and relative placement between the poller antenna and NFC tag antenna must be exactly the same for all measurements. A slight change of distance or relative placement may change the maximum voltage swing considerably, and hence change the validity and accuracy of the results. In order to avoid overflow, the maximum voltage swing should be maximum 80% of VDD.

3. Set the internal resistor R_{IN_OHM} in nRF52832 SoC to a fixed value using `nrfjprog` to change $R_{IN\_REGVALUE}$.

   See Configuring the chip on page 11 to set $R_{IN\_REGVALUE}$ to a fixed value.
4. Measure the maximum voltage swing in the frequency region 13–14 MHz for a set of C_{tune} values. Ensure that the voltage never exceeds VDD as it will affect the results. If the VDD is exceeded, do one of the following actions to reduce the voltage swing:

   - Increase the distance between the two antennas.
   - Increase the value of $R_{IN\_REGVALUE}$.
   - Reduce the power of the signal generator connected to the poller antenna.

5. Choose the value of C_{tune1} and C_{tune2} that results in the largest voltage swing at a signal frequency of 13.56 MHz.

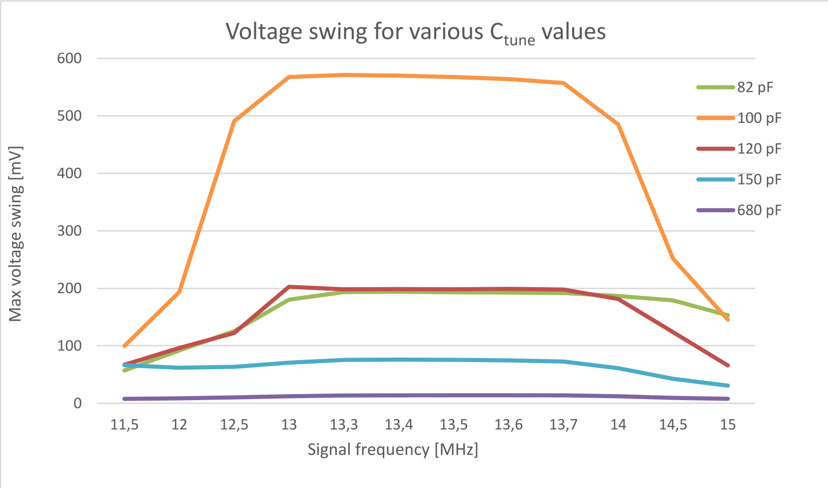

Figure 7: Maximum voltage swing for various C_{tune} values

4.2.1 Configuring the chip

To tune the NFC antenna with the method Varying the frequency, the NFC module in the nRF52832 SoC must be enabled, and the internal variable resistor R_{IN_OHM} must be set to a fixed value using the register value $R_{IN\_REGVALUE}$.

It consists of running the following commands:

`Nfc_settings.bat` for nRF52832:

```
nrfjprog -f NRF52 --memwr 0x40005668 --val 15
nrfjprog -f NRF52 --memwr 0x40005650 --val 4
nrfjprog -f NRF52 --memwr 0x40005000 --val 1
```

`Nfc_settings.bat` for nRF52840:

```
nrfjprog -f NRF52 --memwr 0x4000568C --val 0x38D48
nrfjprog -f NRF52 --memwr 0x40005000 --val 1
```

When the tuning is finished, $R_{IN\_REGVALUE}$ has to be set to automatic again by disabling the overriding of $R_{IN\_REGVALUE}$. This can be done by power-cycling the device or by setting the override registers to "0".

To set the override register to "0", enter the following commands in command prompt:

```
nrfjprog –f NRF52 –memwr 0x40005668 --val 0
nrfjprog –f NRF52 –memwr 0x40005650 --val 0
```

The purpose of $R_{IN\_REGVALUE}$ is to maximize the voltage between the pins NFC1 and NFC2, while not exceeding VDD. For a fixed swing, a large value of $R_{IN\_REGVALUE}$ means high current in the LC-circuit and into the pins NFC1 and NFC2, and a small value of $R_{IN\_REGVALUE}$ means low current.

When the NFC module is enabled, a DC voltage can be measured between the NFC1/NFC2 pins and ground. Table 1: NFC module enabled/disabled voltage on page 12 shows the voltage between NFC1/NFC2 and ground when the NFC module is enabled and disabled:

NFC module	Voltage
Enabled (TASKS_ACTIVE)	Approximately 0.45 * VDD
Disabled (TASKS_DISABLE)	Approximately 0 V

Table 1: NFC module enabled/disabled voltage

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