PTX2xxR Antenna Matching Guidelines

Introduction

This document explains how to configure the PTX2xxR for different output driver operating modes, modify the hardware, and tune the antenna matching circuitry.

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1. Overview

This document explains how to configure the PTX2xxR for different output driver operating modes, modify the hardware, and tune the antenna matching circuitry. The document is not intended to be exhaustive but will provide references for further information.

1.1 Abbreviations and Terminology

NFC	Near Field Communication
EVK	Evaluation Kit; a set of hardware and software
Die	A die, in the context of integrated circuits, is a small block of semiconducting material on which a given functional circuit is fabricated
CF	Central Frequency; nominal CF for NFC application is 13.56 MHz
LP	Low Pass
Tx	Transmitter
Rx	Receiver
VNA	Vector Network Analyzer

2. Architecture

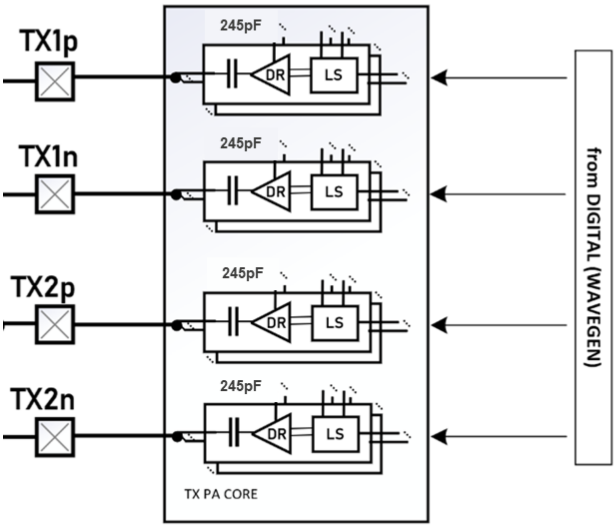


Figure 1. Block Diagram of PTX2xxR Output Stage

The PTX transmitter directly outputs a sine wave, eliminating the need for most matching components. This enables very fine regulation of the output power and allows superior control of the wave shaping for optimization of the modulation envelope.

The transmitter is split into two parts that are connected on the PCB for the default high power use case. Each transmitter has an embedded serial capacitor *CS_INT* with a value of 245 pF giving a total of 490 pF of capacitance in this configuration.

The receiver can handle a peak-to-peak voltage of up to 75 V differential and can be connected to the TX pins using a capacitive divider in the event the voltage exceeds the limit.

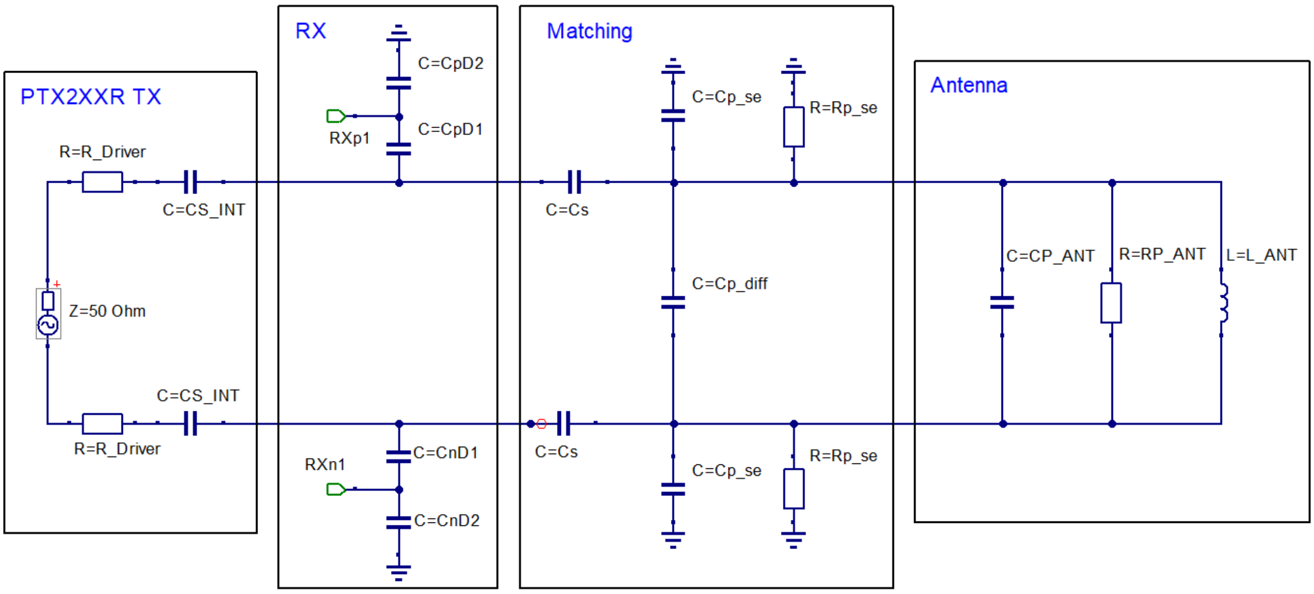


Figure 2. PTX2xxR using Differential Antenna Matching Topology

3. Antenna Matching Network

A well-designed and well-tuned antenna ensures optimum operating distance and optimum power transfer from the PTX2xxR antenna driver output pins. For a 13.56 MHz reader device, a matching network adjusts the antenna impedance to a desired value for the PTX2xxR driver output. This is needed for optimum power transfer and to meet specific requirements. Contrary to most HF devices, the target matching impedance for the PTX2xxR is not 50 Ω but rather between 5 Ω and 8 Ω.

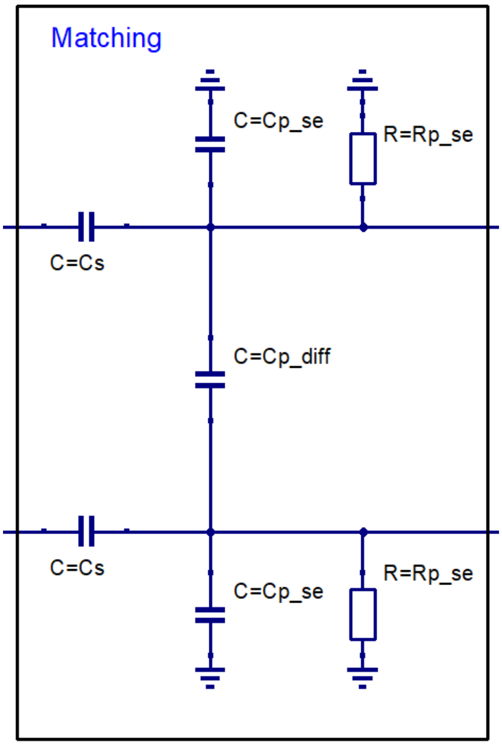


Figure 3. Differential Antenna Matching

The matching network that needs to be configured is composed of an external series capacitor, parallel capacitors, and a parallel resistor for system Q-factor adjustment.

A simulation tool can be used to determine the matching components. Note that this is an example. Any simulation tool can be used to simulate the matching with the antenna.

The matching component estimation starts with data coming from the antenna measurements in its final housing/position. This is important as nearby conductive objects like screws; shields and the PCB itself will have a significant impact on the antenna parameters.

Knowing the inductance (*L_ANT*) and resistance (*Rp_ANT*) of the antenna *Cs*, *Cp_se*, *Cp_diff* and *Rp_se* can be determined.

The higher the value of *Cs*, the higher the voltage of the antenna. The antenna voltage should not exceed 75 Vpp. Additionally, the differential voltage of the PTX2xxR transceiver pins (*Tx_p*, *Tx_n*) should not exceed 12V RMS with respect to ground, representing 75 Vpp differential.

4. Antenna Modeling

A well-designed antenna is the base for good performance. Factors like antenna area, number of tracks, track gap, and width determine the electrical parameters of the antenna: inductance, series and parallel resistance, self-resonance frequency, and Q-factor.

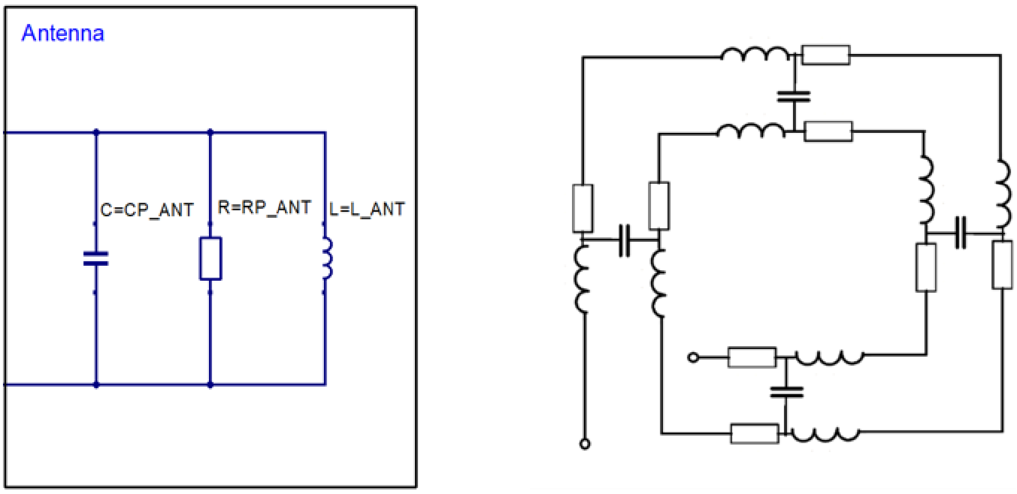


Figure 4. NFC Antenna Discrete Element Representation

The antenna of the HF reader is a magnetic loop antenna. The loop antenna is a distributed component with inductance (*L*) as the main element, capacitance (*C*) and resistance (*R*) as parasitic network elements. For simulation, it must be represented by an equivalent circuit network of lumped elements.

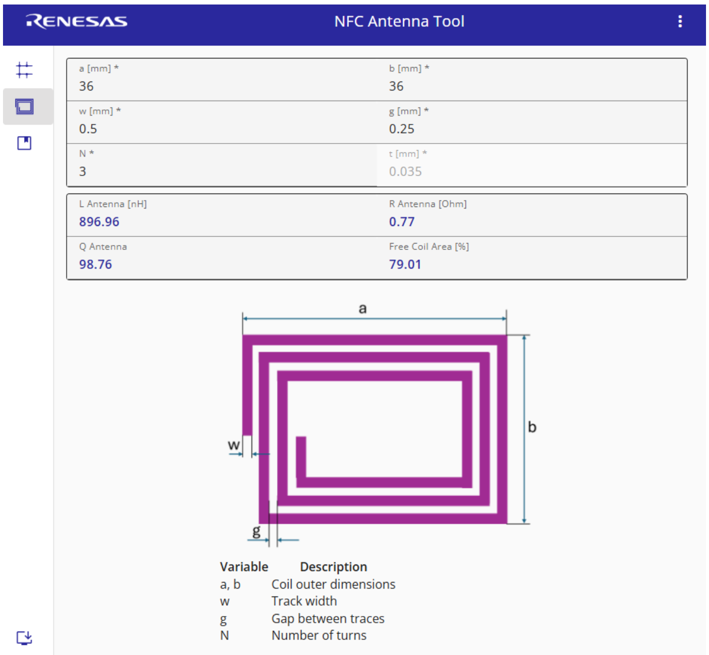
The antenna parameters to be considered in the electrical RF characterization are:

- Area of the antenna
- Number of tracks
- Tracks length
- Tracks width
- Gap between tracks
- Material properties

Based on these parameters, it is possible to characterize the antenna and extrapolate the electrical characteristics with calculations or simulations. This approach is valid in the case where the antenna is in free-air and is not influenced by the environment.

5. NFC Antenna Tool – Coil Calculation

NFC antenna coil calculation supports the process of designing and determining the electrical parameters (like inductance, number of turns, and dimensions) of the loop antenna (coil) used in Near Field Communication (NFC) systems.



a [mm] * 36	b [mm] * 36
w [mm] * 0.5	g [mm] * 0.25
N * 3	t [mm] * 0.035

L Antenna [nH] 896.96	R Antenna [Ohm] 0.77
Q Antenna 98.76	Free Coil Area [%] 79.01

Variable	Description
a, b	Coil outer dimensions
w	Track width
g	Gap between traces
N	Number of turns

Figure 5. NFC Antenna Tool – Coil Calculation

Based on the available area for the antenna, trace width, gap, and number of turns, the inductance and the resistance of the coil is calculated.

A general recommendation for **IoT** applications is **900 nH ±10%**, and for **behind display** applications it should be **600 nH ±10%**. For other applications, please contact your local Renesas representative to assist in choosing the most appropriate value.

To achieve the desired inductance the track width *w*, the gap *g* and the number of turns *N* must be adjusted.

- By increasing *w* the inductance decreases
- By increasing *g* the inductance decreases
- By increasing *N* the inductance increases

This approach is only valid in free-air applications (conductive free surrounding). The minimum distance between the antenna and conductive materials should be larger than 10 mm. Avoid conductive closed loops around the antenna. In case of the presence of conductive materials near the coil, the use of ferrite sheets is recommended. Ferrite sheets generally increase the inductance of the coil and lower the quality factor, thus increasing losses.

6. Antenna Parameter Measurement

A more practical way is to follow an empirical approach by using a Vector Network Analyzer (VNA) to measure the antenna RF characteristics and using a circuit simulator to calculate the required matching network components.

Measurements with the VNA are to be made according to the procedure detailed below:

- Set the measurement mode of the network analyzer to S11 reflection measurement
- Use the Smith chart format ($R + jX$) to display the impedance curve
- Set the start frequency to 10 MHz and the stop frequency to 20 MHz

- Connect a short SMA cable to the RF port of the network analyzer and start the calibration using OPEN, SHORT, and a 50 Ω LOAD resistance as load
- Connect the SMA cable to the antenna to be measured with one pin soldered to the signal pin of an SMA connector, and a second pin soldered to one of its ground connections.

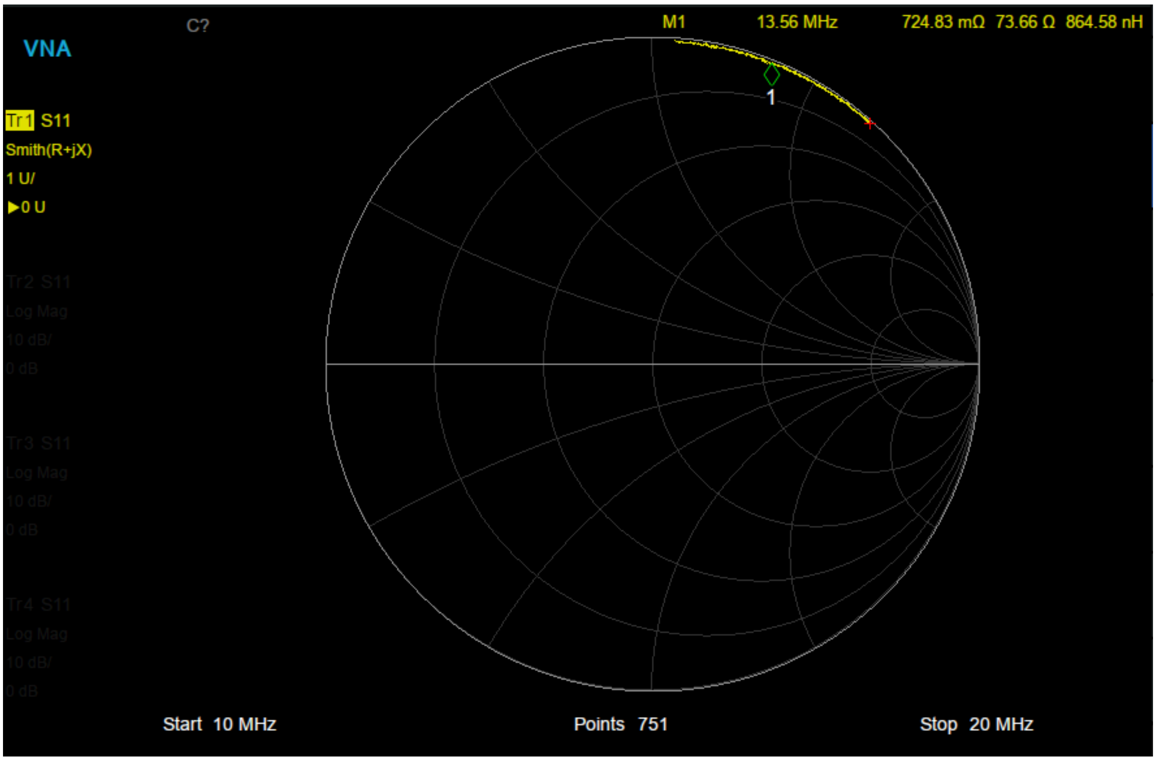


Figure 6. Smith Chart – Loop Antenna Measurement with VNA

The antenna inductance for PTX2xxR should be in the range between 300 nH to 1500 nH. A value in the range of 600 nH to 900 nH is recommended to have a good compromise for performance and tuning flexibility. It is recommended to use 2 or 3 turns, depending on the area available. The track width should be larger than 0.5 mm to reduce the parasitic resistance, and a gap between tracks as small as the PCB process allows to avoid unwanted stray flux.

7. Quality Factor

The Q-factor (quality factor) is critical in NFC design because it determines efficiency, range, and communication reliability at the 13.56 MHz carrier frequency.

The Q-factor of the NFC antenna coil represents how “sharp” its resonance is:

$$Q = \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R}$$

- **High Q**: Stronger magnetic field, higher voltage, but narrower bandwidth (harder to maintain communication if detuned).
- **Low Q**: Weaker field, more bandwidth (more tolerant to detuning and load changes).

The quality factor needs to be chosen to get a good trade-off between efficiency and robustness.

Typical coil antennas in free-air have quite a high *Q* in the range of 100, whereas antennas close to metal or behind a display will be in the range of 10–20.

The Q-factor is important in terms of power transfer, timing, and data rates. Specific standard testing like EMVCo systems, are limited to 106kbit/s. An excessively high Q-factor can lead to timing and overshoot errors when running analog tests.

A lower system Q-factor can help simplify the waveshape testing and receiver LMA testing due to less detuning on the PICC's antenna.

If the Q-factor of the antenna is higher than this (which is likely the case with no surrounding damping elements), an external resistor in parallel to the antenna allows for downward adjustment.

For IoT applications, the target Q-factor is dependent on the data rate.

For low data rates, a higher Q-factor (above 25) can be accepted.

8. Defining Target Impedance

The target matching of the impedance is the most important criterion to determine the PTX2xxR output power. When designing the matching circuitry and defining the target matching impedance with higher target matching impedance, less power will be transferred forward to the antenna, and therefore the power consumption of the whole reader unit will be reduced.

For example, an antenna’s RF performance underneath a display will be affected due to the losses generated by the materials which compose the display itself. A larger antenna or more power is then required to fulfill the voltage over volume of the EMVCo standard.

In general, the graph below shows the relation between power and matching impedance.

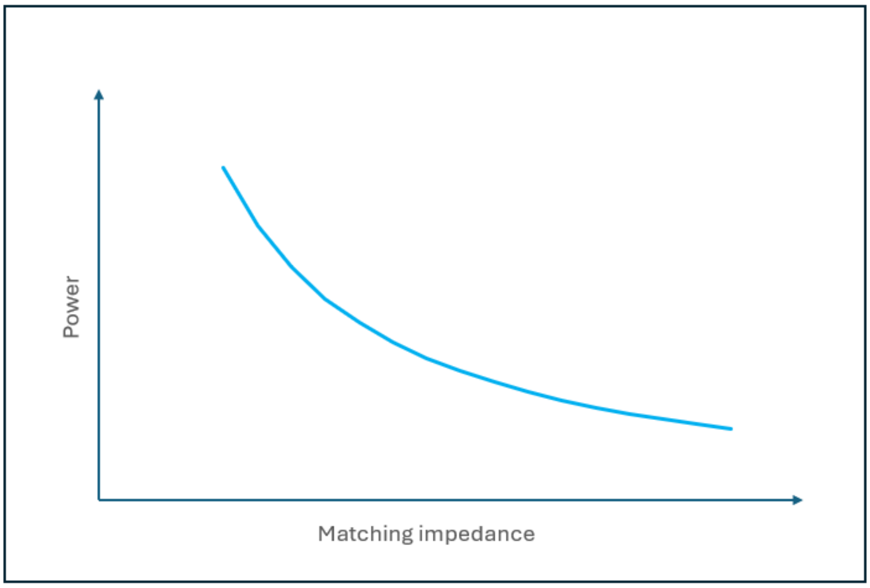


Figure 7. Behavior of the Output Power vs Matching Impedance

The relation between power, voltage, and impedance in the formula:

$$P_{RMS} = \frac{V^2}{2Z}$$

A good starting point for the target matching impedance is 6.5 Ω with 5 V supply voltage.

When the antenna is nearby conductive material (metal frame, display, etc.), a low target impedance can be difficult to achieve. Reducing the number of windings in the antenna could help in achieving a lower matching impedance.

9. Antenna Matching Topologies and Driver Configurations

The PTX2xxR output stage can be configured to operate in different conditions. Antenna matching is performed to tune and transform the antenna's resistive value to the input impedance of the IC for maximizing the RF performance.

Matching topologies can be divided into two categories based on the antenna coil configuration: differential mode and single-ended mode.

9.1 Differential Mode

The differential mode is the primary choice for the PTX2xxR. The RF power delivered by the driver in this configuration optimizes the reader-to-card communication distance by providing twice the signal swing for a given supply voltage and offering superior immunity to noise. The PTX2xxR drivers are set to deliver a signal in anti-phase and to obtain a large voltage swing on the antenna coil.

The advantage of this architecture is to achieve high performance by increasing the voltage and reducing the current delivered by drivers. This reduces common mode noise, avoids ground current through the antenna path and improves EMI symmetry.

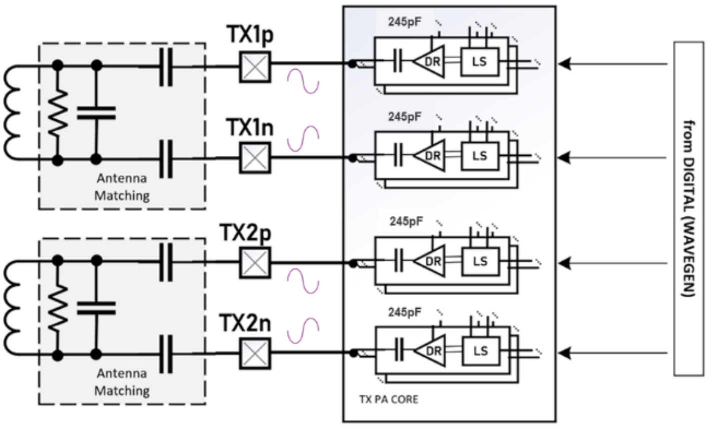


Figure 8. Dual Antenna Differential Mode

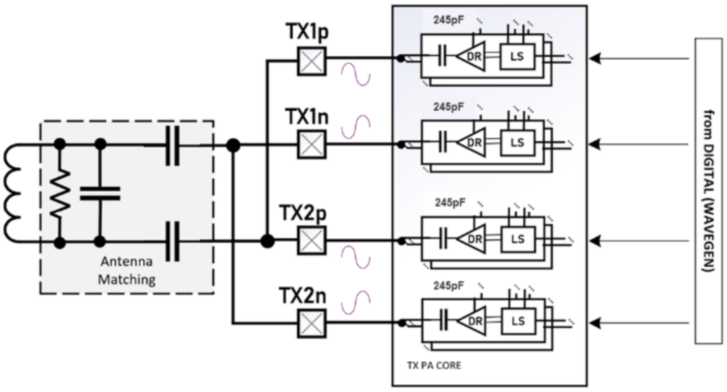


Figure 9. High Power Differential Mode

PTX2xxR can drive a maximum of two antenna coils in differential configuration. By connecting the TXp and TXn drivers in parallel it is possible to achieve the highest performance on a single coil.

When connecting the TX pins in parallel the resulting internal capacitance of the drivers is doubled (490 pF) and the matching network needs to be calculated accordingly. In the dual antenna configuration, the internal capacitance to be used in the calculation is 245 pF.

The RX signal is connected to the TX pins via voltage divider and shared in the case of dual antenna configuration.

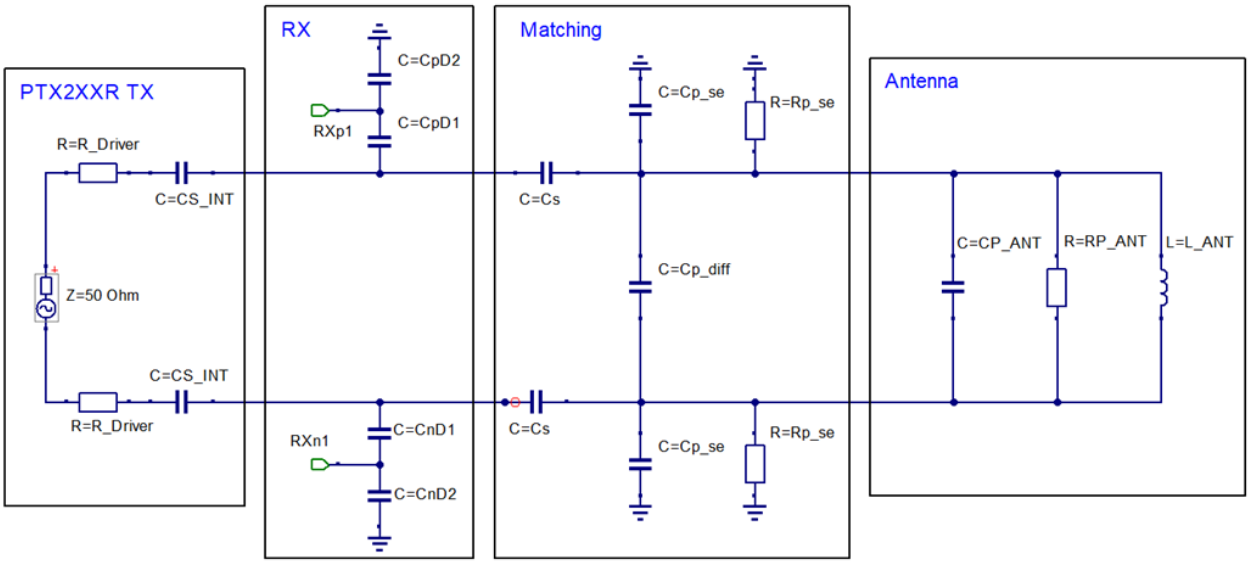


Figure 10. PTX2xxR using Differential Antenna Matching Topology

9.2 Single-Ended Mode

In the single-ended mode, the NFC antenna has one end connected to the NFC IC output and the other end connected to ground (or a reference point).

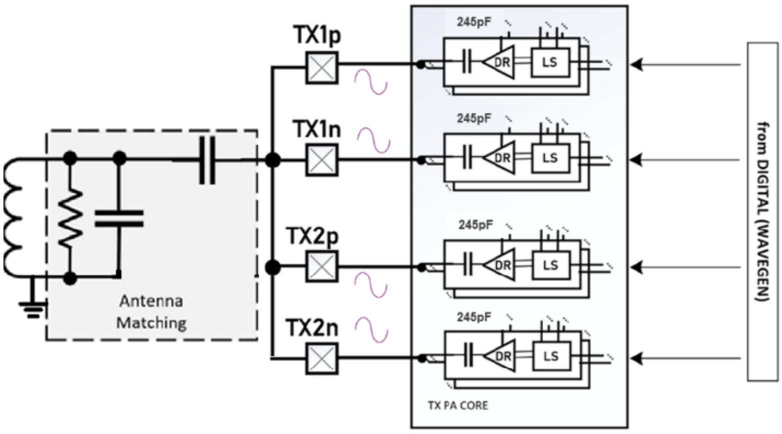


Figure 11. High Power Single-Ended Mode

This differs from a differential antenna, where both ends are driven actively and no part of the loop connects to ground. The drivers are set to deliver a signal that is in-phase with all the others, resulting in a maximum voltage equal to the supply voltage.

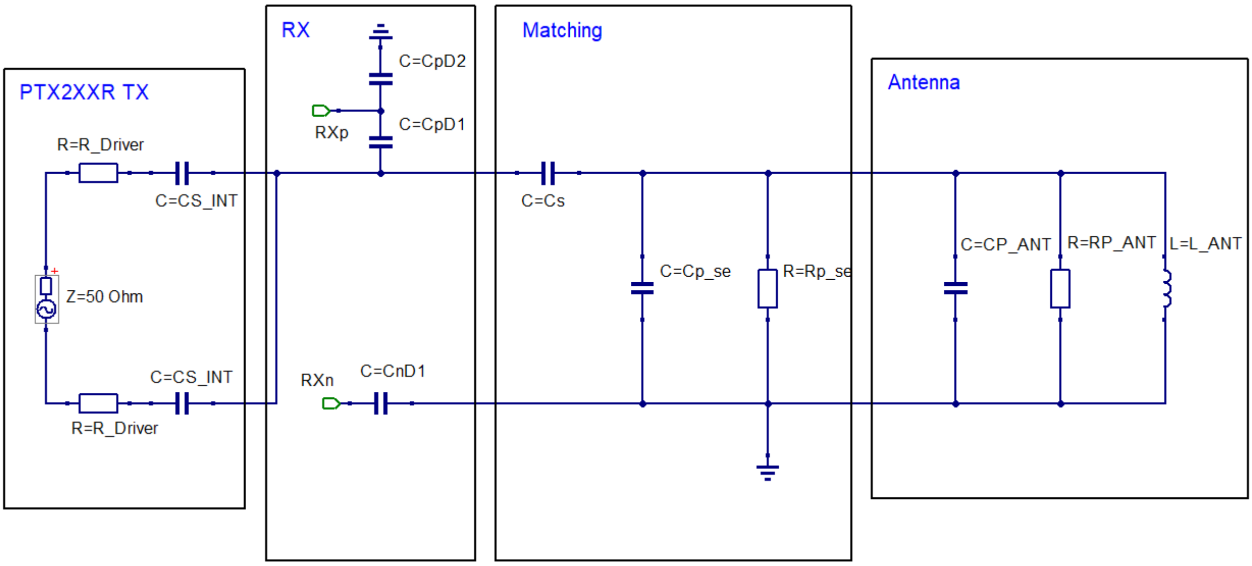


Figure 12. PTX2xxR Matching Network for High Power Single-Ended Mode

The single-ended configuration antenna coil is still inductive and must resonate at 13.56 MHz (so the magnetic field is strongest) and must be matched to the IC’s output impedance (so maximum current/power transfer occurs).

The single-ended configuration is typically used when the antenna coil is positioned far away from the PTX2xxR and a coax cable or twisted-paired cable connects the antenna.

Using this configuration, multiple antennas can be driven and based on the power requirements and the TX pins need to be connected in a dedicated way together with a specific driver configuration.

The maximum power can be achieved by connecting all four TX pins together, and the resulting internal driver capacitance is the sum of all the single ones (980pF). The matching network needs to be designed accordingly and one of the RX pins is to be connected to GND through a capacitor.

9.3 Single-Ended Mode with Balun

A single-ended antenna can be driven with the IC drivers in differential mode using a Balun. The balun is an element used to switch between a balanced circuit in unbalanced circuit. Baluns used in NFC circuits have a turn ratio of 1:1 and keep insertion loss low in the 13.56 MHz band.

Compared to the pure single-ended solution, the driver voltage doubles due to the driver acting in opposite phase, resulting in a larger voltage swing on the antenna.

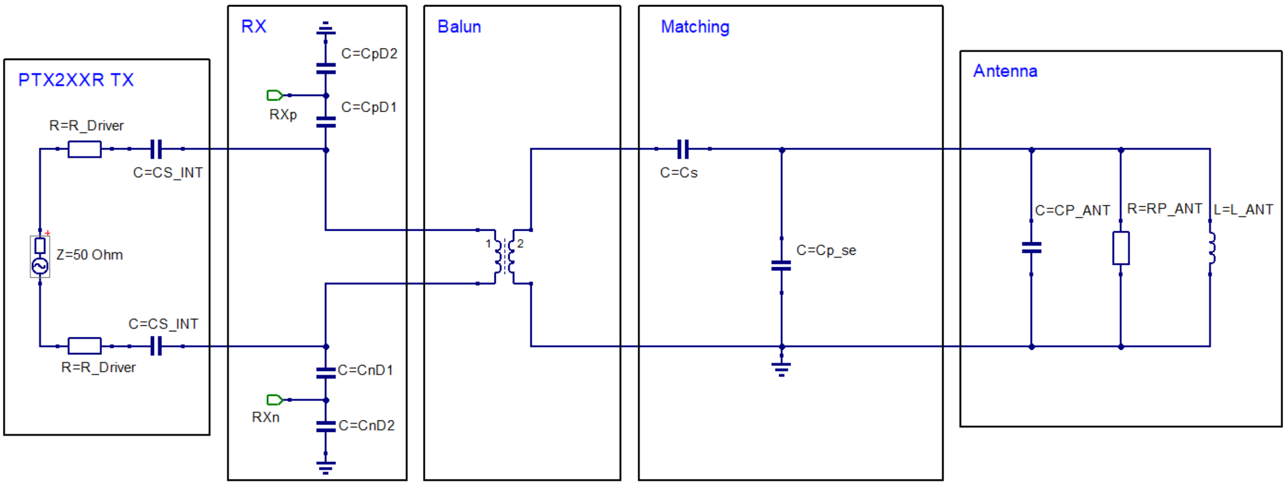


Figure 13. PTX2xxR Single-Ended Antenna with Balun

The transmitter and receiver configuration is identical to the differential case.

9.4 Using a Low Pass Filter

While the matching network defines the target impedance and handles intentional RF resonance, the system can still radiate or conduct unintended noise, both from and into the NFC transceiver.

An EMI filter (often an LC network) is added for electromagnetic compatibility (EMC) reasons:

1. **To suppress conducted noise on power and I/O line**s.

   The NFC chip's switching currents (especially the H-field driver) generate harmonics and broadband noise. This noise can be coupled into VDD, GND, or other signal lines, radiating via cables or the PCB.

   EMI filters block this conducted noise, helping meet EMC standards (like CISPR 22/32).

2. **To prevent external RF noise from detuning or interfering**.

   External EMI sources (for example, cellular, Wi-Fi, DC/DC converters) can be coupled into the antenna lines. Without filtering, this interference could shift your matching point or corrupt communication.

   EMI filters help to protect the sensitive NFC front end from out-of-band noise.

3. **To reduce harmonic emissions**.

   The PTX2xxR output stage generates a signal at 13.56 MHz, but the transceiver and matching network can generate high order harmonics. These harmonics can exceed EMC limits or interfere with nearby radios.

   EMI filters (low-pass filters) attenuate those harmonics while leaving 13.56 MHz intact.

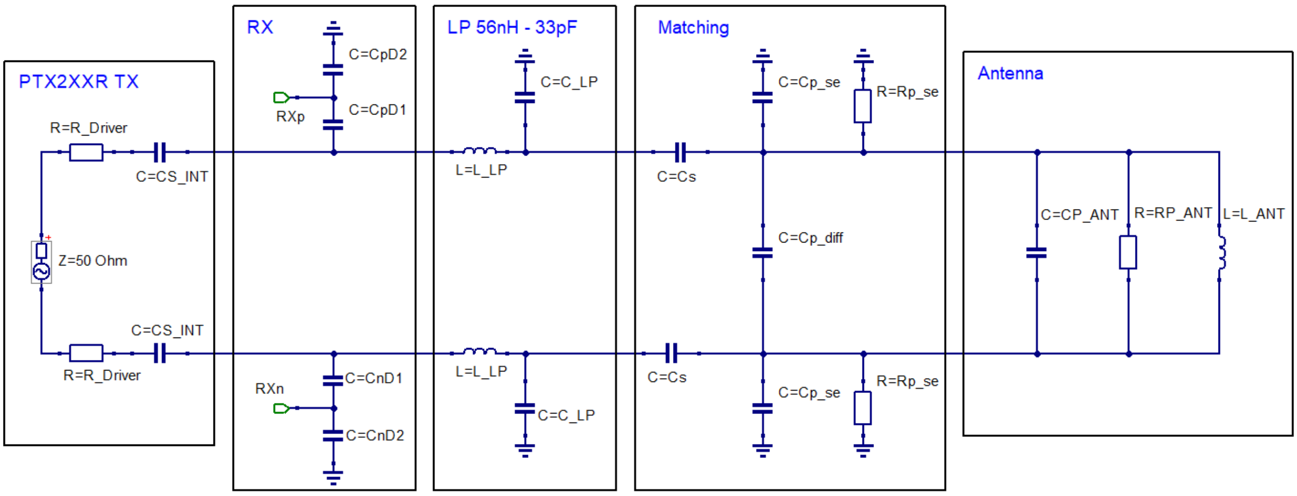
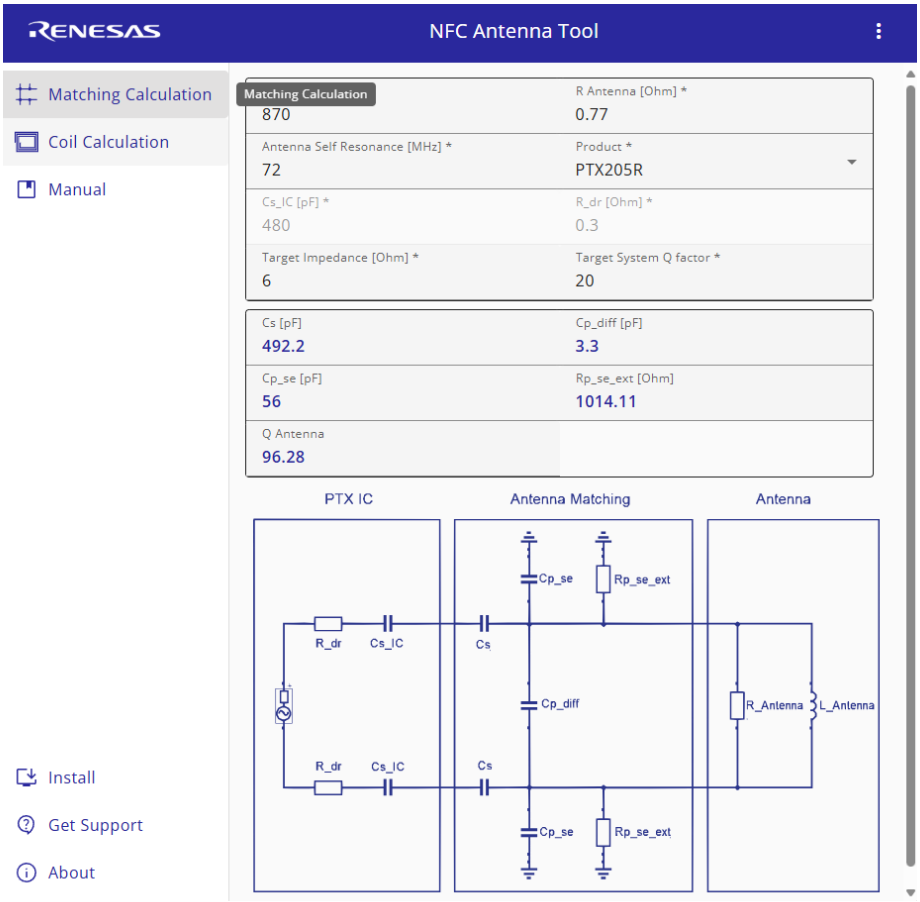


Figure 14. LP Filter on Differential Matching

In applications where lengthy wiring is necessary to power or communicate with the NFC system, a low pass filter with a cut-off frequency around 100 MHz is generally sufficient to get rid of high-frequency spurious emissions. A recommended value for the inductors and the capacitors forming the LP filter is provided in the example, *L_LP = 56 nH* and *C_LP = 33 pF*. The inductors need to be selected to guarantee low losses and the rated current in-line with the expected performance requirements.

10. NFC Antenna Tool – Matching Calculation

The **Matching Calculation** function is available in the NFC Antenna Tool. It assists with designing and tuning the matching network between the antenna (coil) and the output driver stage of the PTX2xxR so that maximum power is transferred and resonance is achieved at the target frequency of 13.56 MHz.



870

R Antenna [Ohm] * 0.77

Antenna Self Resonance [MHz] * 72

Product * PTX205R

Cs_IC [pF] * 480

R_dr [Ohm] * 0.3

Target Impedance [Ohm] * 6

Target System Q factor * 20

Cs [pF] 492.2

Cp_diff [pF] 3.3

Cp_se [pF] 56

Rp_se_ext [Ohm] 1014.11

Q Antenna 96.28

Figure 15. NFC Antenna Tool – Matching Calculation

The antenna parameters are used as input for calculating the matching network components.

Target matching impedance and System Q-factor can be set based on the application. The target impedance for most of the NFC applications can be set around 6 Ohms with a Q-factor value dependent on the required maximum data rate. The matching impedance can be set to a different value based on the driver’s supply voltage.

It is possible to achieve a certain output power for a defined voltage level by modifying the target impedance.

10.1 Using Simulation Tools

A simulation model representing the PTX2xxR IC can be built using different tools, allowing easy calculation of the matching network values.

The advantage of using simulation tools is to visualize the impedance on a Smith chart and allowing the user to fine tune the system using built-in optimizers.

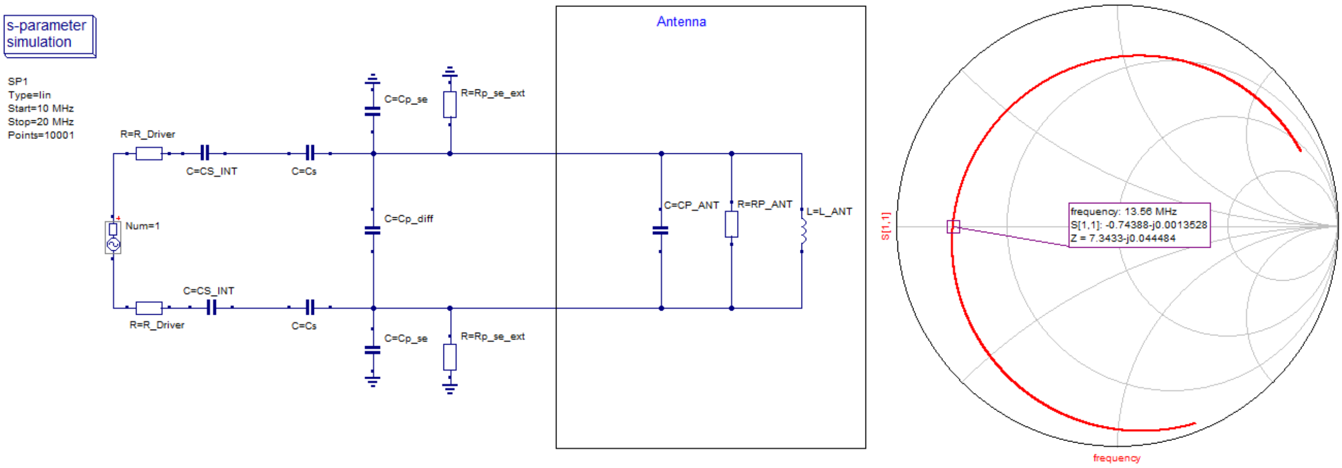
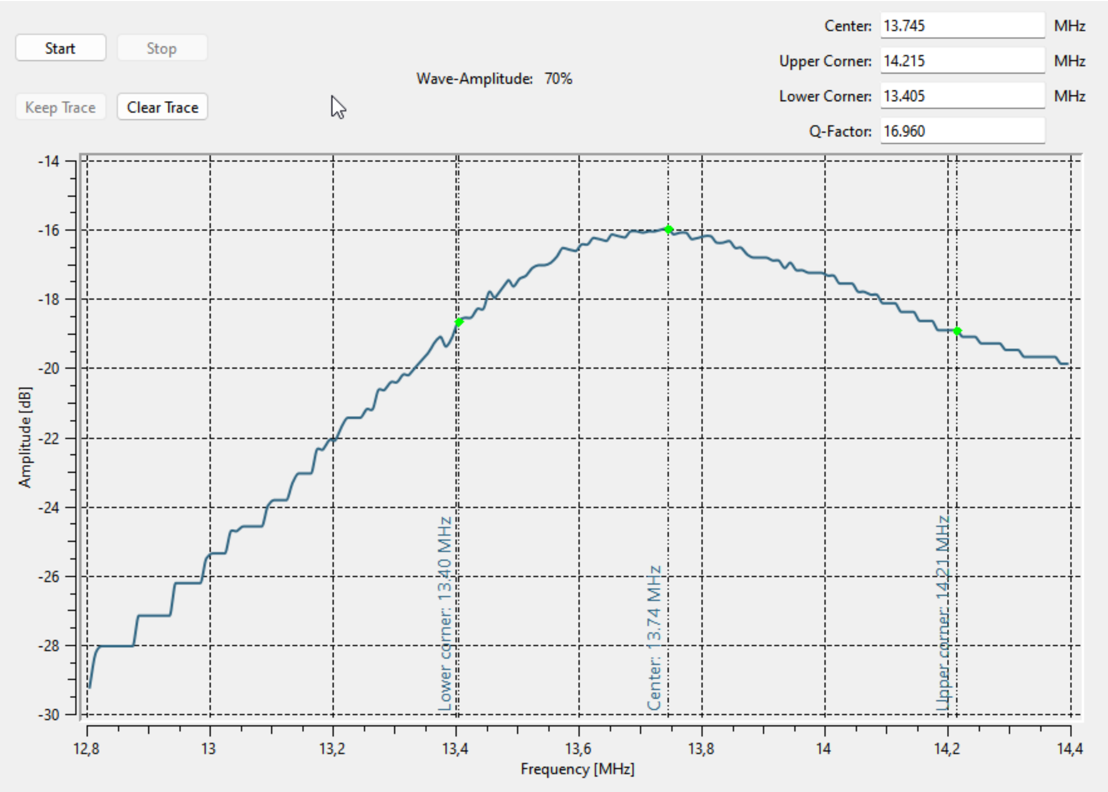


Figure 16. Matched Antenna on Smith Chart using a Simulation

The simulated values can be used to populate the matching network and a verification method can be executed via the GUI or a VNA.

11. System Matching Check

The PTX2xxR matching check can be performed using the SW tools available in the evaluation kit. The resonance frequency and the quality factor are directly displayed in the GUI.


Wave-Amplitude: 70%

Center: 13.745 MHz

Upper Corner: 14.215 MHz

Lower Corner: 13.405 MHz

Q-Factor: 16.960

Figure 17. Quality Factor Check using the GUI

If a connection to the GUI is not possible, an alternative method for checking the antenna is to use a pickup coil connected to a VNA:

- Place the board on a non-conductive surface far from conductive materials
- Place the pickup coil ~5 mm above the reader antenna

- Power the reader without starting it (supply voltage provided but no polling started)
- Double check that there is no field emitted by the reader (this can damage the VNA)
- Record the magnitude trace on the VNA
- Set a marker at the minimum of the trace to determine center frequency
- Set markers at 3 dB above minimum to determine bandwidth and thereby Q-factor
  - Keep in mind that the Q-factor calculated this way is very unreliable because it strongly depends on the pickup coil used and the positioning
  - When possible, perform the Q-factor evaluation via the GUI

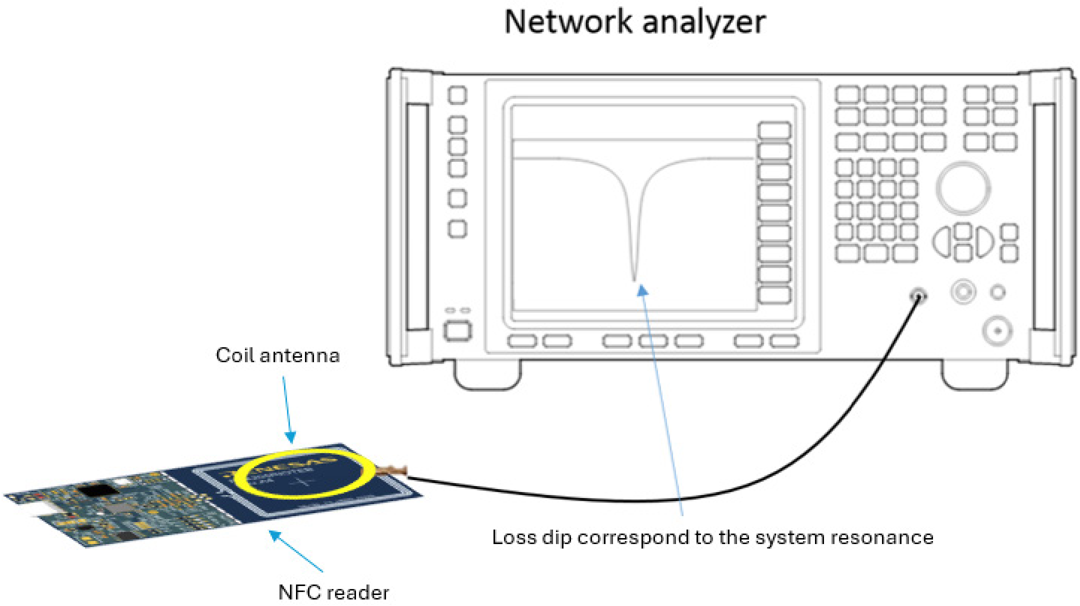
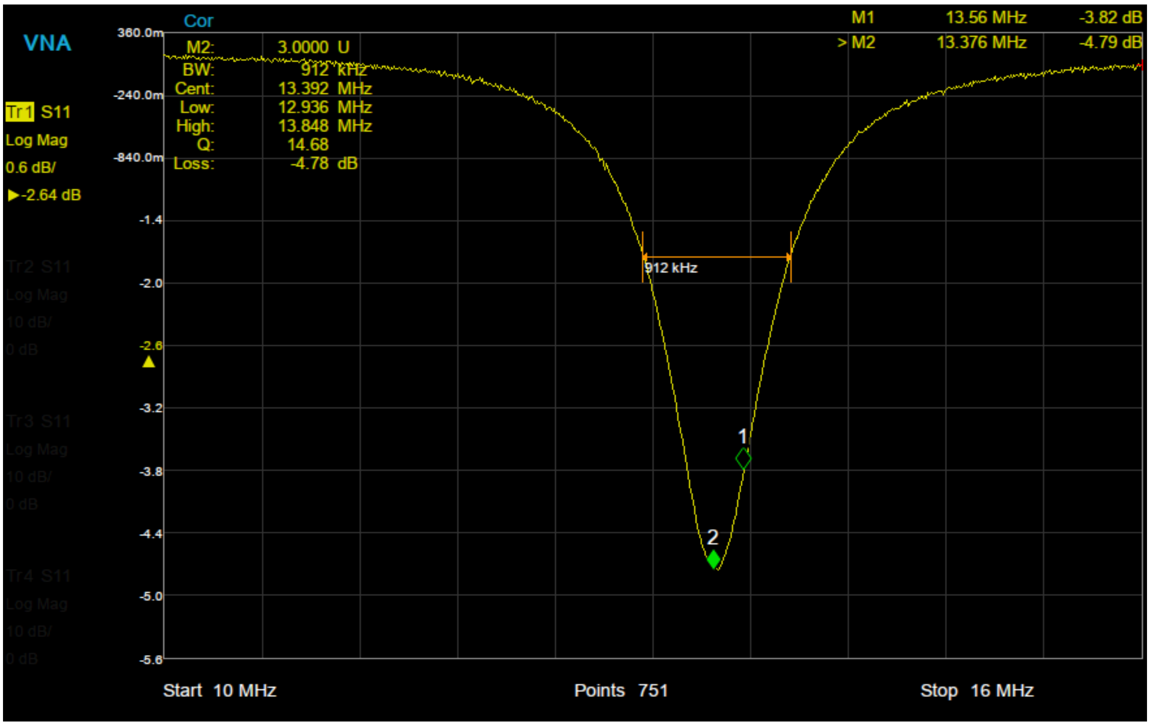


Figure 18. Antenna/Matching Measurement with VNA


Cor
M2: 3.0000 U
BW: 912 kHz
Cent: 13.392 MHz
Low: 12.936 MHz
High: 13.848 MHz
Q: 14.68
Loss: -4.78 dB

M1 13.56 MHz -3.82 dB
> M2 13.376 MHz -4.79 dB

Tr1 S11
Log Mag
0.6 dB/
▶-2.64 dB

Start 10 MHz
Points 751
Stop 16 MHz

Figure 19. Center Frequency and Q Measured with a VNA

12. Revision History

Revision	Date	Description
1.00	Nov 10, 2025	Initial release.

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