AN5248
Application note

ST25R95 transceiver antenna tuning circuit with EMI filter

Introduction

The purpose of this application note is to describe the antenna tuning circuit of the ST25R95 RF transceiver board embedding the EMI filter.

It explains how to use the STSW-ST25R003 tool by using ST25R95 EMI FILTER CALCULATION.xlsm excel worksheet. Both are available on *www.st.com*.

The different impedance matching calculation steps are presented.

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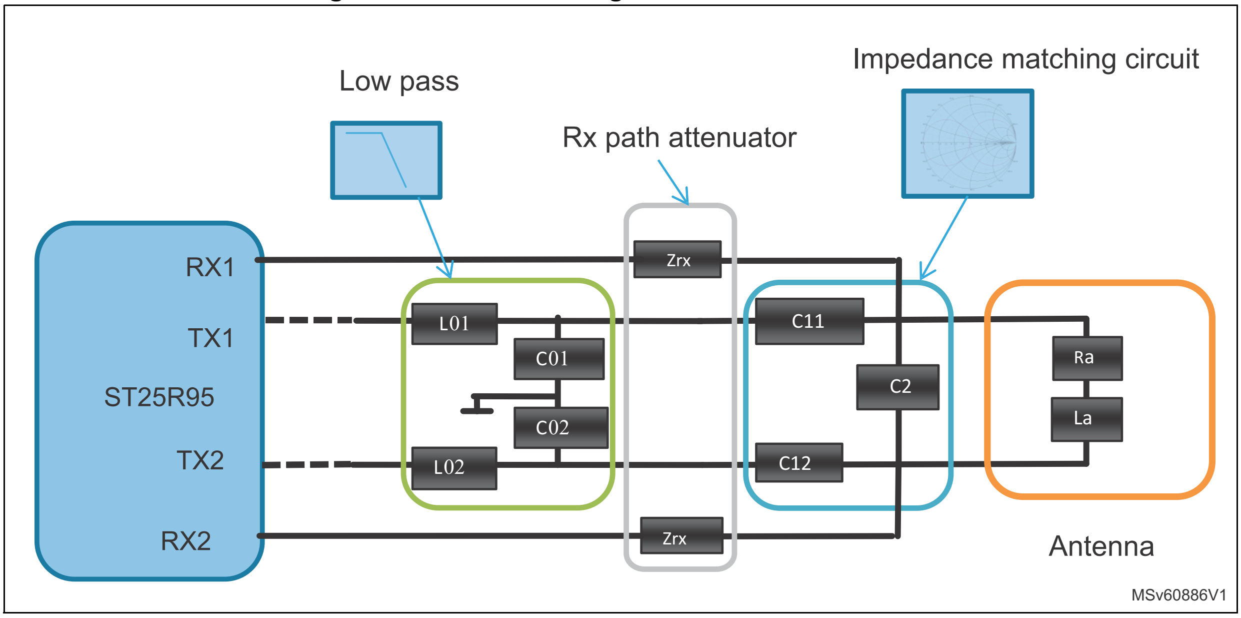
1.1 Description

To limit the spurious emission at high frequencies, the ST25R95 RF transceiver board embeds a second order low-pass filter (so called EMI filter).

The EMI filter is placed between the ST25R95 and the antenna tuning circuit, as you can see on *Figure 1*. Its goal is to attenuate the frequencies above 13.56 MHz.

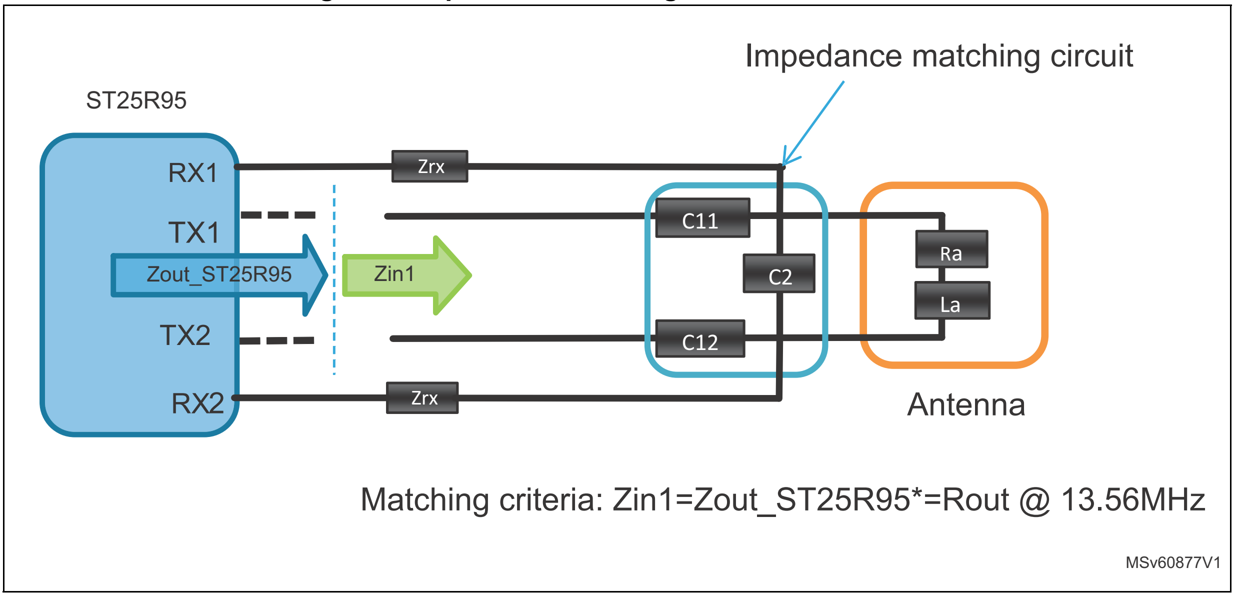
Figure 1. ST25R95 tuning circuit with an EMI filter



1.2 Designing a tuning circuit without an EMI filter

Designing a tuning circuit without an EMI filter for the ST25R95 consists in calculating the C11, C12 and C2 capacitor values, so that the input impedance (Zin1) of the circuit, seen from TX1 and TX2, matches the complex conjugate of the ST25R95 output impedance (see AN3394).

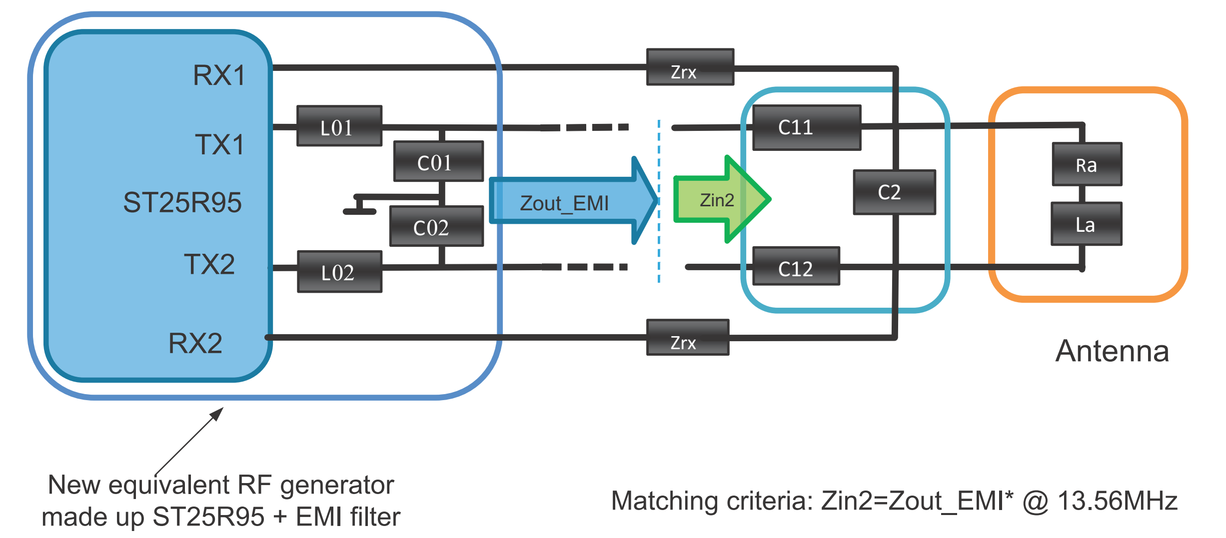
Figure 2. Impedance matching without an EMI filter



1.3 Designing a tuning circuit with an EMI filter

Designing a tuning circuit with an EMI filter for the ST25R95 follows the same procedure except that C11, C12 and C2 are calculated so that the tuning circuit input impedance (Zin2) matches the complex conjugate output impedance of the new RF generator, which is made of the ST25R95 and its EMI filter (see *Figure 3*).

Figure 3. Impedance matching with an EMI filter

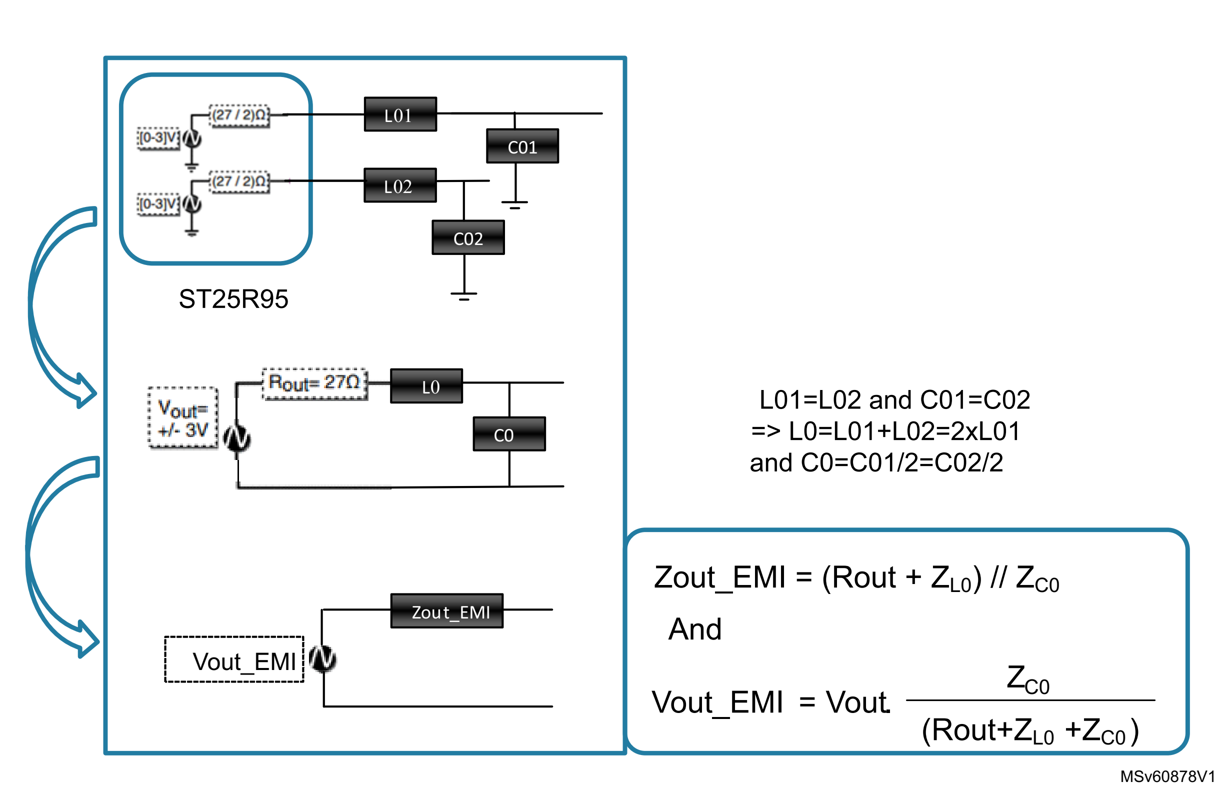


When the matching criteria is satisfied, the input impedance (Zin) of the circuit seen from TX1-TX2 also satisfies the condition Zin = Rout, and a maximum power transfer occurs between the ST25R95 and the antenna.

2 Calculation explanations

The ST25R95 + EMI filter equivalent circuit comes after some simple transformation (see *Figure 4*).

Figure 4. ST25R95 + EMI filter equivalent generator



The cut-off frequency of the EMI filter defined by $fc = \frac{1}{2\pi\sqrt{(L0 \times C0)}}$ is chosen above 14 MHz.

It is recommended to use an inductance wired on ferrite cores.

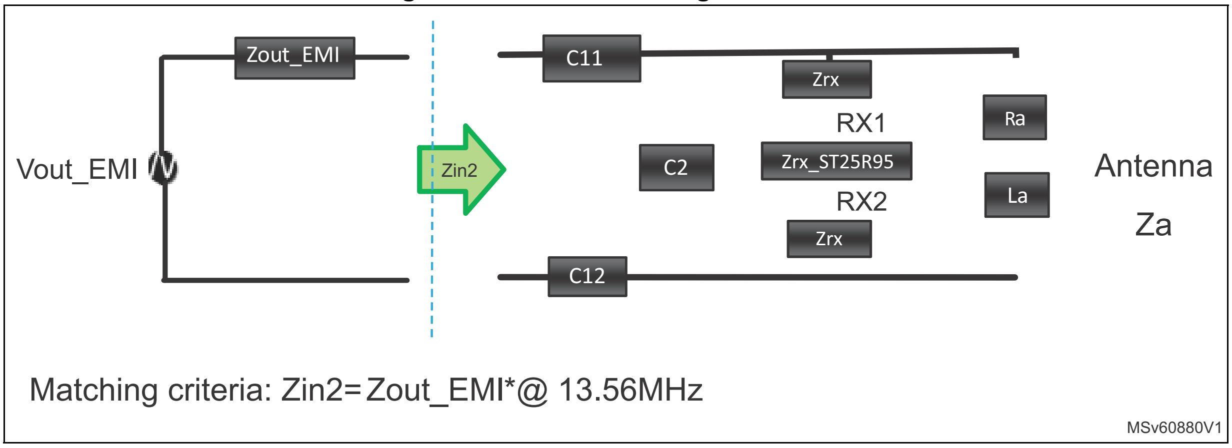
For instance typical value of 560 nH can be used. For more flexibility in value adjustment, C01 and C02 can be layout using two capacitance footprint connected in parallel: With two 100pF capacitance mounted in parallel (C01=C02=200pF), the EMI filter cut-off frequency is: :

$$fc = \frac{1}{2\pi\sqrt{(L0 \times C0)}} = \frac{1}{2\pi\sqrt{(2 \times 560nH) \times \left(\frac{200pF}{2}\right)}} = 14.6MHz$$

The ST25R95 receiving path RX1-RX2 input impedance ZRX_ST25R95 = 22pF // 80 kΩ

After replacing the RX path by its impedance, the circuit becomes as in *Figure 5*.

Figure 5. Circuit for tuning calculation



Assuming C11 = C12 = C1, the resulting equation is:

$$Zin2 = \frac{C1}{2} + (C2 \,||\, (2Zrx + Zrx_{ST25R95}) \,||\, Za)$$

Solving the Impedance matching criteria Zin2 = Zout_EMI* allows you to find the values for C11 = C12 and C2.

This calculation is done using the ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet. Connect to *www.st.com* to download this Excel calculation tool.

3 Calculation tool

The ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet includes 4 tabs:

1. Tuning circuit calculation
2. Input impedance curves
3. Circuit voltages
4. Magnetic fields vs distance
5. Smith chart

This tool allows you to:

- Calculate the ideal tuning capacitance C11, C12 and C2 based on the system components (select the 1st tab).
- Calculate the theoretical circuit input impedance according to the system parameters and custom tuning capacitance values (select the 1st tab)
  - This feature lets you use tuning capacitance values different from the ideal values, and check the impact on the input impedance.
  - In combination with the impedance curve given in the 2nd tab, this feature lets you adjust the tuning capacitance values on the Printed circuit board (PCB).
- Trace the theoretical circuit input impedance curve (magnitude and phase) versus the frequency, according to the custom tuning capacitance values defined in the 2st tab.
- Trace the voltage amplitude at different points of the circuit according to the custom tuning capacitance value (select the 3rd tab).
- Estimate the magnetic field strength generated by the reader according to the system parameters of the system (select the 4th tab).
- Draw the input impedance of the tuning circuit using the Smith chart representation (select the 5th tab).

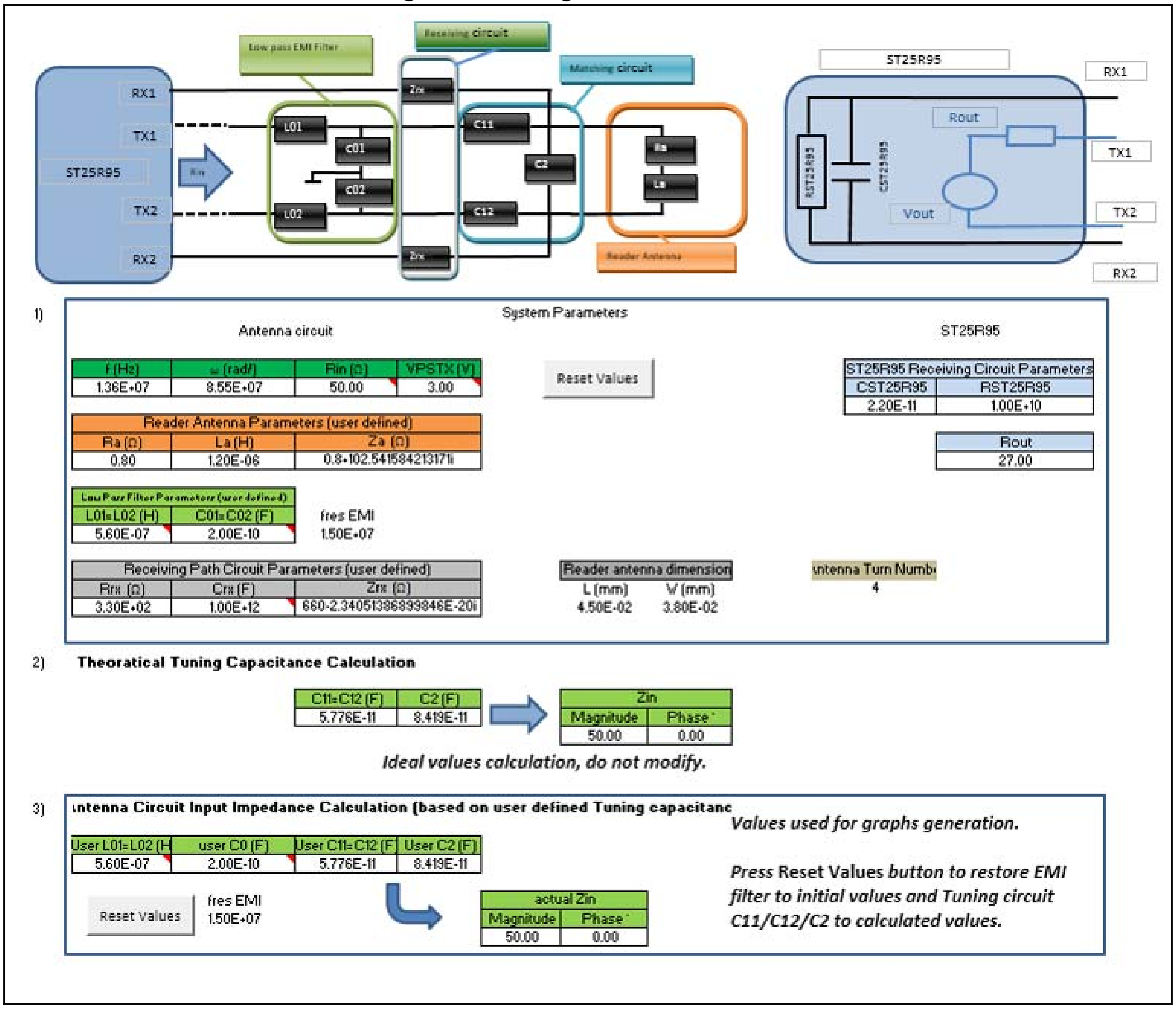
3.1 Tuning circuit calculation

Select the 1st tab of ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet:

- Tuning circuit calculation

Various configurations can be calculated, as you can seen on Figure 6.

Figure 6. Tuning circuit calculation



1. Section 1 contains ST25R95HF and user defined parameters used for the ideal tuning capacitance calculation:
   a) f(Hz): frequency at which tuning circuit calculation has to be done
   b) Rin: desired input impedance for the antenna circuit
   c) Ra and La: antenna impedance measured at desired frequency
   d) L0i and C0i: EMI filter component values
   e) Rrx and Crx: receiving path component values.

Reset button can be used to restore values to example values.

Note: Pressing the “Reset values” button restores all parameters to arbitrary default values.

2. *Section 2* shows the ideal C11/C12 and C2 tuning circuit capacitance calculated values
3. *Section 3* is used to calculate the resulting antenna circuit input impedance based on custom values for EMI filter components L0/ C0 and C11/C12/C2 tuning capacitances. pressing the Reset Values button restores the EMI filter components values to those in *Section 1* and C11/C12/C2 tuning circuit capacitances to ideal values calculated in *Section 2*)
   Input impedance curves, circuit voltages curves, theoretical field strength curve as well as curve shown on Smith chart are based on EMI filter and tuning circuit component from this section.

3.1.1 EMI filter

It is possible to calculate the tuning circuit without the EMI filter by simply choosing L01 = L02 = 0 and C01 = C02 = 10^{-40} (simulating an open circuit)

Receiving path

The calculation tool allows to use a resistor in series with a capacitor in the receiving path, by choosing:

- Crx= 10^{12}
  The calculation is made with a resistor only in the receiving path.
- Rrx= 0
  The calculation is made with a series capacitor only in the receiving path.

3.2 Input impedance curves

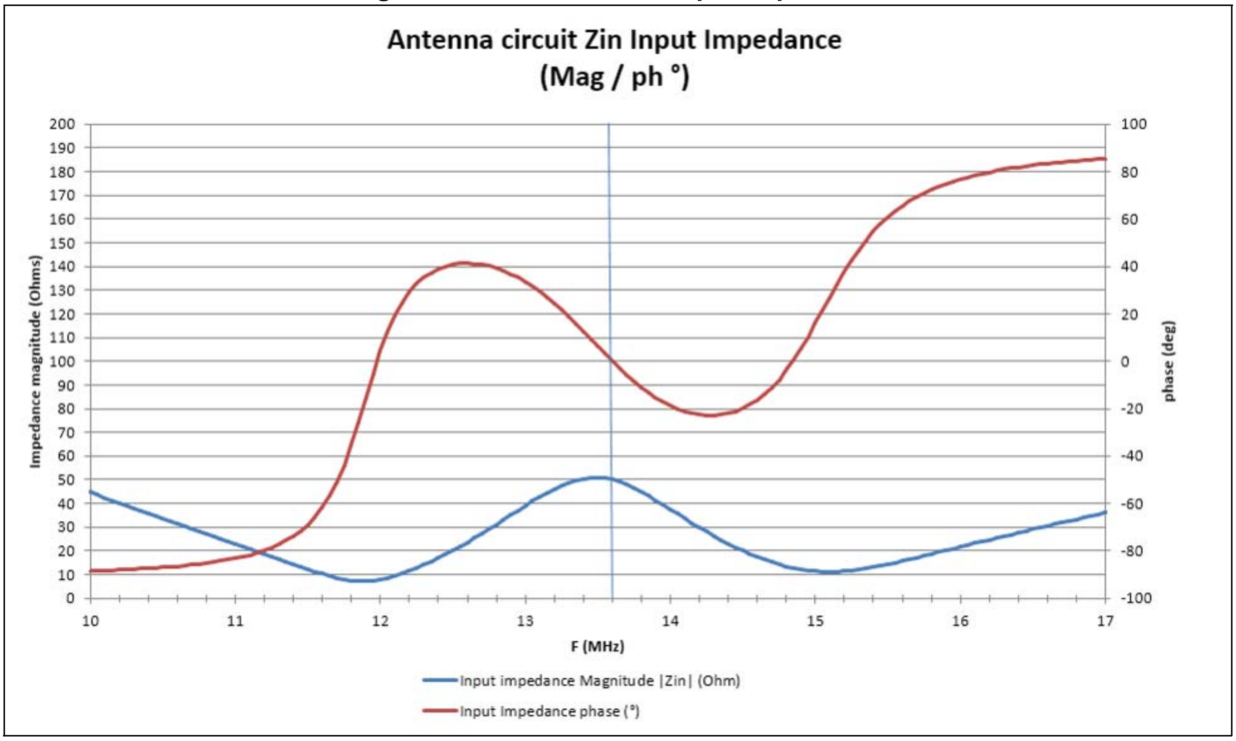
Select the 2nd tab of ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet:

- Input impedance curves

Based on circuit parameters, the antenna circuit input impedance is calculated over the frequency.

Antenna input impedance is drawn in magnitude/phase format.

Figure 7. Antenna circuit input impedance



3.3 Circuit voltages

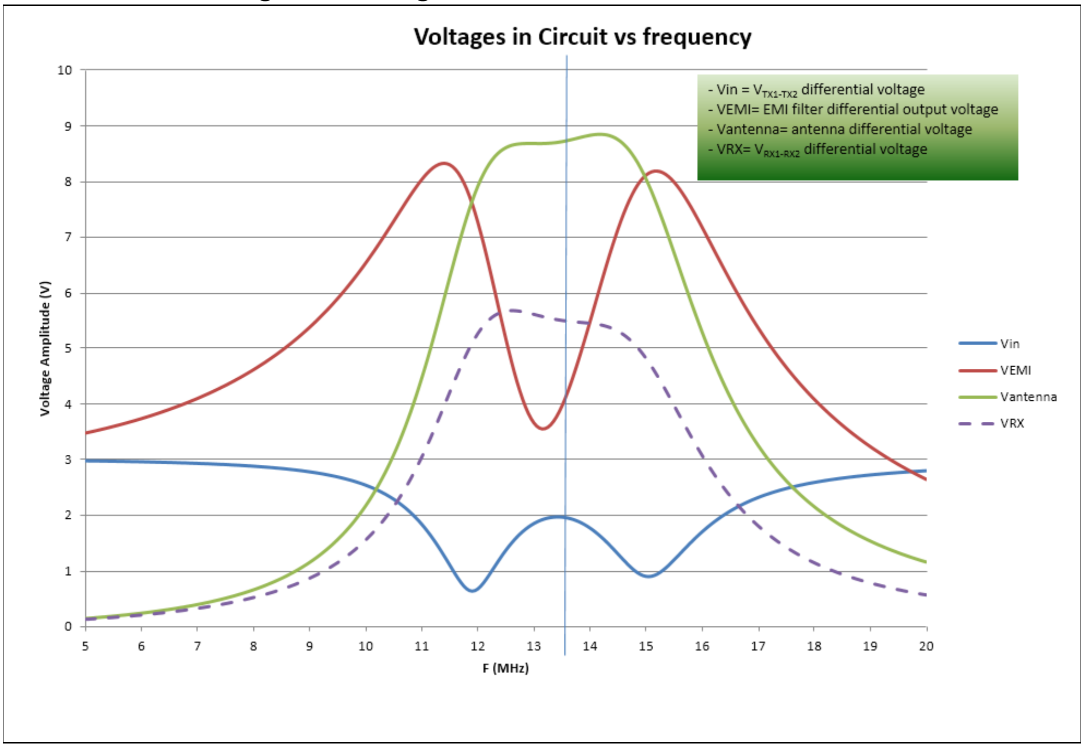
Select the 3rd tab of ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet:

- Circuit voltages

Based on circuit parameters, voltages at various locations of the circuit are calculated.

This feature is useful to estimate the RX path attenuation which is necessary to limit VRX1-RX2 below 7 V.

Figure 8. Voltage calculation at various locations



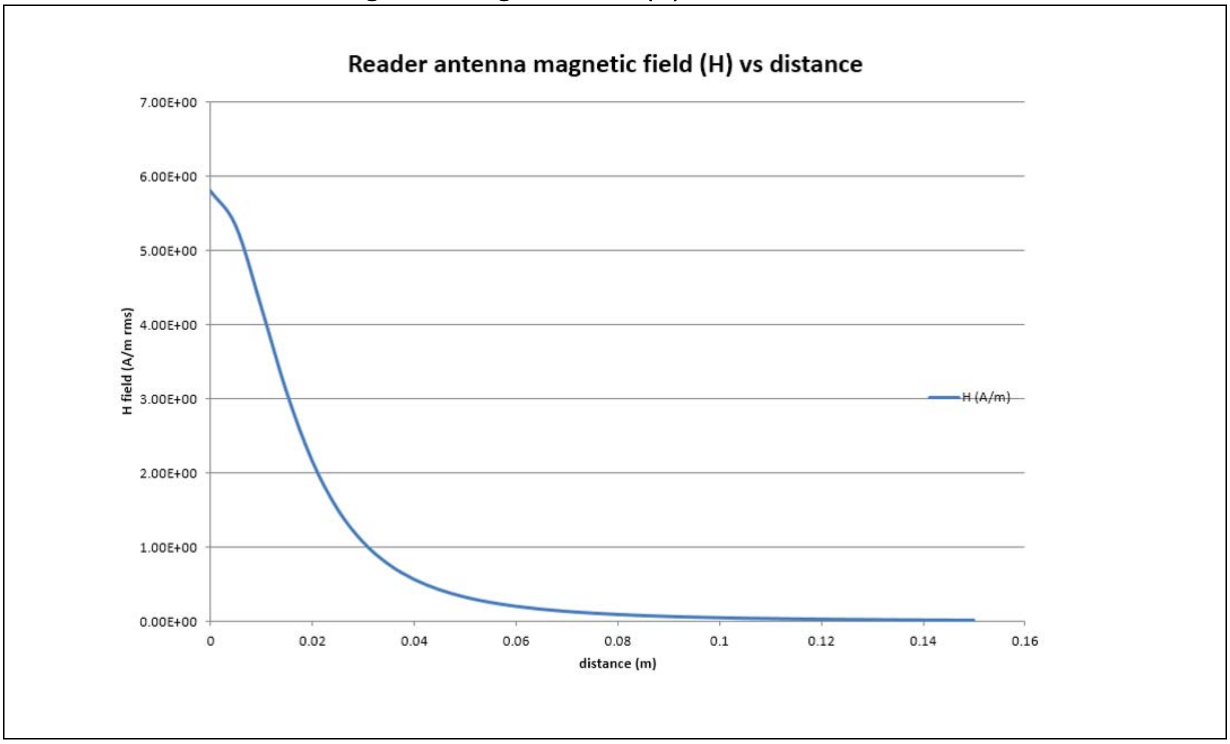
3.4 Magnetic field vs distance

Select the 4th tab of ST25R95 EMI FILTER CALCULATION.xlsm spreadsheet:

- Magnetic field vs distance.

Based on the differential antenna voltage Vantenna and the antenna parameters (dimensions and number of turns) chosen in the 1st tab, an estimation of the generated magnetic field is calculated (see *Figure 9*).

Figure 9. Magnetic field (H) versus distance



Note: For information only.

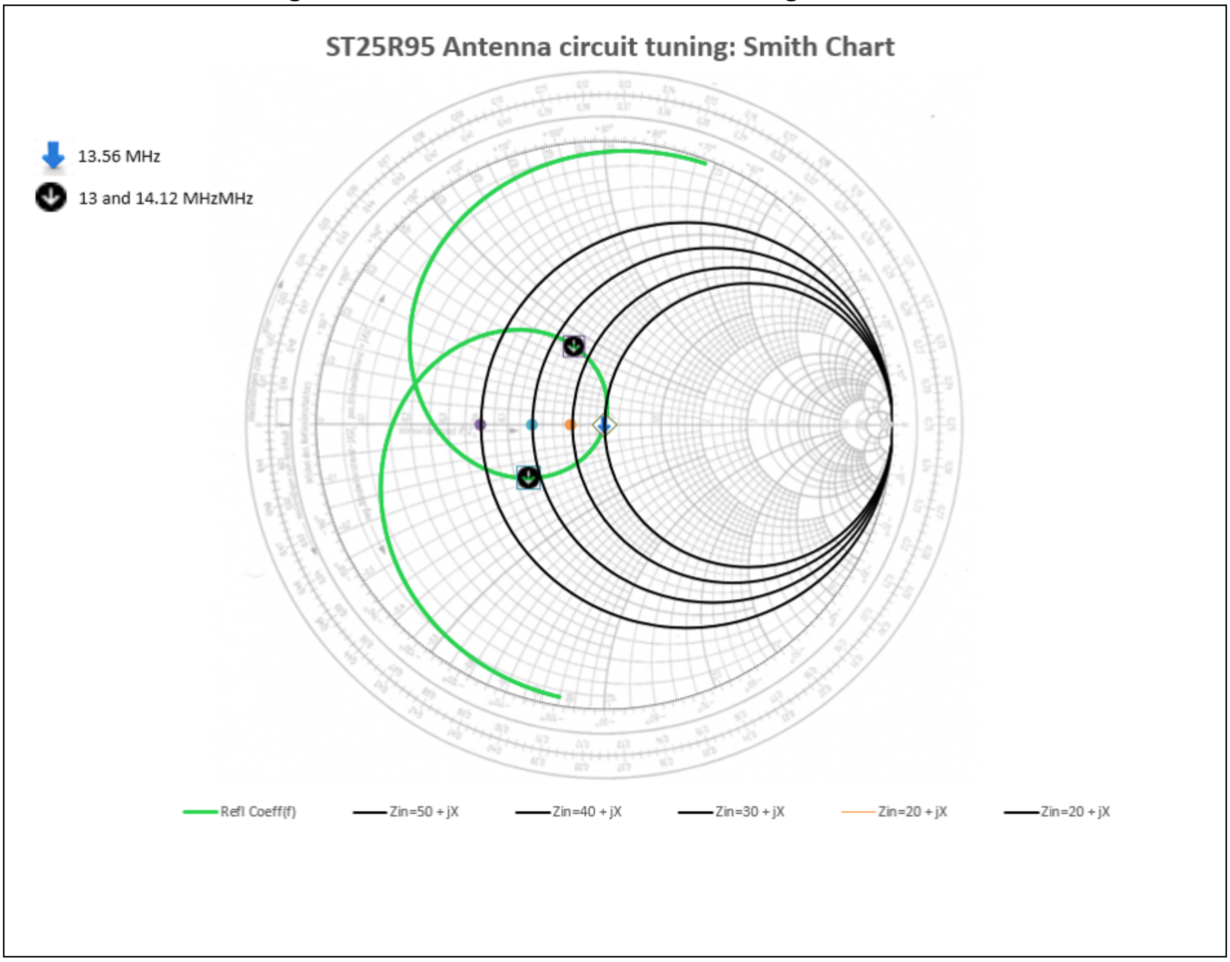
4 Smith chart

Based on circuit parameters, the reflection coefficient Γ(f) defined as

$$\Gamma(f) = \frac{Zin(f) - 50}{Zin(f) + 50}$$

is drawn on a the Smith Chart from 10 to 20 MHz. Circles corresponding to Re(Zin)=20, 30 40 and 50 are highlighted.

Figure 10. ST25R95 Antenna circuit tuning: Smith Chart



5 Practical tuning circuit design

5.1 Step by step procedure

Four steps are needed:

Step 1

Measure the ST25R95 antenna impedance on the PCB.

Step 2

Estimate the C11, C12, C2 and ZRX impedance values using the ST25R95 EMI filter calculation tool. Mount the component values from step 2 on the PCB.

Step 3

a) Without powering the board, measure the circuit input impedance between TX1 and TX2 using a network analyzer or an impedance analyzer. Tune the C11, C12 and C2 capacitance values, if necessary.

b) As a design trick, the tuning frequency can be adjusted using C2, and the impedance magnitude can be adjusted using C11/C12. This can be verified using the impedance curve feature of the ST25R95 EMI filter calculation tool.

c) Power up the board and activate the RF generation (this can be achieved by sending a Protocol_Select command to the ST25R95).

d) Measure the DC voltage in the ST_R0 pin: adjust the ZRX component value to limit the voltage measured on ST_R0 below 7 V.

e) After powering down the PCB, check the input impedance and adjust it with C11, C12 and C2, if necessary.

Step 4

Check the RF performance with a tag.

5.2 Input impedance choice

Due to the reader antenna detuning that occurs when the tag is very close to the reader, the magnetic field strength can go down causing communication hole or tag energy loss.

To overcome this, it is appropriate to choose an input impedance higher than the ST25R95 output impedance. The target input impedance can go up to 50 Ω: such value has a minor impact on ST25R95 ability to power tags at large distance and maintains a large magnetic field strength, which can be useful for applications using the energy harvesting feature of M24LRXXE-R and ST25DV-I^{2}C tag families.

6 Revision history

Table 1. Document revision history

Date	Revision	Changes
05-Nov-2018	1	Initial release.

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