PTX100R/105R antenna matching guidelines for IoT applications

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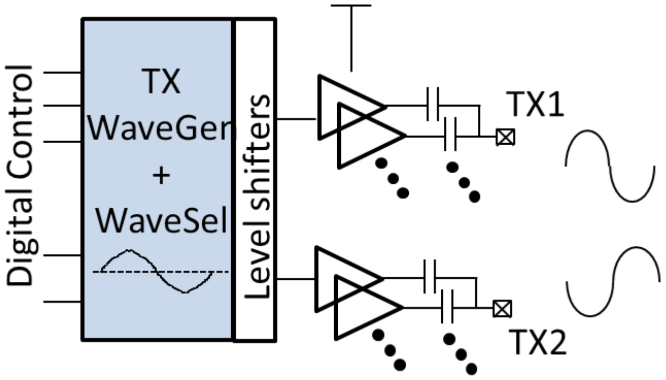
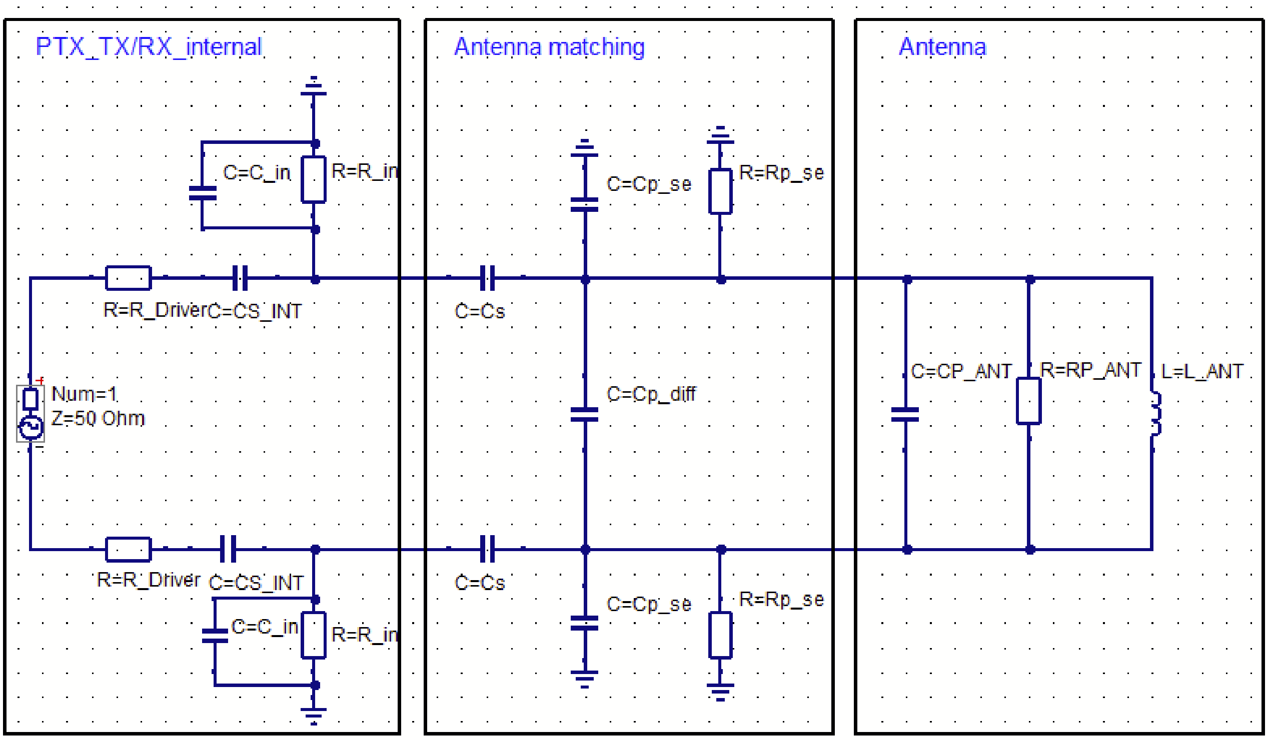
1 PTX10xR family output drivers

The PTX transmitter directly outputs a pure sine wave, therefore, eliminating the need for external EMC and most matching components resulting in a significant reduction of over- and undershoot. Furthermore, this enables very fine regulation of the output power and allows superior wave shaping for optimizing the modulation envelope

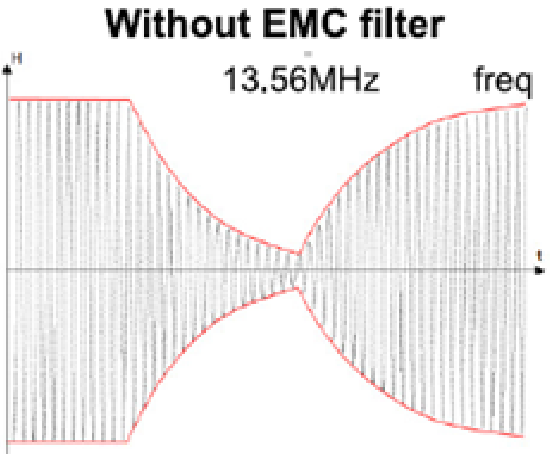
The transmitter and receiver are internally connected for the PTX100R and PTX105R, and the serial capacitor CS_INT is embedded in the IC with a value of 630pF.

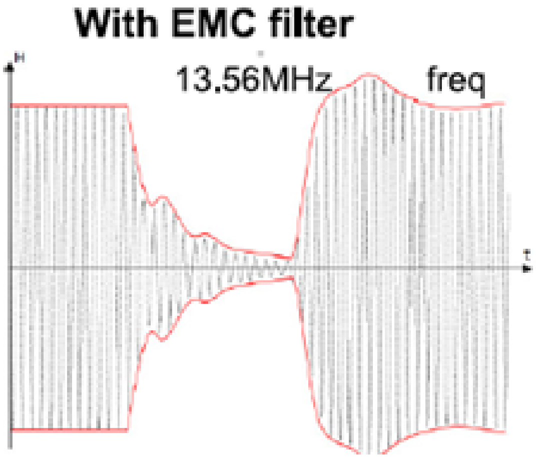




Compared to a conventional architecture PTX10xR enables a direct antenna connection and the removal of the EMI filter for better power efficiency, an optimized BoM, and antenna design flexibility.

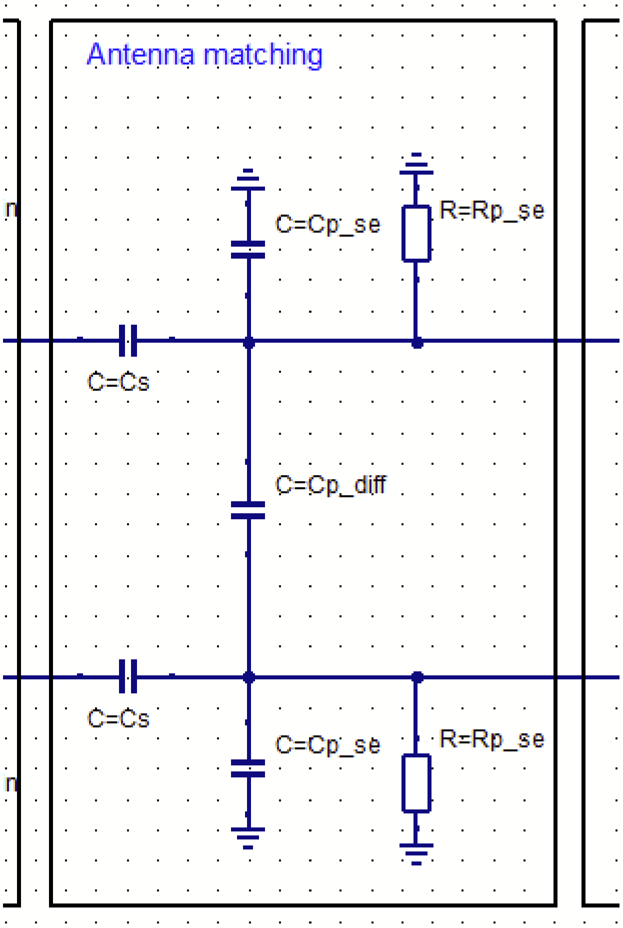
In the Figure below the benefit of having a sine wave output (without EMC filter) compared to a conventional square wave (with EMC filter) is depicted. Notice the non-monotonic falling edge in the picture on the right (with EMC filter)


Without EMC filter
H
13.56MHz
freq
t


With EMC filter
H
13.56MHz
freq
t

2 Antenna matching network

A well-designed and well-tuned antenna ensures optimum operating distance and optimum power transfer from the PTX10xR antenna driver output pins. For a 13.56MHz reader device, a matching network adjusts the antenna impedance to a desired value for the PTX10xR driver output. This is needed for optimum power transfer and to meet specific requirements.

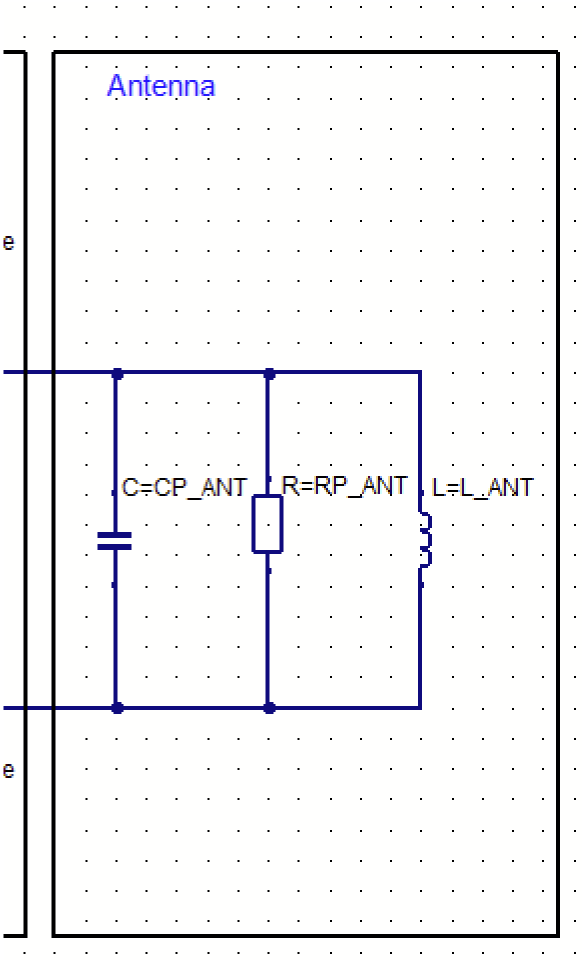


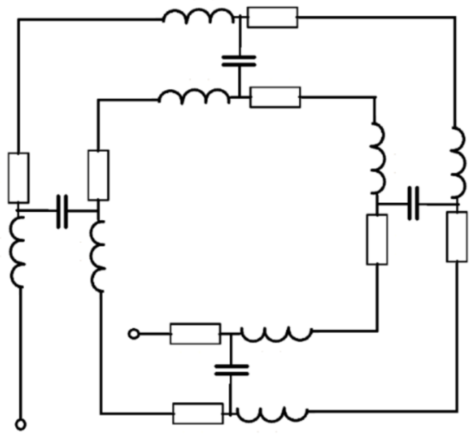
The matching network that needs to be designed is composed of an external series capacitor, parallel capacitors, and a parallel resistor for system Q factor adjustment.
A simulation tool, e.g. LTSpice or QUCS can be used to determine the matching components. Note that this is an example. Any simulation 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.
With the values of L_ANT and RP_ANT, Cs, Cp_diff, and Rp_se can be determined.
As a rule of thumb: Cs = 10 x Cp. The higher the value of Cs, the higher the voltage of the antenna will be. A voltage higher than 100V should not be exceeded. The differential voltage of the PTX transceiver pins (TRx_p, TRx_n) should not be higher than 50V.

3 Antenna modeling

A well-designed antenna is a 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.





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, (C) as capacitance, 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

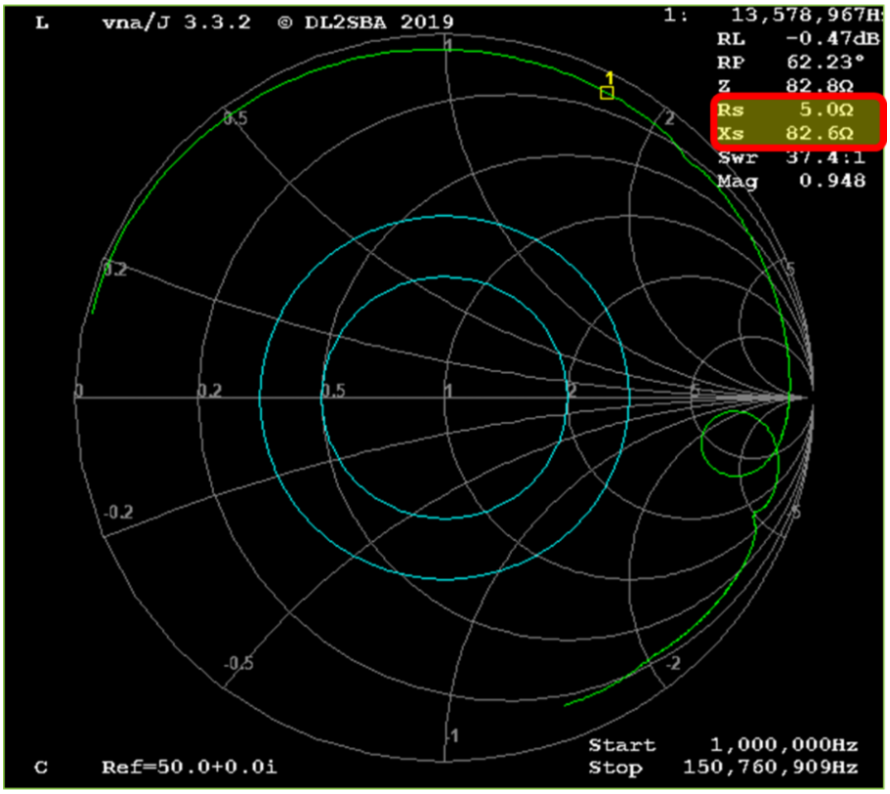
Based on these parameters it is possible to characterize the antenna and extrapolate the electrical characteristics with calculations or simulations. This approach could be a valid one in the case the antenna is in free air and is not influenced by the environment. A more practical way is to follow an empirical approach by using a Vector Network Analyzer to measure the antenna RF characteristics and use a circuit simulator to calculate the required matching network components.

4 Antenna parameters measurement

In order to measure the antenna parameters a network or impedance analyzer shall be used and set up 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 at 1 MHz and the stop frequency at 1500 MHz.
- Connect a short SMA cable to the RF port of the network analyzer and start the calibration using OPEN, SHORT, and 50 Ω LOAD resistance as load.
- Connect the SMA cable to the antenna to be measured with one pin soldered to the HOT of an SMA connector and a second pin soldered to one of its ground connections.

Smith chart. Loop antenna measurement with VNA



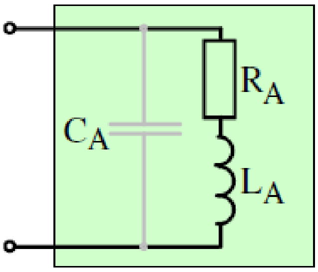
```
L     vna/J 3.3.2   © DL2SBA 2019          1:    13,578,967H
                                                RL    -0.47dB
                                                RP    62.23°
                                                Z     82.8Ω
                                                Rs     5.0Ω
                                                Xs    82.6Ω
                                                Swr   37.4:1
                                                Mag    0.948

                                          Start   1,000,000Hz
C     Ref=50.0+0.0i                       Stop  150,760,909Hz
```

In order to retrieve the loop antenna impedance a marker needs to be set at 13.56MHz and the real (Rs) and imaginary parts (Xs) converted to resistance **R_A** and inductance **L_A**.

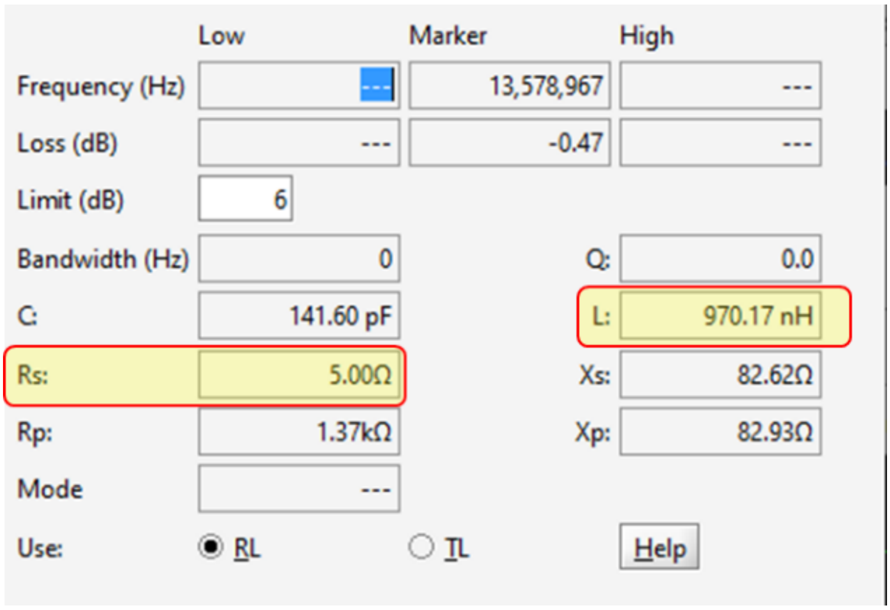
R_A=Rs L_A=XS/2πf

The parasitic capacitance **C_A** is relatively low and can be omitted in the matching network calculation, for completeness the formula to calculate it is:



$$f_0 = \frac{1}{2\pi\sqrt{L_A C_A}} \qquad => \qquad C_A = \frac{1}{4\pi^2 L_A f_0^2}$$

In most of the Network analyzers, the impedance value is internally processed and the values are already available.



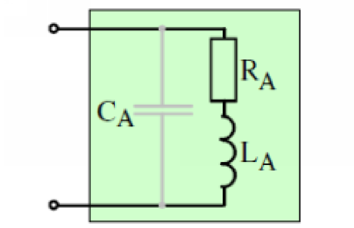
	Low	Marker	High
Frequency (Hz)	---	13,578,967	---
Loss (dB)	---	-0.47	---
Limit (dB)	6		
Bandwidth (Hz)	0	Q:	0.0
C:	141.60 pF	L:	970.17 nH
Rs:	5.00Ω	Xs:	82.62Ω
Rp:	1.37kΩ	Xp:	82.93Ω
Mode	---		
Use:	● RL	○ TL	Help

Based on this measurement it is possible to extrapolate the electrical parameters of the antenna which can be synthesized like in the schematic in the next figure.

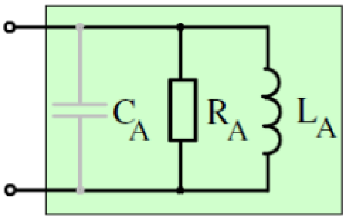
The antenna inductance for PTX100R is in the range between 300nH to 1500nH, a value in the range of **500nH** to **700nH** is recommended to have a good compromise for performance and tuning flexibility. It is recommended to use 2 or 3 turns depending on the area available, the track width larger than 0.5mm to reduce the parasitic resistance, and a gap between tracks as close as possible in order to avoid unwanted stray flux.

5 Quality factor

For one frequency the serial equivalent circuit can be calculated to an equivalent parallel circuit for the inductor using the Q_A equation:



$$Q_A = \frac{\omega L_A}{R_{SERIAL}} \equiv \frac{R_{PARALLEL}}{\omega L_A}$$



This way, an external resistor in parallel to the antenna allows for adjustment of the intended Q_A.

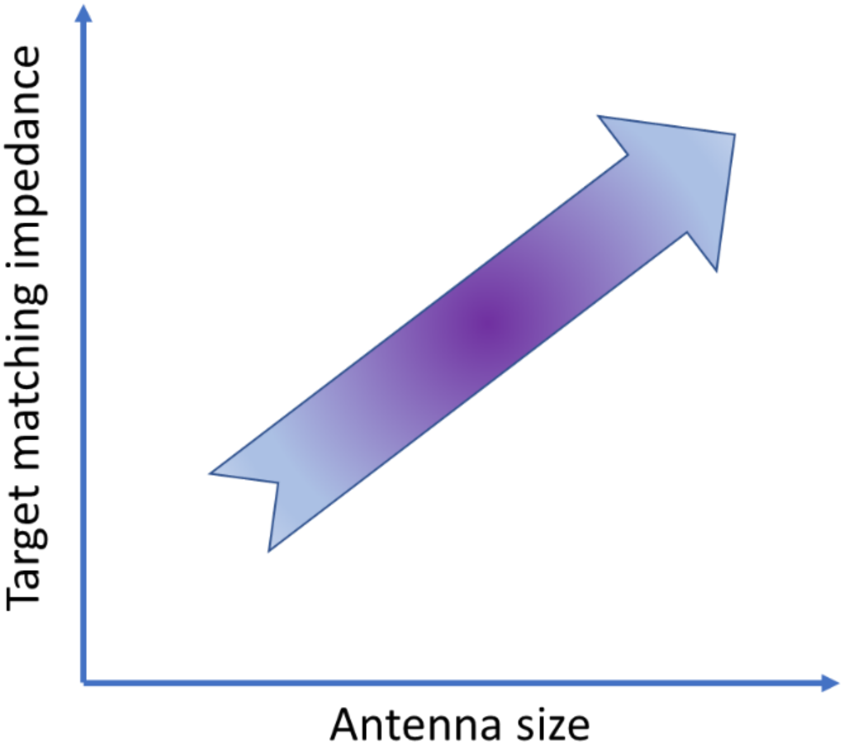
The Q-factor is important in terms of power transfer, timing, and data rates. EMV systems are limited to 106 kbit/s. A too high Q-factor can lead to timing errors and overshoot errors when running EMVCo tests.

A lower system Q-factor could help to simplify the EMVCo waveshape testing and receiver LMA testing due to less detuning on the PICC's antenna. Keep in mind that a too low Q-factor can lead to failures in the EMVCo power transfer tests.

6 Define target impedance

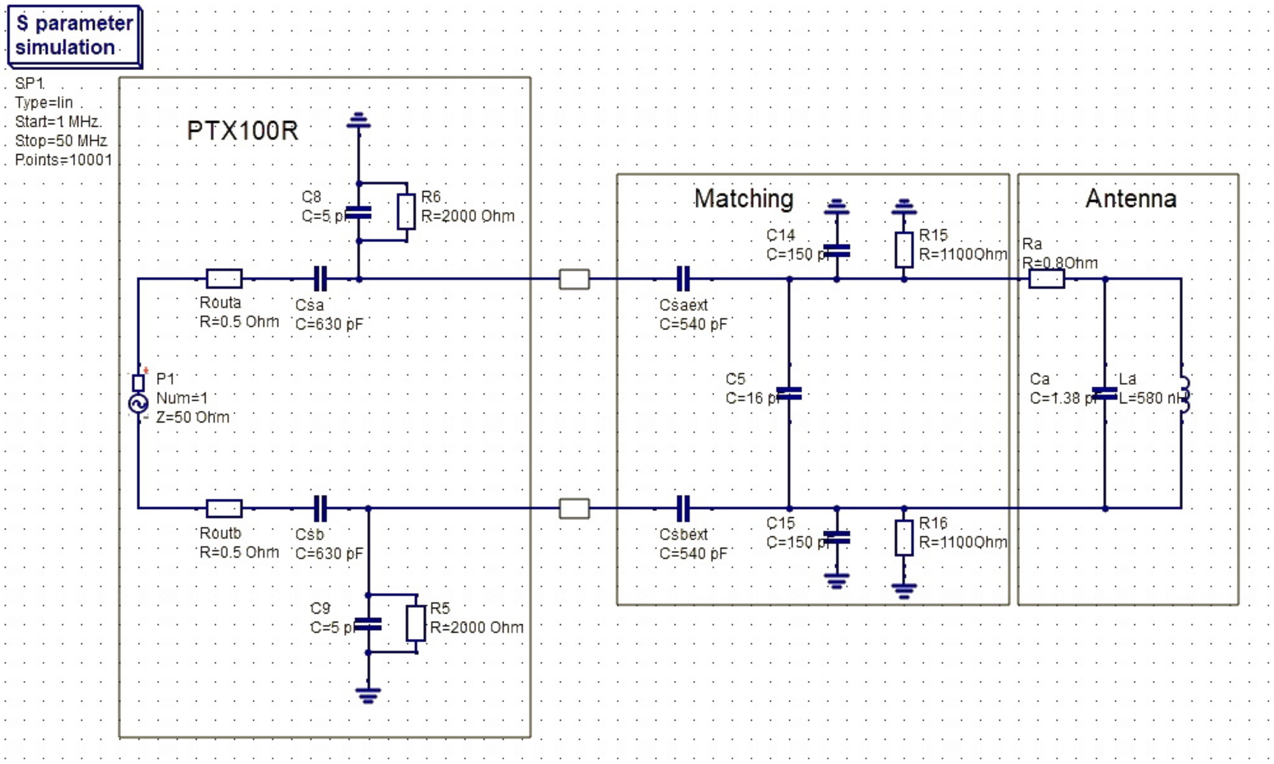
The target matching of the impedance is the most important criterion to determine the PTX1xxR output power. When designing the matching circuitry and defining the target matching impedance, with higher target matching impedance less power will be transferred forward to the antenna, and therefore the power consumption of the whole reader unit will be reduced.
For example, an antenna underneath a display will be affected in RF performance due to the losses generated by the materials which compose the display itself. A larger antenna or more power is than required to fulfill the voltage over volume requirements of the EMVCo standard.
In general, the graph below shows the relation between antenna size and matching impedance.

Antenna size vs Matching impedance

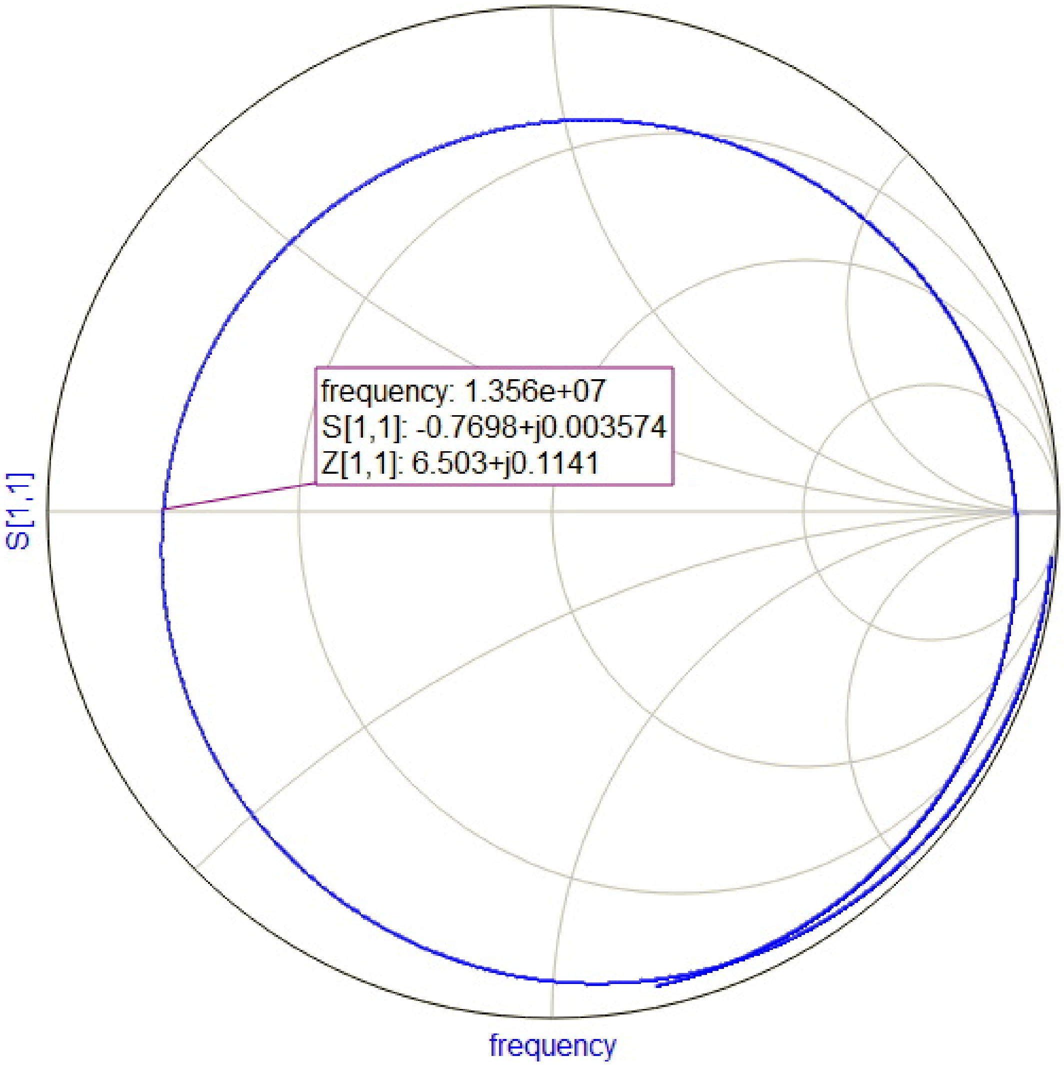


A good starting point for the target matching impedance is **6.5Ω** with **5V** supply voltage and the Q-factor in a range between **12** to **15.**

Matching network simulation example



Matched antenna on smith chart



The simulated value can now be used to populate the matching network and a first sanity check can be executed with the Q-measurement in the GUI.

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