5.1. Generalization of L-Match circuits

5.1.1. The Smith chart

The Smith Chart is a polar map of the reflection coefficient of a given impedance. It allows plotting on the same chart infinite impedances and admittances, which is not possible on a complex plane plot.
The reflection coefficient expression in given below:

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

The transformation is shown below, with several example of impedance and admittances:

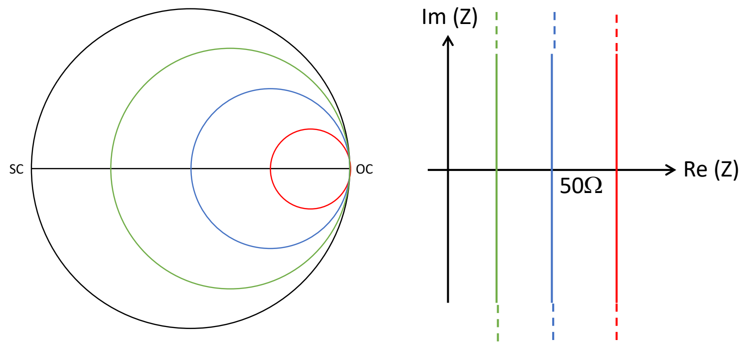

Figure 24 - Smith chart mapping of impedances with the real part of impedance constant

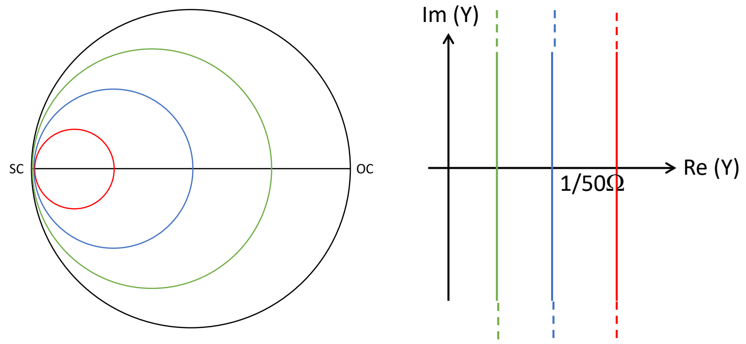

Figure 25 - Smith chart mapping of admittances with the real part of admittance constant

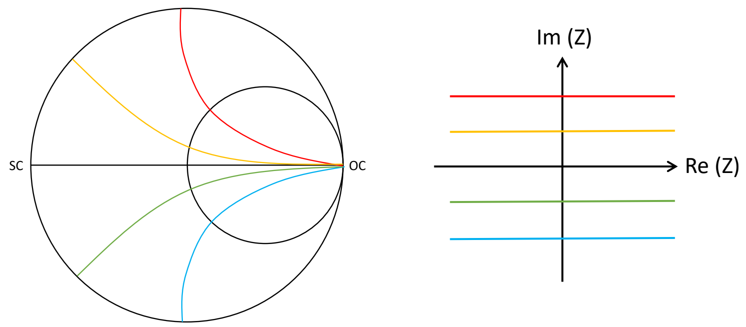

Figure 26 - Smith chart mapping of impedances with the imaginary part of impedance constant

5.1.2. Mapping of common reactive impedances

Adding series and parallel inductors or capacitors can be mapped on a Smith chart using the following schemes:

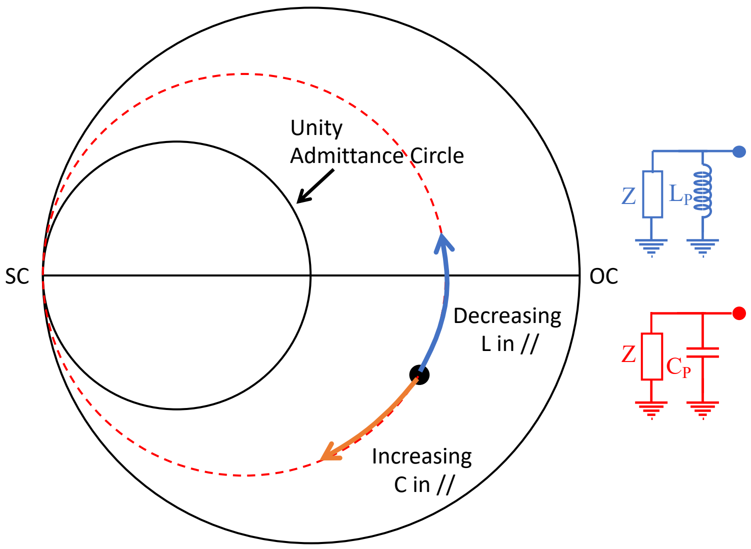

Figure 27 - Mapping of parallel inductor and capacitors. Note that the locus of the resulting reflexion is on constant admittance circles

Note that the shunt inductors have a large value when starting from the impedance.

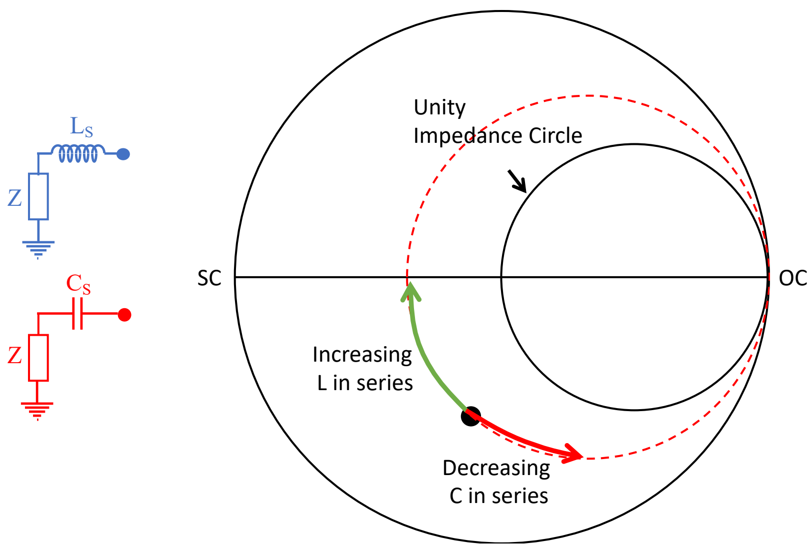

Figure 28 - Mapping of parallel inductor and capacitors. Note that the locus of the resulting reflexion is on constant admittance circles

Note that the series capacitors have a large value when starting from the impedance.
Adding series or parallel reactive elements allow rotating the starting impedance along constant real part of impedance or admittance circles. Using successive rotations, it is possible to match any impedance using simple L-C components.

5.2. L-Match on the Smith chart

Simple combinations can be used for matching real impedances, and complex impedances by extension. Simple cases are summarized below:

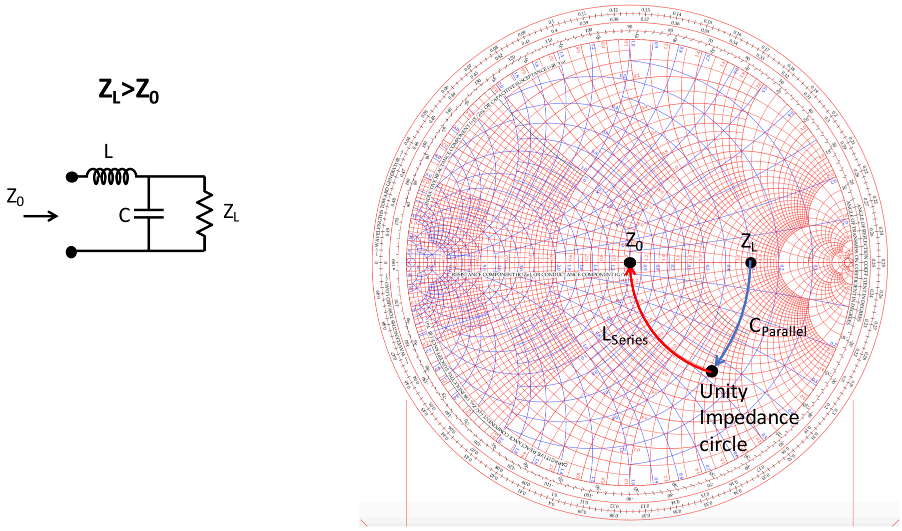

Figure 29 - Illustration de l'utilisation du circuit L-C transformateur haute impédance vers basse impédance pour l'adaptation d'une charge $Z_L > Z_0$ dans un circuit RF

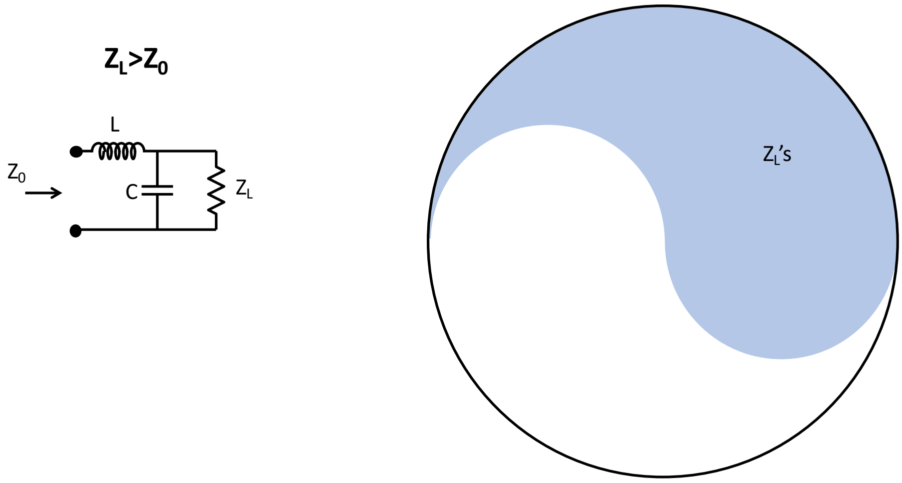

Figure 30 – Couverture Ying-Yang du circuit L-C transformateur haute impédance vers basse impédance $Z_L > Z_0$

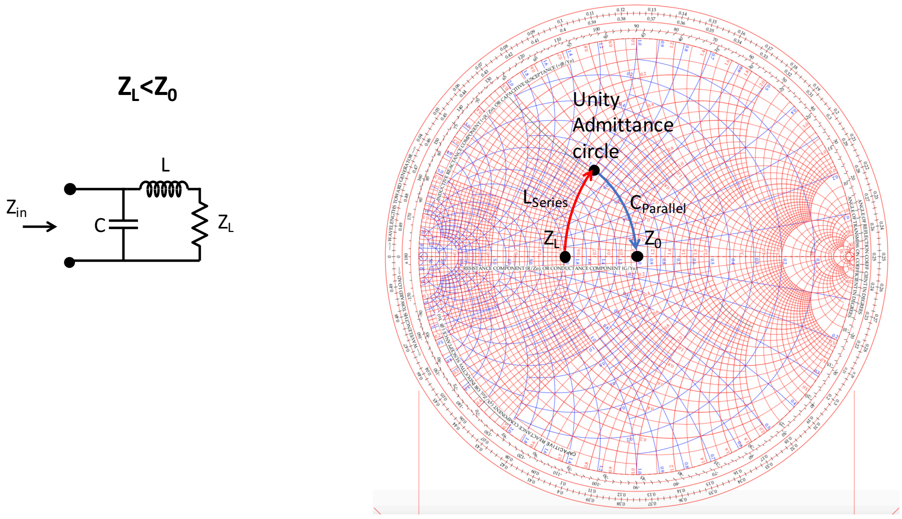

Figure 31 – Illustration de l'utilisation du circuit L-C transformateur haute impédance vers basse impédance pour l'adaptation d'une charge $Z_L < Z_0$ dans un circuit RF

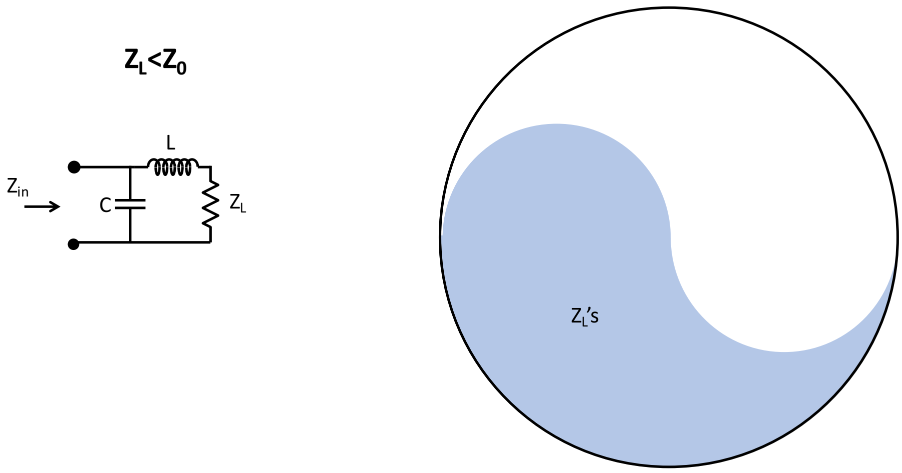

Figure 32 - Couverture Ying-Yang du circuit L-C transformateur haute impédance vers basse impédance $Z_L < Z_0$

Examples (In french)

Exemple 1 :
On cherche à déterminer les valeurs de L et C qui permettent de réaliser le circuit d'adaptation suivant à 1 GHz :

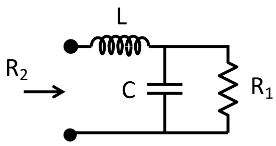

Figure 33 - Exemple d'application 1

$$R_1 = 50\ Ohms$$
$$R_2 = 5\ Ohms$$

On détermine d'abord Q:

$$Q = \sqrt{\frac{R_1}{R_2} - 1} = 3$$

Du coté de la self d'entrée :

$$Q = \frac{L\omega_0}{R_2}$$

Soit

$$L = \frac{QR_2}{\omega_0} \approx 2.39\,nH$$

Du coté de la capacité de sortie :

$$Q = R_1 C\omega_0$$

Soit

$$C = \frac{Q}{R_1\omega_0} \approx 9.55\,pF$$

Example 2:

Redo the same computation with 75 and 50 Ohms. L-C circuit Q is <1.

5.3. Possible matching circuits for 3 impedances

Let's consider three impedance points on the Smith chart A, B, C as shown below:

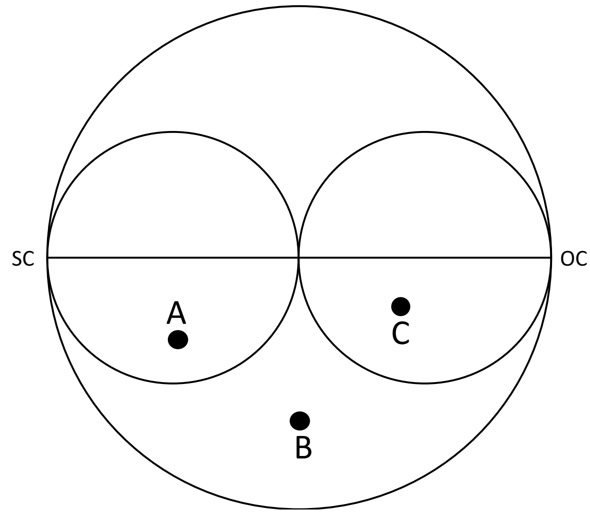

Figure 34 - Points A,B,C on the Smith chart

5.3.1. Matching point A

Point A is located inside the unity admittance circle on the Smith chart, and therefore, we have two possibilities for matching to the center point of the Smith chart, using two reactive elements.
The general idea is to take point A to the unity admittance circle, either on its upper side or the lower side. Then, the resulting admittance can be taken to the center by adding a second reactive element in parallel to achieve a rotation to the center of the chart.
The possibilities are summarized on the drawing below, with the corresponding circuit topologies:

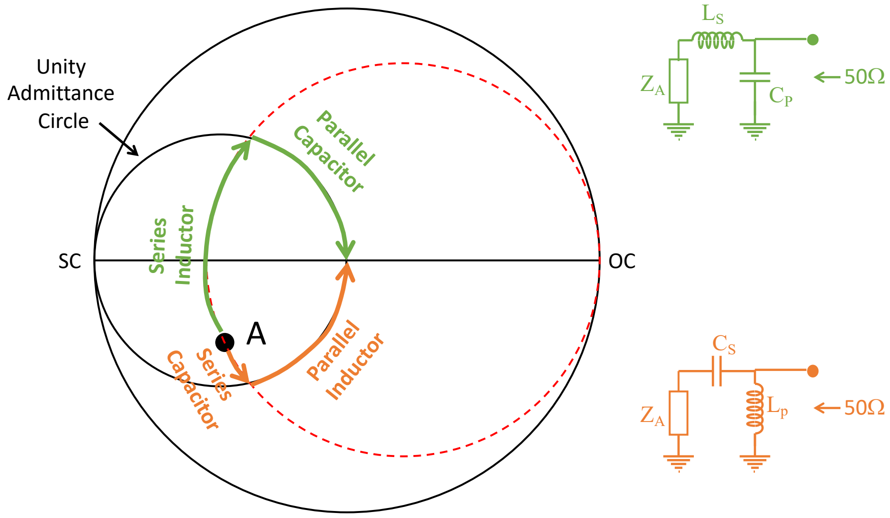

Figure 35 - Matching topologies for impedance A, and corresponding trajectories on the Smith chart.

5.3.2. Matching point C

Point C is located inside the unity impedance circle on the Smith chart, and therefore, we have two possibilities for matching to the center point of the Smith chart, using two reactive elements. This situation is the dual of matching point A.

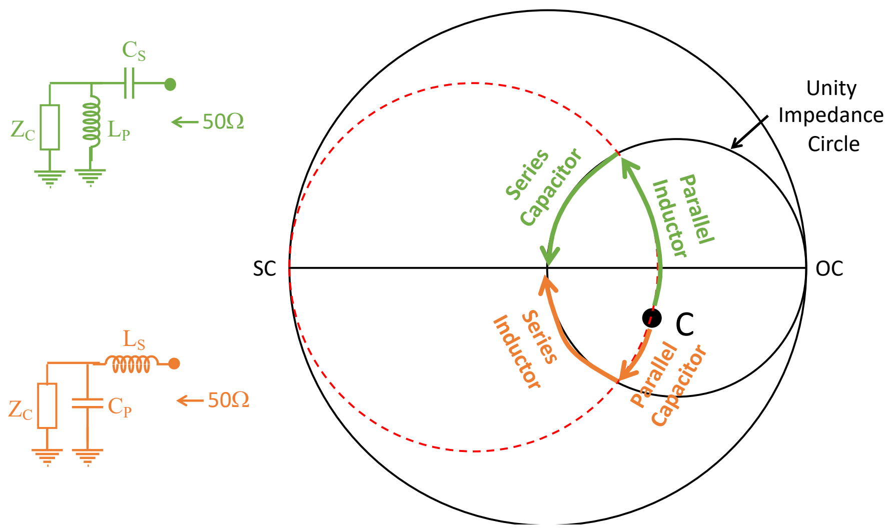

Figure 36 - L-C Matching topologies for impedance C, and corresponding trajectories on the Smith chart.

5.3.3. Matching point B

Point B is the point where it is possible to have the largest number of combinations. Indeed, this point is located both outside the unity admittance and impedance circles. Therefore, one can take the impedance back to the admittance unity circle, upper or lower side, then to the center using a reactive element connected in parallel. Or, one can take point B to the unity impedance circle, upper or lower side, and then to the center using a reactive element connected in series. This gives a total of four possibilities for impedance matching.

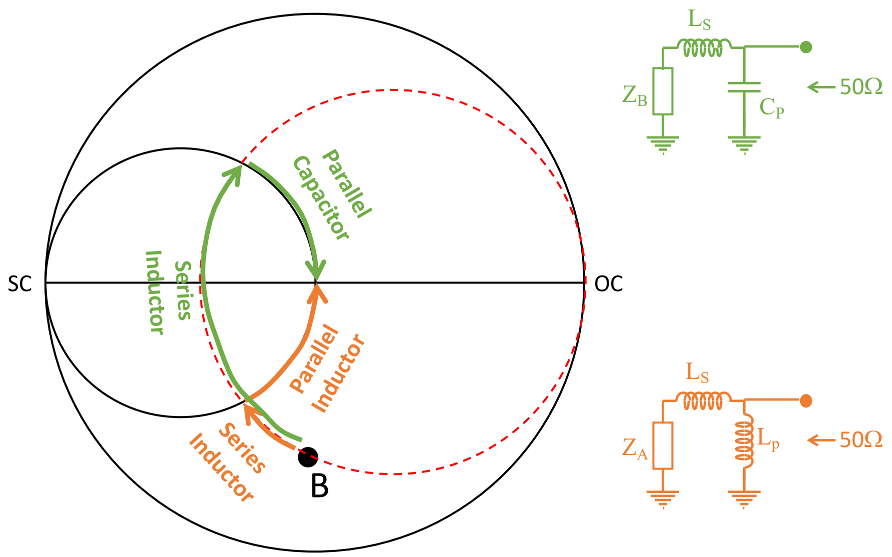

Figure 37 - Matching point B via the unity admittance circle.

Matching via the unity admittance circle is shown in the figure above. It is interesting to note that there is the possibility of matching the circuit using inductors only. The second case, in green, in the one described in paragraph 5.2.

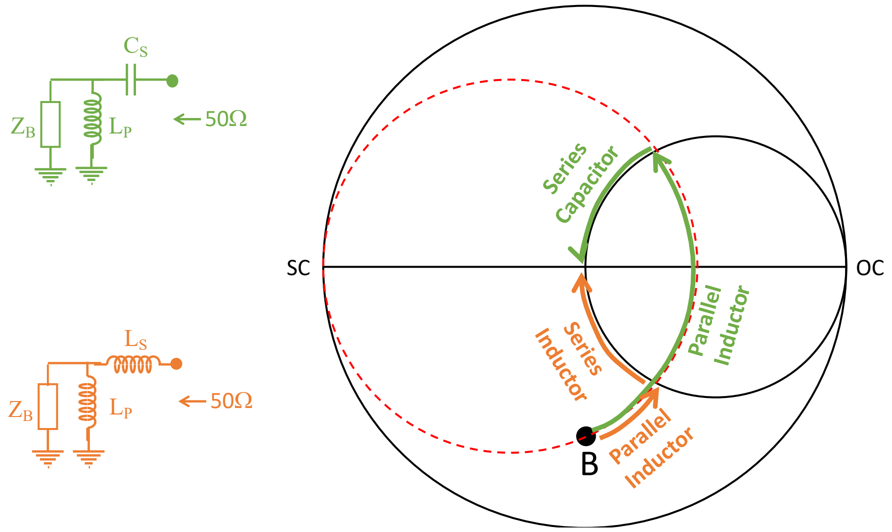

Figure 38 - Matching point B via the unity impedance circle.