EE142 Problem Set 5

Vighnesh Iyer

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Problem 1

Find y for the following normalized impedance on Smith Chart.

The straightforward procedure is to plot z_L on the impedance Smith Chart, and then look at what constant admittance and constant suspectance curves cross over the point in the admittance smith chart.

But, we can also plot z_L on the impedance smith chart, then rotate the point by π degrees along the constant SWR circle, and then read off the admittance by looking at the constant resistance and reactance curves.

I'm going to use the second technique; annotated charts aren't included in this document, but I'll compare the chart result I get to the exact calculation.

(a) $z_L = 1.4 + 2j$

$$y_L = \frac{1}{z_L} = \frac{1}{\alpha + \beta j} = \frac{\alpha - \beta j}{\alpha^2 + \beta^2} = 0.234899 - 0.33557j$$
$$y_{L,chart} = 0.22 - 0.32j$$

(b) $z_L = 0.5 + 0.9j$

$$y_L = 0.471698 - 0.849j$$
$$y_{L,chart} = 0.45 - 0.85j$$

(c) $z_L = 1.6 - 0.3j$

$$y_L = 0.60377 + 0.1132j$$
$$y_{L,chart} = 0.6 + 0.12j$$

Problem 2

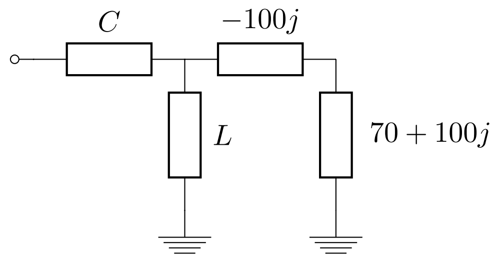
Use the Smith Chart. Also use equations for lumped component matching to check.

(a) Match $Z_L = 70 + 100j\Omega$ to 50 Ohm with lumped components.

Let's clear up some things:

$$Z_C = \frac{1}{j\omega C} \qquad X_C = \Im Z_C = -\frac{1}{\omega C}$$
$$Z_L = j\omega L \qquad X_L = \Im Z_L = \omega L$$

The load is complex, so we have to resonant out the load's complex impedance so only a real part is seen before solving using the L network method.



Now, the L-network will see a purely real 70Ω impedance with which we can use the regular matching equations.

$$R_S = 50$$
$$R_L = 70$$
$$R_{hi} = max(R_S, R_L) = 70$$
$$R_{lo} = min(R_S, R_L) = 50$$
$$\text{Boosting factor: } m = \frac{R_{hi}}{R_{lo}} = 1.4$$
$$Q = \sqrt{m-1} = 0.632$$
$$\text{Dropping resistance so, } X_p = \frac{R_L}{Q} = 110.76$$
$$X_p' = \frac{X_p}{1+Q^{-2}} = 31.613$$
$$X_s = -X_p' = -31.613$$

We arrive at the capacitor reactance of $-79.15j$ and the inductor reactance of $110.76j$. The circuit is simulated in ADS to match at 1 Ghz with component values $C = 5.0344$ pF, $L = 17.6$ nH, and $C_{res} = 1.59$ pF. S-parameter simulation verifies that the source and load are perfectly matched at 1 Ghz with $S_{21} = 0dB$.

The same calculation can be performed using the smith chart.

$$Z_{L,norm} = 1.4 + 2j$$
$$Z_{L,real} = 1.4$$
$$X_p = (1/0.45)j \cdot 50 = 111.1j$$
$$X_s = -0.62 \cdot 50 = -31j$$

The values calculated using the Smith Chart are very close to the values from the equations.

(b) Match $Z_L = 70 + 100j\Omega$ to 50 Ohm using transmission lines.

(c) Match $Z_L = 160 - 30j\Omega$ to 100 Ohm using lumped circuits.

Assume a resonating inductor with reactance $30j$ to make the load purely real.

$$R_S = 100$$
$$R_L = 160$$
$$R_{hi} = max(R_S, R_L) = 160$$
$$R_{lo} = min(R_S, R_L) = 100$$
$$\text{Boosting factor: } m = \frac{R_{hi}}{R_{lo}} = 1.6$$
$$Q = \sqrt{m-1} = 0.775$$
$$\text{Dropping resistance so, } X_p = \frac{R_L}{Q} = 206.452$$
$$X_p' = \frac{X_p}{1 + Q^{-2}} = 77.47$$
$$X_s = -X_p' = -77.47$$

We simulate in ADS with $L_{res} = 4.77$ nH, $L = 32.858$ nH, $C = 2.05$ pF. The simulation shows that these values give a perfect match at 1 Ghz. This match appears more broadband than the one in part a).

(d) Match $Z_L = 160 - 30j\Omega$ to 100 Ohm using transmission lines.

(e) Match $Z_L = 25 + 90j\Omega$ to 50 Ohm using lumped circuits.

(f) Match $Z_L = 25 + 90j\Omega$ to 50 Ohm using transmission lines.