ECE 6180 Stepped-Impedance Filter Design

Portfolio Question: How do you design a stepped-impedance filter?

Text Section 8.6

What is a stepped impedance filter?

- Made up of high impedance (thin) and low impedance (thick) lines
  - Want Z high / Z low to be as large as possible, so this is determined by manufacturing.
  - In our case, Z high = 100 ohms, and Z low = 10 ohms.
- Impedances stay the same, but lengths change for each section. Each length is less than $\lambda/4$.

Why a stepped impedance filter?

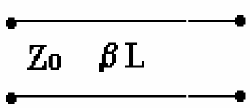
- Smaller than stub-filter
- Easier to design (no Kuroda identities!)

Why NOT a stepped impedance filter?

- Approximations in the design equations make them less accurate

Analysis of stepped impedance filters:
(Note: these are analysis steps, not design steps. You don't do these each time you design a filter, they are just to show how the stepped impedance filter is derived.)

1. For a length of transmission line: (see table p.208)

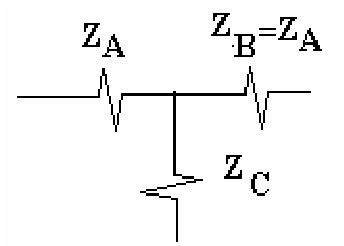


$$A = \cos(\beta\ell)$$
$$B = jZo\sin(\beta\ell)$$
$$C = jYo\sin(\beta\ell)$$
$$D = \cos(\beta\ell)$$

2. Convert from ABCD to Z-matrix (table p. 211)

$$Z_{11} = Z_{22} = \frac{A}{C} = -jZo\cot\beta\ell$$
$$Z_{12} = Z_{21} = \frac{1}{C} = -jZo\csc\beta\ell$$

3. Calculate the Z-matrix of a T-junction circuit (p.195)



$$Z_{11} = Z_{22} = Z_A + Z_C$$
$$Z_{12} = Z_{21} = Z_C$$

4. Relate Z_A, Z_C to Z_{11}, etc. (Solve for Z_{11}, etc.)

$$Z_A = Z_{11} - Z_{12} = -jZo\left[\frac{\cos\beta\ell - 1}{\sin\beta\ell}\right] = jZo\tan\left(\frac{\beta\ell}{2}\right)$$
$$Z_C = Z_{12} = -jZo\csc\beta\ell$$

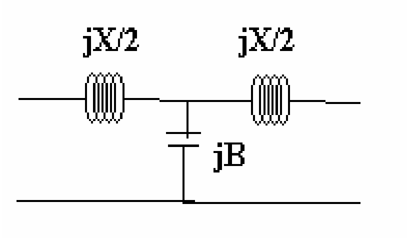
4. Are Z_A and Z_C inductors or capacitors?

For a length of line with $\beta L < \lambda/2$:

Z_A = + imaginary part (inductor)

Z_C = - imaginary part (capacitor)

$$Z_A = j\frac{X}{2} = -jZo\left[\frac{\cos\beta\ell - 1}{\sin\beta\ell}\right] = jZo\tan\left(\frac{\beta\ell}{2}\right) \Rightarrow X = 2Zo\tan\left(\frac{\beta\ell}{2}\right)$$
$$Z_C = \frac{1}{jB} = -jZo\csc\beta\ell \Rightarrow B = \frac{1}{Zo\csc\beta\ell} = \frac{1}{Zo}\sin\beta\ell$$

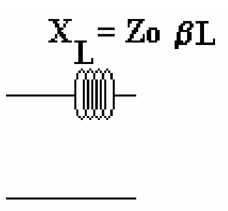


5. Assume a short length of line (β<λ/4) ….
   (Here are the approximations that make this method less than perfectly accurate…)

   a. When Zo is large:

$$X \approx 2Zo\left(\frac{\beta\ell}{2}\right) = Zo\beta\ell$$

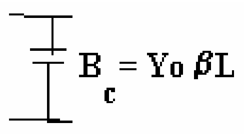
$$B \approx 0$$



   b. When Zo is small:

$$X \approx 0$$

$$B \approx \frac{1}{Zo}\beta\ell$$



6. Solve for lengths of lines that are needed for filter design:

$$\beta\ell = \frac{LZo}{Z_{high}}$$

$$\beta\ell = \frac{CZ_{low}}{Zo}$$

Note: These lengths are given in RADIANS. HP/Eesof ADS Linecalc (e_eff) is given in DEGREES. Multiply these values by 180 / π to get them in degrees.

Filter Design Steps:

1. Design the lumped element filter as before (sections 8.3 and 8.4)
2. Solve for lengths (βL) of each element. (Remember to convert to degrees if using Linecalc.)