8.6 Stepped-Impedance Low-Pass Filters

Reading Assignment: *pp. 412-416*

Another distributed element realization of a lumped element low-pass filter designs is the **stepped-impedance** low-pass filter.

These filters are also know as "**hi-Z, low-Z**" filters, and we're about to find out why!

HO: STEPPED-IMPEDANCE LOW-PASS FILTERS

Q: *Are there **other** methods for building microwave filters?*

A: There are a **bundle** of them!

All distributed elements (e.g., transmission lines, coupled lines, resonators, stubs) exhibit **some** frequency dependency. If we are clever, we can construct these structures in a way that their frequency dependency (i.e., $S_{21}(\omega)$) conforms to a desirable function of ω.

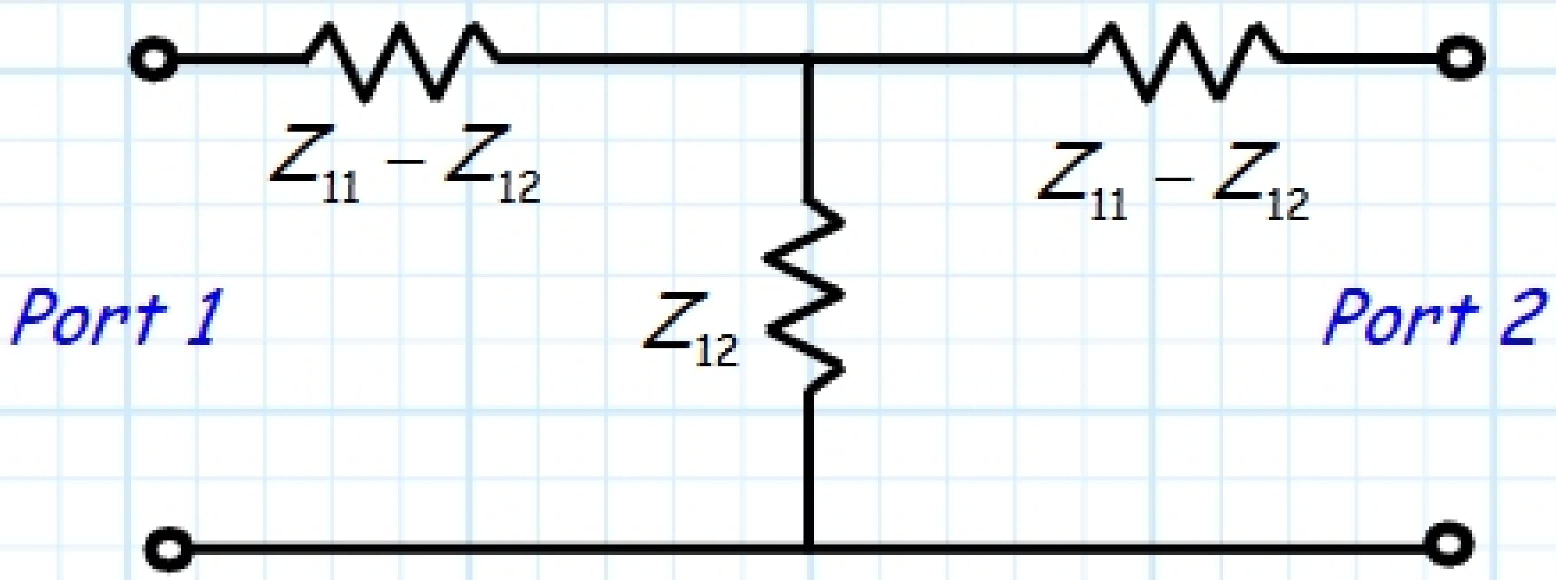
Other examples of filter realizations—ones applicable to **band-pass** filters—are discussed in sections **8.7** and **8.8** of your book.

Stepped-Impedance Low-Pass Filters

Say we know the impedance matrix of a **symmetric** two-port device:

$$\mathcal{Z}=\begin{bmatrix} Z_{11} & Z_{21} \\ Z_{21} & Z_{11} \end{bmatrix}$$

Regardless of the construction of this two port device, we can **model** it as a simple "T-circuit", consisting of three impedances:

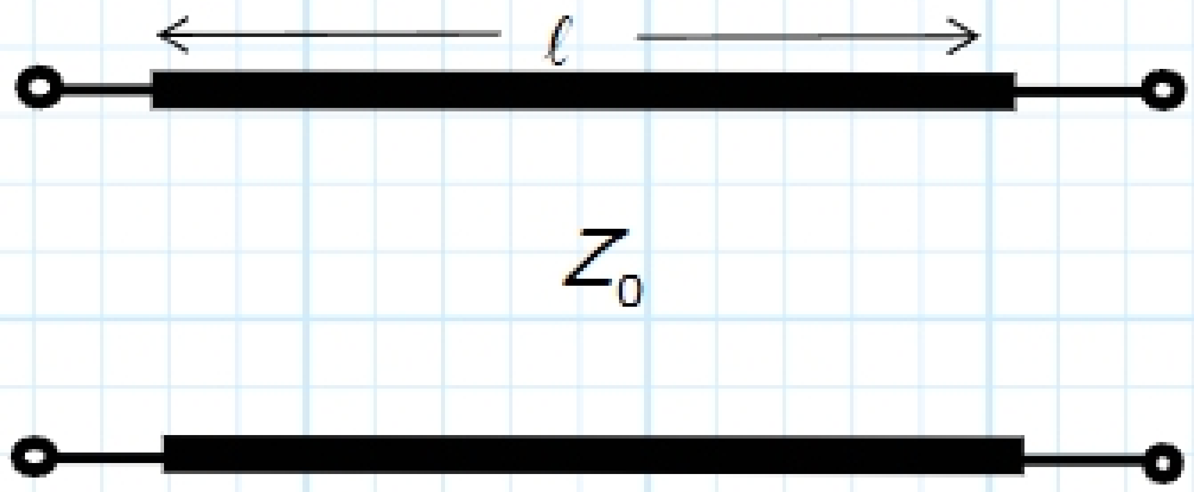


In other words, if the two **series impedances** have an impedance value equal to $Z_{11}-Z_{21}$, and the **shunt impedance** has a value equal to Z_{21}, the impedance matrix of this "T-circuit" is:

$$\mathcal{Z}=\begin{bmatrix} Z_{11} & Z_{21} \\ Z_{21} & Z_{11} \end{bmatrix}$$

Thus, **any** symmetric two-port network can be modeled by this "T-circuit"!

For example, consider a length ℓ of **transmission line** (a symmetric two-port network!):



Recall (or determine for yourself!) that the **impedance parameters** of this two port network are:

$$Z_{11} = Z_{22} = -jZ_0 \cot \beta\ell$$

$$Z_{12} = Z_{21} = -jZ_0 \csc \beta\ell$$

With a little **trigonometry**, ICBST :

$$Z_{11} - Z_{12} = j\, Z_0 \tan\left(\frac{\beta\ell}{2}\right)$$

Furthermore, if $\beta\ell$ is **small**:

$$\sin \beta\ell \approx \beta\ell \quad \cos \beta\ell \approx 1 \quad \tan \beta\ell \approx \beta\ell$$

where $\beta\ell$ is expressed in **radians**. Thus,

$$Z_{11} - Z_{12} \approx j\, Z_0 \left(\frac{\beta\ell}{2}\right)$$

and also: