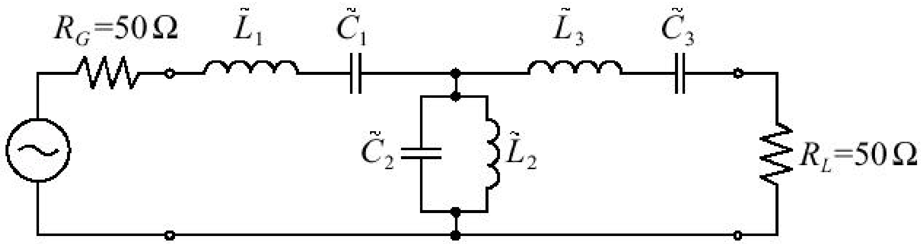
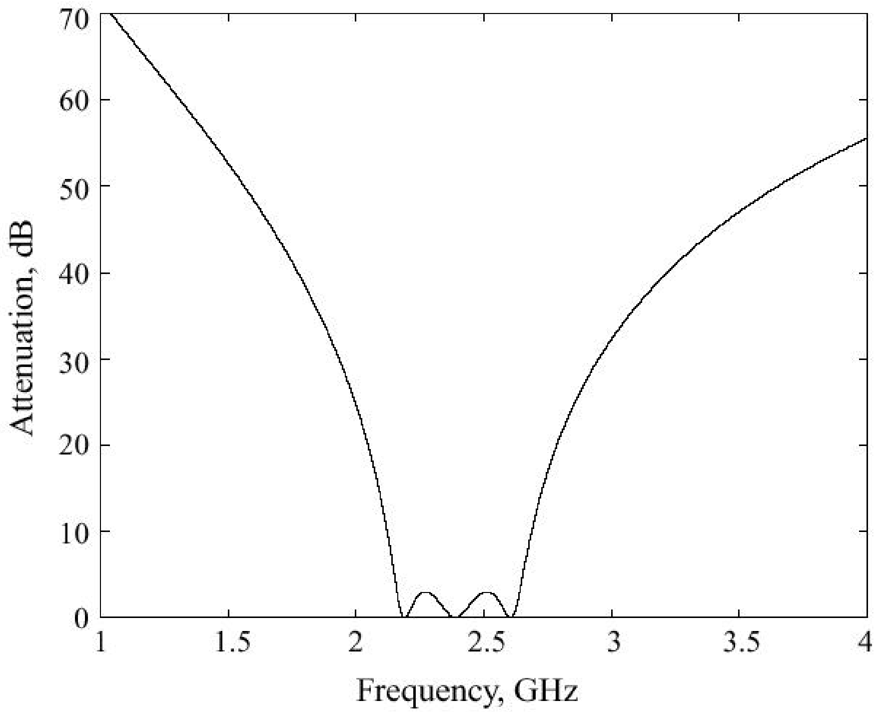
Band-Pass Filter Design Example





Attenuation response of a third-order 3-dB ripple bandpass Chebyshev filter centered at 2.4 GHz. The lower cut-off frequency is f_L = 2.16 GHz and the upper cut-off frequency is f_U = 2.64 GHz.

RF/mW Stripline Filters

- Filter components become impractical at frequencies higher than 500 MHz
- Can apply the normalized low pass filter tables for lumped parameter filters to stripline filter design
- Richards Transformation and Kuroda's Identities are used to convert lumped parameter filter designs to distributed filters

Richards Transformation: Lumped to Distributed Circuit Design

- Open- and short-circuit transmission line segments emulate inductive and capacitive behavior of discrete components
- Based on: $Z_{in} = jZ_o \, tan\left(b \, l \right) = jZ_o \, tan\left(q \right)$
- Set Electrical Length $l = \lambda/8$ so

$$q = b \, l = \frac{p}{4} \frac{f}{f_o} = \frac{p}{4} \Omega$$

Richards Transformation: Lumped to Distributed Circuit Design

- Richards Transform is:

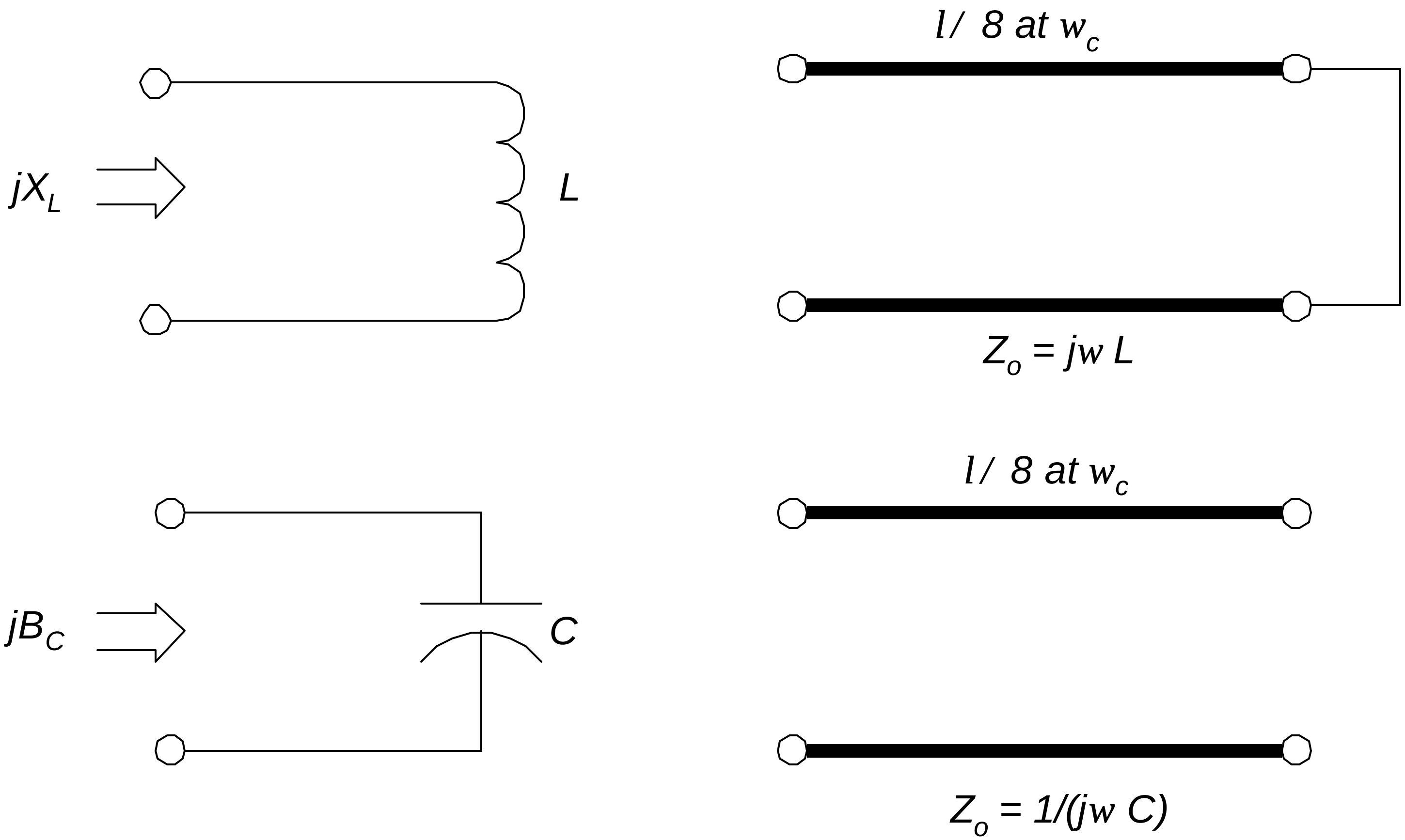
$$jX_L = jwL = jZ_o \, tan\left(\frac{p}{4}\Omega\right) = SZ_o$$

and

$$jB_C = jwC = jY_o \, tan\left(\frac{p}{4}\Omega\right) = SY_o$$

- For $l = l/8$, $S = j1$ for $f = f_o = f_c$

Richards Transformation: Lumped to Distributed Circuit Design

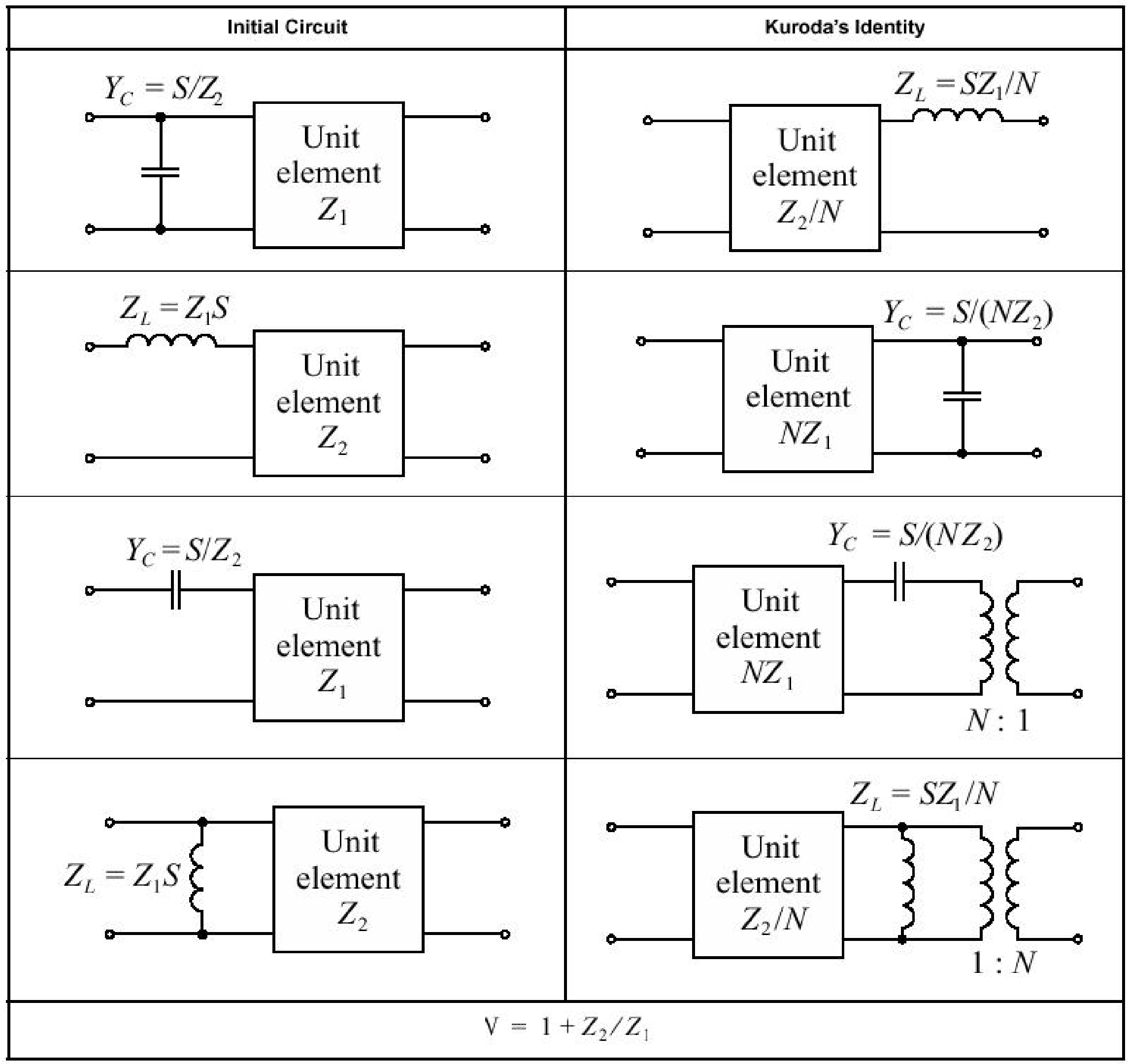


Unit Elements : UE

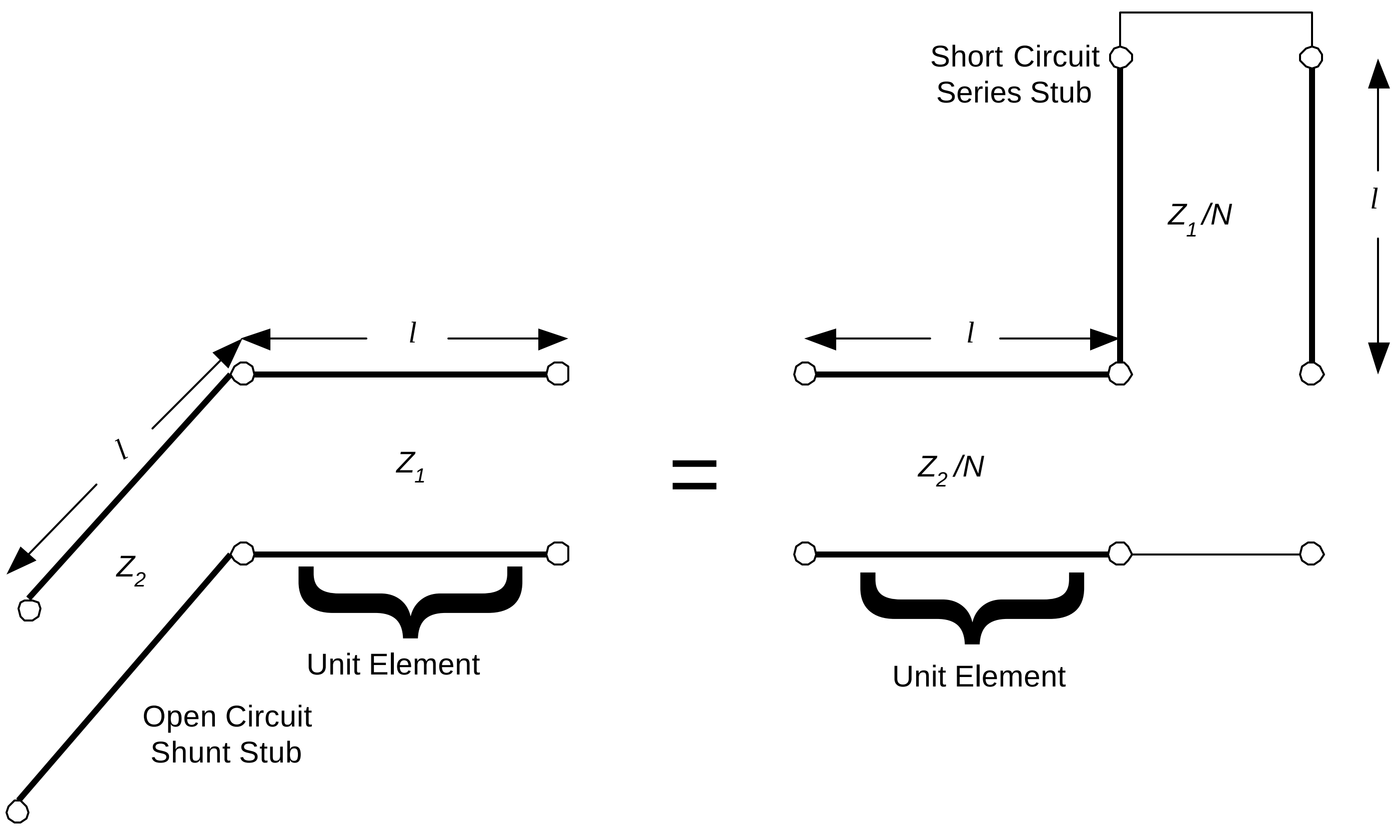
- Separation of transmission line elements achieved by using Unit Elements (UEs)
- UE electrical length: $q = pW/4$
- UE Characteristic Impedance Z_{UE}

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{UE} = \begin{bmatrix} cos q & jZ_{UE}\, sin q \\ \dfrac{j}{Z_{UE}} sin q & cos q \end{bmatrix} = \frac{1}{\sqrt{1+\Omega^2}} \begin{bmatrix} 1 & j\Omega Z_{UE} \\ \dfrac{j\Omega}{Z_{UE}} & 1 \end{bmatrix}$$

The Four Kuroda's Identities



Kuroda’s Equivalent Circuit



Realizations of Distributed Filters

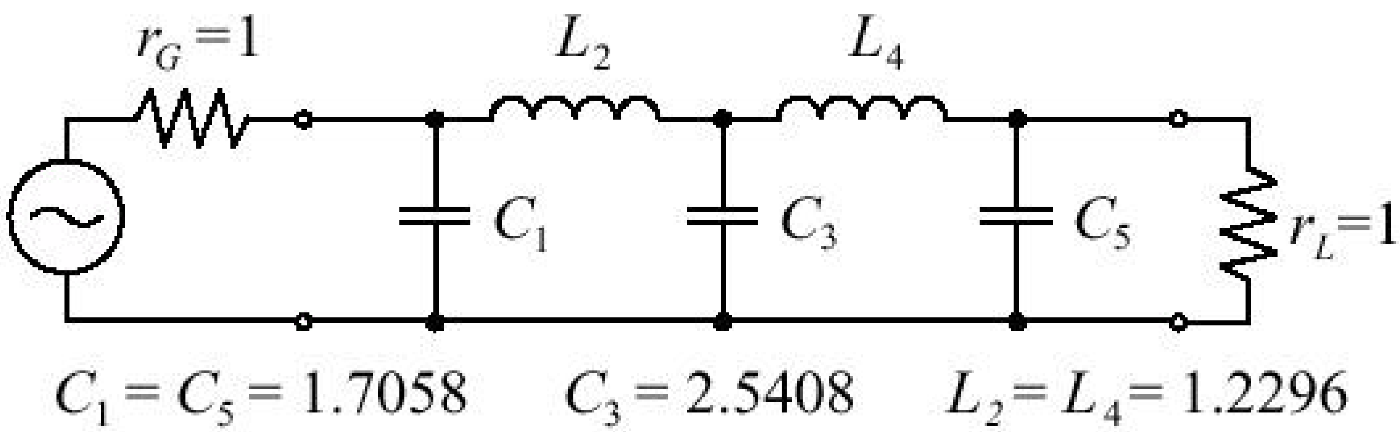
- Kuroda's Identities use redundant transmission line sections to achieve practical microwave filter implementations
- Physically separates line stubs
- Transforms series stubs to shunt stubs or vice versa
- Change practical characteristic impedances into realizable ones

Filter Realization Procedure

- Select normalized filter parameters to meet specifications
- Replace *L*'s and *C*'s by $l_o/8$ transmission lines
- Convert series stubs to shunt stubs using Kuroda's Identities
- Denormalize and select equivalent microstriplines

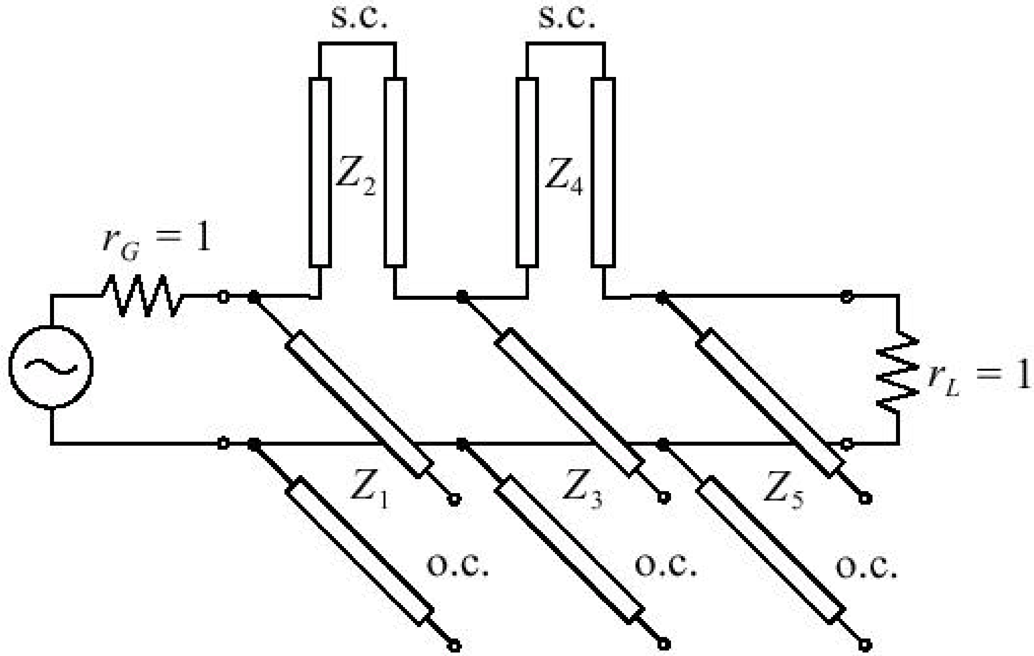
Filter Realization Example

- 5^{th} order 0.5 dB ripple Chebyshev LPF
- $g_1 = g_5 = 1.7058$, $g_2 = g_4 = 1.2296$, $g_3 = 2.5408$, $g_6 = 1.0$



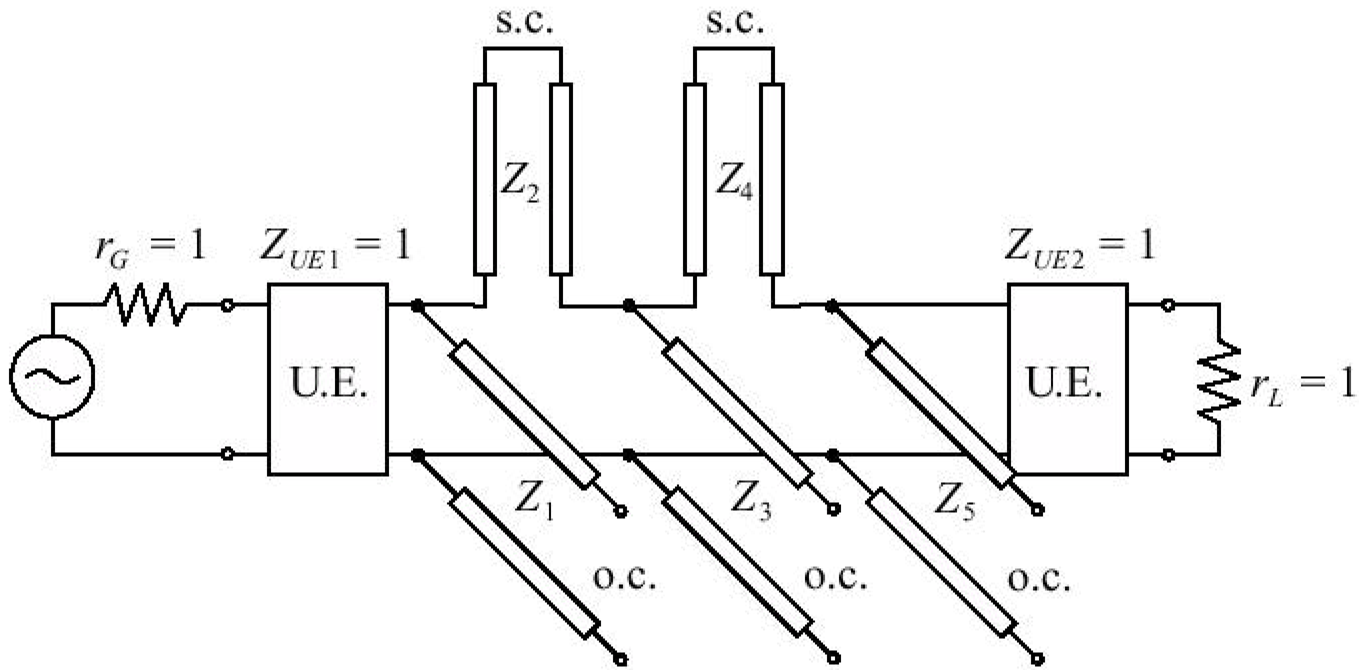
Filter Realization Example

- $Y_1 = Y_5 = 1.7058$, $Z_2 = Z_4 = 1.2296$, $Y_3 = 2.5408$; and $Z_1 = Z_5 = 1/1.7058$, $Z_3 = 1/2.5408$



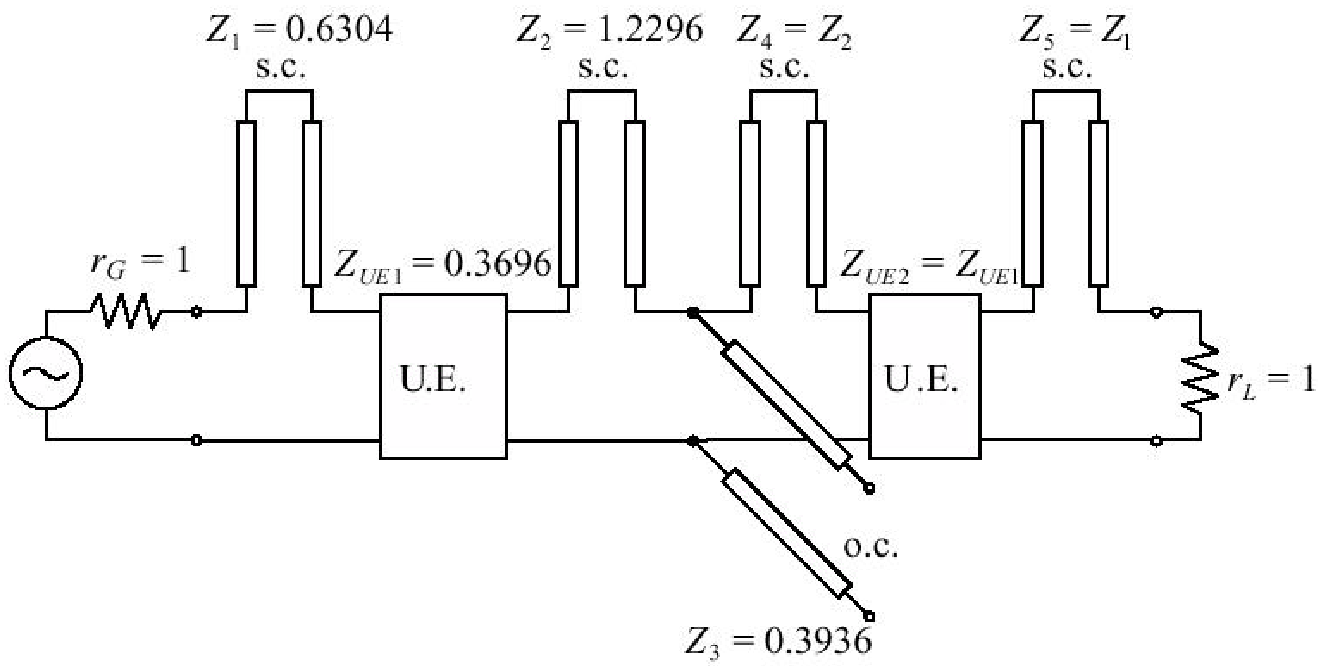
Filter Realization Example

- Utilizing Unit Elements to convert series stubs to shunt stubs



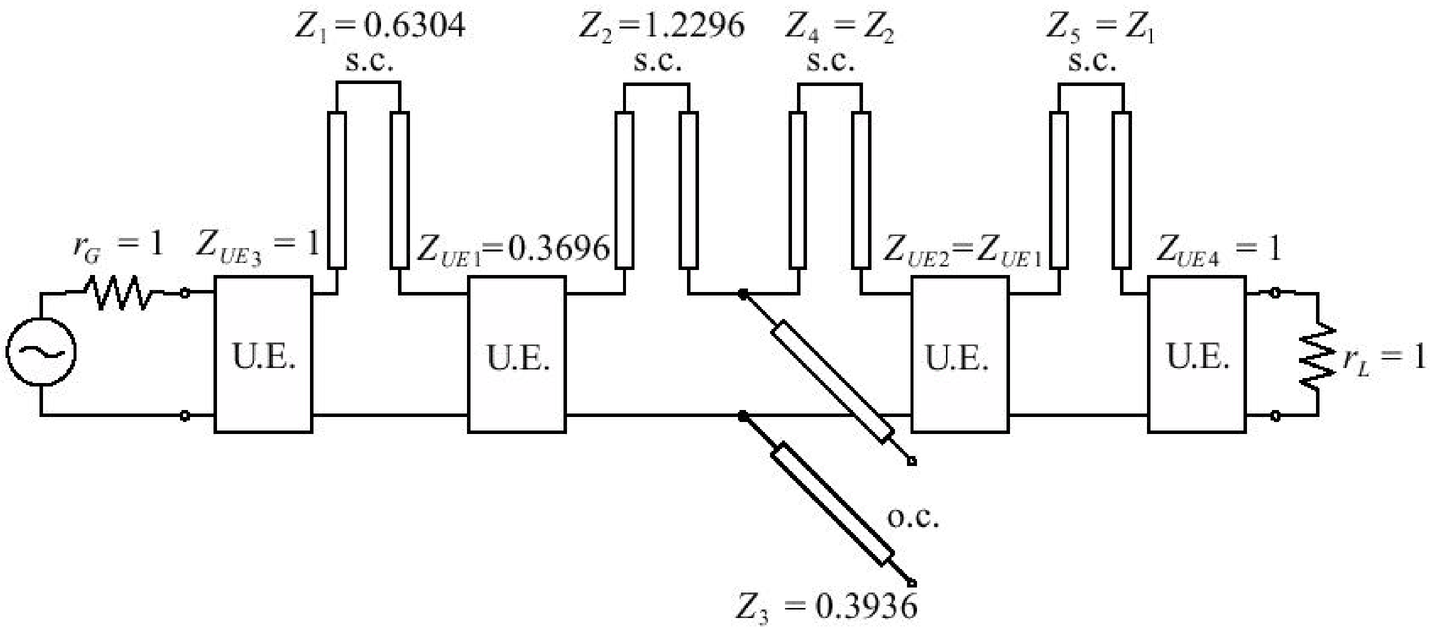
Filter Realization Example

- Apply Kuroda's Identities to eliminate first shunt stub to series stub



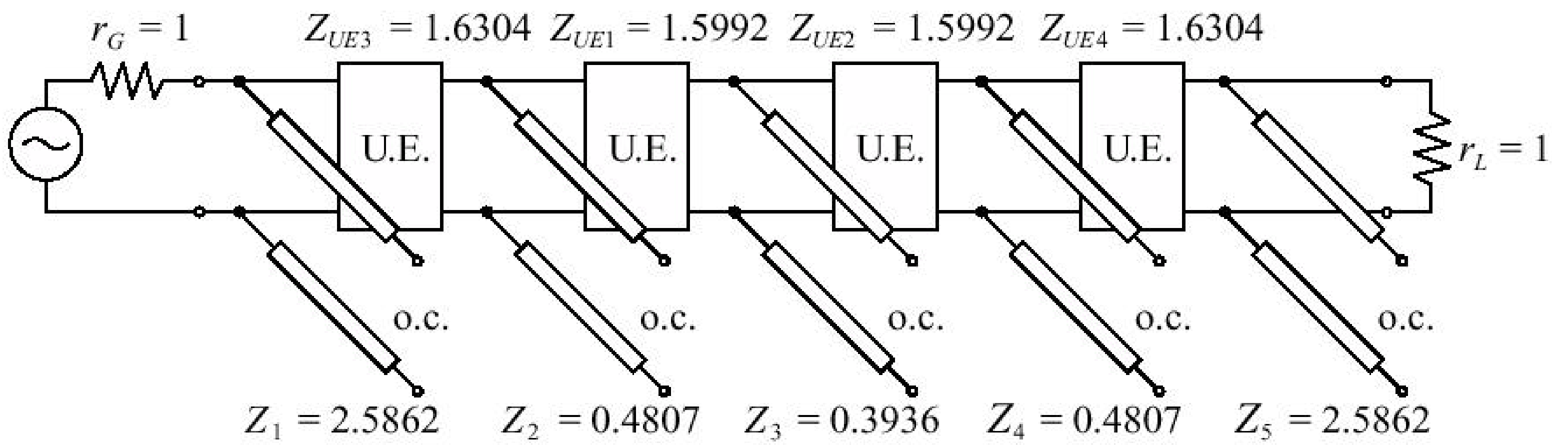
Filter Realization Example

- Deploy second set of UE's in preparation for converting all series stubs to shunt stubs



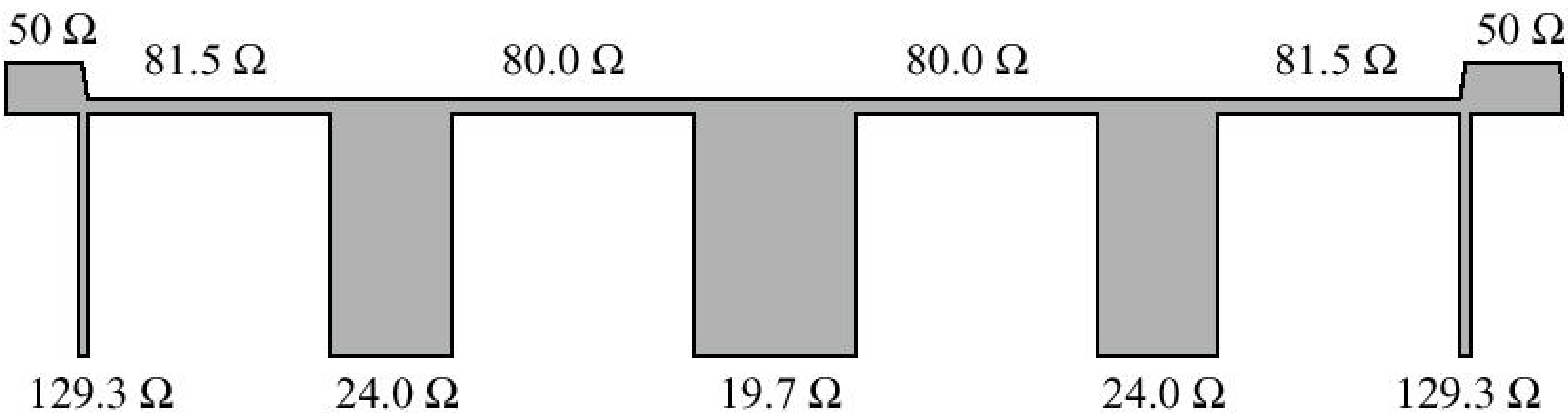
Filter Realization Example

- Apply Kuroda's Identities to eliminate all series stubs to shunt stubs
- $Z_1 = 1/Y_1 = NZ_2 = (1+Z_2/Z_1)Z_2$ $=1+(1/0.6304)$; $Z_2 = 1$ and $Z_1 = 0.6304$



Filter Realization Example

- Final Implementation



Filter Realization Example

- Frequency Response of the Low Pass Filter