Laboratory #6: Microstripline Filter Design

I. OBJECTIVES

Design microstripline filters using Richard's Transformations and Kuroda's Identities.

A. Design a low-pass Chebyshev filter with a cutoff frequency of 600 MHz and 3 dB ripple with equal terminations of 50 Ω. The filter stopband is 50 dB attenuated at 1 GHz.

B. Design a high-pass Chebyshev filter with a cutoff frequency of 15 GHz and 3 dB ripple with equal terminations of 50 Ω. The filter stopband is 40 dB attenuated at 7.5 GHz.

II. INTRODUCTION

Richard's Transformation and Kuroda's Identities focus on uses of λ/8 lines, for which $X = jZ_o$. Richard's idea is to use variable Z_o (width of microstripline, for example) to create lumped elements from transmission lines. A lumped low-pass prototype filter can be implemented using λ/8 lines of appropriate Z_o to replace lumped L and C elements.

So if we need an inductance of L for a prototype filter normalized to cutoff frequency $\omega_c = 1$ and admittance $g_o = 1$, we can substitute a λ/8 transmission line stub that has $Z_o = L$. The last step of the filter design will be to scale the design to the desired ω_c and Z_o (typically 50Ω).

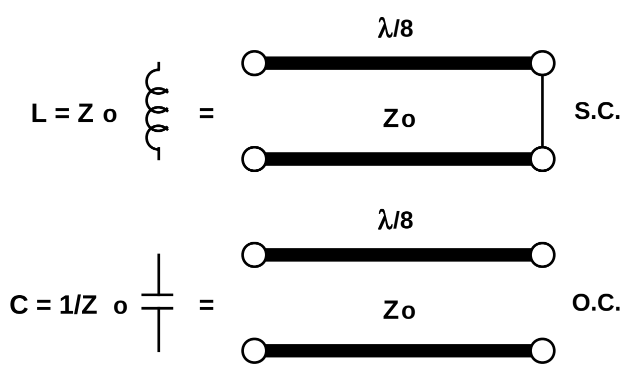

Figure 1. Equivalent Transmission Line Configuration for Lumped Parameters

The λ/8 transmission line sections are called commensurate lines, since they are all the same length in a given filter.

Kuroda's idea is use the λ/8 line of appropriate Z_o to transform awkward or unrealizable elements to those with more tractable values and geometry. As an example, the series inductive stub in the diagram here can be replaced by a shunt capacitive stub on the other end of the λ/8 line, with different values of characteristic impedance determined by

$$N = 1 + \frac{Z_1}{Z_2}$$

For example, consider a prototype network with the values

$L = Z_1 = 0.5$ and $Z_2 = 1$, $N = 1 + \dfrac{Z_1}{Z_2} = 1.5$.

So for the equivalent network, the series transmission line element has $Z = 1.5Z_1 = 0.75$ and the shunt capacitive stub has $Z = 1.5Z_2 = 1.5$. Kuroda's four identities are a means of eliminating series stubs that arise from series L or C in prototype networks.

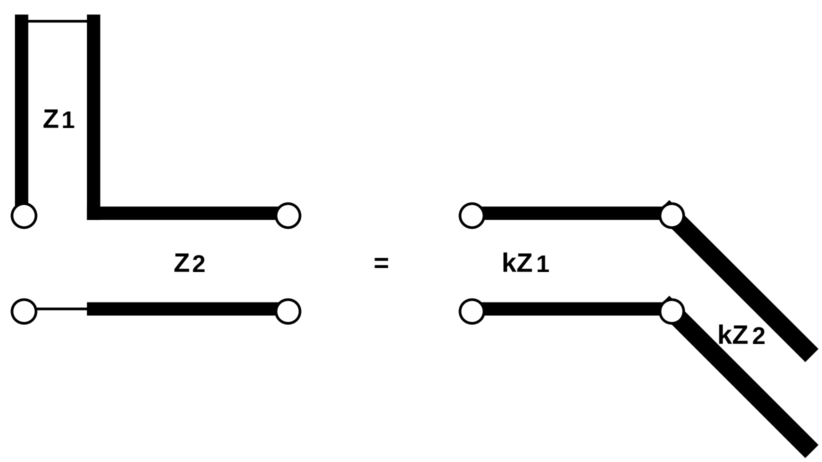

Figure 2. Application of Kuroda's Identities to Transform Series Short Circuit Stub to Parallel Open Circuit Stub

The prototype lowpass *LC* structure employs series inductors, so a direct conversion to transmission line stubs by Richard's transformation would result in series stubs. However, we can use the Kuroda identity for series inductors to create a structure that has only series transmission line sections and shunt open stubs.

In order to do this we must be aware that we should begin by adding unit elements ($\lambda/8$ transmission lines of $Z_o = 1$) at each end of the filter, so that there will be structures that are of the form of the Kuroda identities. The filter is designed by the following steps:

- Lumped element low pass prototype (from tables, typically)
- Convert series inductors to series stubs, shunt capacitors to shunt stubs
- Add $\lambda/8$ lines of $Z_o = 1$ at input and output

- Apply Kuroda identity for series inductors to obtain equivalent with shunt open stubs with λ/8 lines between them
- Transform design to 50Ω and f_C to obtain physical dimensions (all elements are λ/8).

The completed filter in microstrip form looks like this:

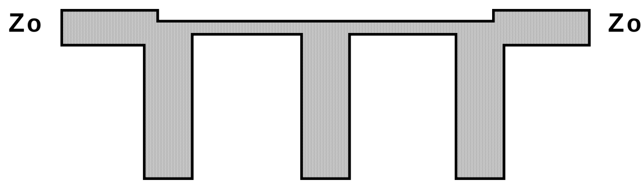

Figure 3. Completed Distributed Filter

III. PROCEDURE

A. Design of the distributed filters

- Design the microstripline filters
- For the 600 MHz filter, use FR-4 or G-10 PCB material. For the KU band filter, use Duroid RO4003 (ε_r =3.38, 60 mils thick, 1 oz. Cu)..
- Determine all waveguide segment impedances

B. Modeling of distributed filters using Agilent ADS

- Model the circuit using ADS and determine $|S_{11}|$ and $|S_{21}|$ on grid plots. Also plot $|S_{11}|$ on a Smith chart.
- Sweep the frequency of operation across the frequency bands of interest
- Remember to define the circuit as a two-port and terminate with the specified load and a perfect match at the input.

C. Comment On Your Results

We will be constructing the low-pass filter at the next scheduled laboratory session.