4th Order Hairpin Bandpass Filter

# Youssef Samwel

# [yo800238@ucf.edu](mailto:yo800238@ucf.edu)

# EEL5437C Microwave Engineering

Prof. Dr. Xun Gong - Section 0012



# Resonator Synthesis

From microwave theory we know that a transmission line terminated with opens on both ends will be resonant at half the guided wavelength. The guided wavelength is determined from effective epsilon and trace characteristic impedance. For this filter, the desired resonance was at 3.6 GHz; given this constraint we can compute the guided wavelength of a microstrip transmission line using the following method.

The first critical step in the synthesis of the resonator is determining the copper trace width. To compute the dimensions of microstrip line I used an online calculator [https://www.pasternack.com/t-calculator-microstrip.aspx] and was able to compute a width of 1.78mm for a 50 transmission line.

Given that the substrate is a Roger’s RO4003C with a dielectric constant of 3.55 and height of 31 mil (.7874 mm); we can compute the effective dielectric constant using the following equation,

Now we can compute the ideal resonator length,

Given this information we can simulate the resonator in HFSS, the following is resonator structure,

A green and yellow road

Description automatically generated

Initial Resonator Structure

The following are the dimensions of the structure: Trace width: 1.78 mm, Probe length: 11.03 mm, Resonator length: 24.96 mm, substrate thickness: 31 mil, substrate width: 16mm, substrate length: 50mm.

The following is S21 dB plot of the resonator,

A graph with red lines

Description automatically generated

Initial S21 dB Plot

It is apparent that the resonator center frequency is not 3.6 GHz but 3.442 GHz. This is due to assumption that were made in previous computations. The previously computed resonator length did not account for edge effects. To resolve this issue, we can adjust the resonator length to reach the desired frequency. In this case to increase the center frequency, we need to shorten the resonator length.

|  |  |
| --- | --- |
| Length | Center Frequency |
| 24.96 | 3.442 |
| 24.52 | 3.6105 |
|  |  |

A graph with a red line

Description automatically generated

We now can move to the hairpin resonator structure,

A green square with a yellow letter on it

Description automatically generated

Initial Hairpin Structure

I arbitrarily decided to make the gap 24% of total length and the lines

A graph of a graph

Description automatically generated

A graph of a graph

Description automatically generated  
 A graph with lines and numbers

Description automatically generated

3.6 GHz, Ripple BW = 0.24 GHz, Fourth Order, Hair Pin Structure, S11 in the ripple bandwidth: < -15 dB

Friday - 11/17/2023

The following is the design Chebyshev table,

A screenshot of a computer screen

Description automatically generated

Low pass prototype



A graph with a line

Description automatically generated

Saturday 11/18/2023

Goal: bandwidth prototype and begin filter T-line transformation.

A graph with blue lines

Description automatically generatedA graph of a graph

Description automatically generated

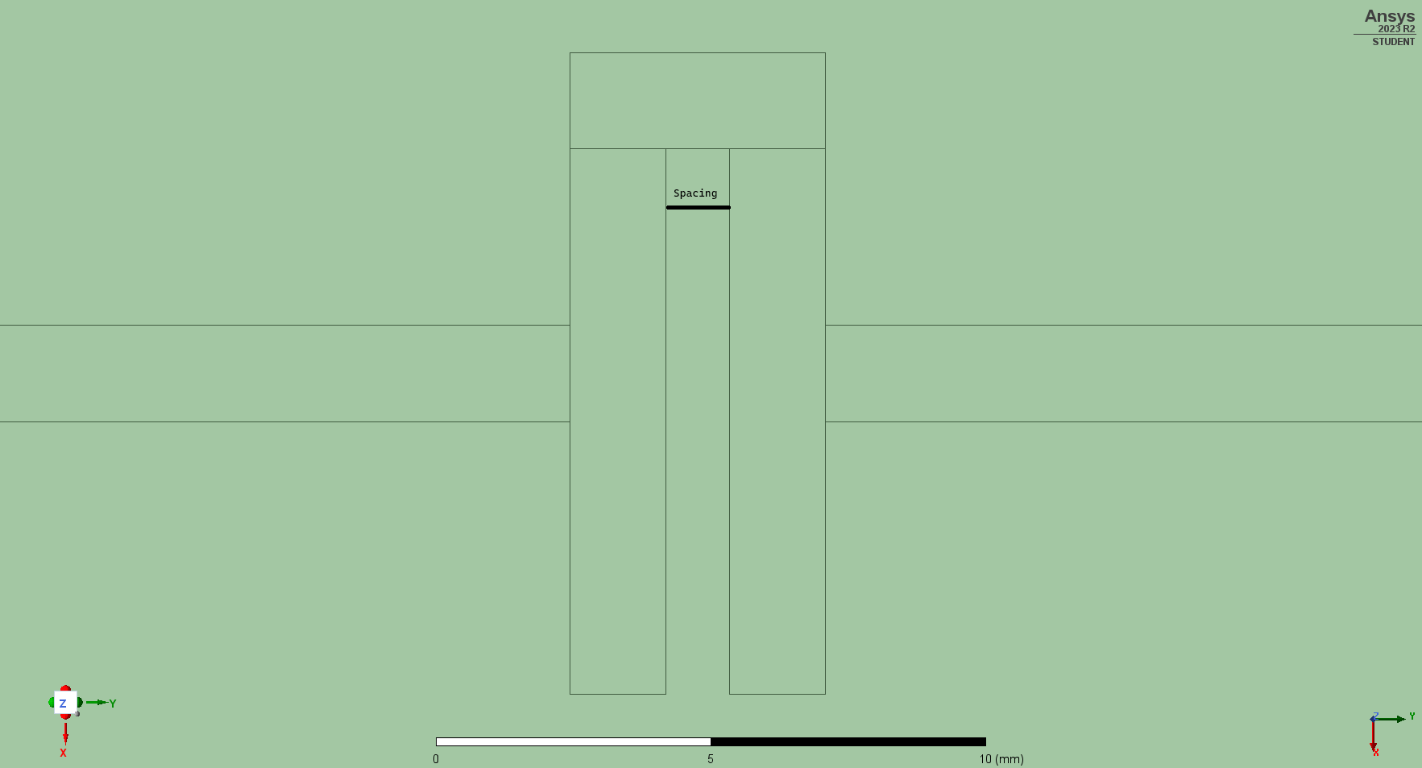
[Resonator Tuning]

A green square with a line on it

Description automatically generated with medium confidence

Initial Resonator Structure

The resonator was initially configured with a total length of λ/2; however, determining the optimal internal coupling to 3.6 GHz necessitated clarification of the appropriate spacing inside the resonator. To address this, I conducted a simulation sweep ranging from 0.1mm to 2mm, with increments of 0.025mm, in order to identify the desired spacing. The following is HFSS simulation of the sweep.

A graph of colored lines

Description automatically generatedTo ascertain the optimal spacing length, we can construct the following design chart and interpolate the spacing values accordingly.

Simulation Sweep

A graph with a line

Description automatically generated

|  |  |
| --- | --- |
| Spacing (mm) |  |
| 3.7480 | 3.798 |
| 4.2977 | 3.600 |
| 4.3726 | 3.573 |
| 4.9973 | 3.404 |
| 5.6219 | 3.349 |
| 6.2466 | 3.256 |
| 6.8713 | 3.207 |
| 7.4959 | 3.170 |

Running the simulation using a spacing of 4.2977 mm (0.172) yielded an plot centered at 3.6 GHz.

A graph of a graph

Description automatically generated

dB Plot

A graph of a function

Description automatically generated

dB Plot

[Qext synthesis]

A graph with different colored lines

Description automatically generated

offset = 1.8mm

A graph with lines and dots

Description automatically generated

offset = 2.1mm

A graph with lines and dots

Description automatically generated

offset = 2.4mm

A graph with different colored lines

Description automatically generated

offset = 2.7mm

A graph of a graph

Description automatically generated with medium confidence

offset = 3mm

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Offset (mm) |  |  |  |  |  |  |  |
| 1.8000 | 4.007 | -7.44 | 3.92 | -97.44 | 4.091 | 82.56 | 23.43275 |
| 2.1000 | 4.018 | -8.05 | 3.912 | -98.05 | 4.122 | 81.95 | 19.13333 |
| 2.4000 | 4.028 | -6.67 | 3.907 | -96.67 | 4.149 | 83.33 | 16.64463 |
| 2.7000 | 4.012 | 0.07 | 3.871 | -89.93 | 4.15 | 90.07 | 14.37993 |
| 2.8521 | 4.023 | -3.44 | 3.876 | -93.44 | 4.172 | 86.56 | 13.59122 |
| 2.8600 | 4.018 | -0.11 | 3.868 | -90.11 | 4.166 | 89.89 | 13.48322 |
| 3.0000 | 4.023 | 0.24 | 3.863 | -89.76 | 4.182 | 90.24 | 12.61129 |

The desired are computed from Chebyshev table in the following method,

Simulation extrapolation for optimal offset,

A graph of a graph

Description automatically generated

[Coupling K simulation]

A graph of a graph

Description automatically generated

First HFSS Sweep

A graph of a graph

Description automatically generated with medium confidence