Title: Triangular Taper Line Design
Course: Microwave Engineering - 01205322
Tools: Sonnet, TXLine2003, EasyEDA, JLCPCB
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Introduction

This work designs a **Triangular taper transmission line** and compares **10-section** and **20-section** implementations. The process follows a practical engineering workflow from impedance calculation to simulation and PCB fabrication.

Design Overview (workflow)

1. Compute impedance profile (Triangular taper)
2. Sonnet **netlist** simulation (10 vs 20 sections)
3. Convert impedance → physical dimensions using **TXLine2003** (W, L, and CPW-G spacing)
4. Sonnet **geometry** simulation (20 sections)
5. Export to PCB layout (EasyEDA) and fabricate via JLCPCB

Impedance profile method

We generate the taper impedance using a **Triangular weighting** with an **exponential impedance mapping** from $50\,\Omega$ to $100\,\Omega$.

Midpoint location of each section

$$x_i = \frac{i - \frac{1}{2}}{N}, \qquad i = 1,2,\dots,N$$

Triangular cumulative function (piecewise)

$$G(x) = \begin{Bmatrix} 2x^2 \; if\; 0 \le x \le 0.5 \\ 4x - 2x^2 - 1 \; if\; 0.5 < x \le 1 \end{Bmatrix}$$

Exponential impedance mapping

$$Z(x) = Z_1 \left(\frac{Z_2}{Z_1}\right)^{G(x)}, \quad (Z_1 = 50\,\Omega\,, Z_2 = 100\,\Omega)$$

Worked example (i=1, N=10)

Midpoint position

$$x_1 = \frac{1 - \frac{1}{2}}{10} = 0.05$$

Since x1 ≤ 0.5

$$G(x_1) = 2x_1^2 = 2(0.05)^2 = 0.005$$

Compute impedance

$$Z_1 = 50\left(\frac{100}{50}\right)^{0.005} = 50 * 2^{0.005}$$

Numeric value

$$2^{0.005} = 1.0034717$$

$$Z_1 = 50(1.0034717) = 50.17\,\Omega$$

i	(x_i)	(G(x_i))	(Z_i) (Ω)
1	0.05	0.005	**50.17**
2	0.15	0.045	**51.59**
3	0.25	0.125	**54.53**
4	0.35	0.245	**59.34**
5	0.45	0.405	**65.97**
6	0.55	0.595	**74.5**
7	0.65	0.755	**84.25**
8	0.75	0.875	**91.78**
9	0.85	0.955	**96.96**
10	0.95	0.995	**99.83**

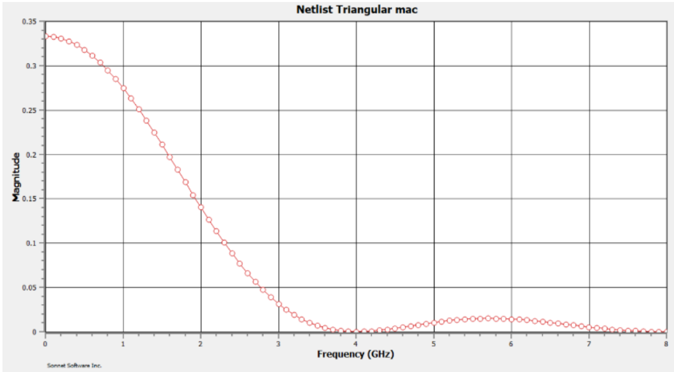
Netlist simulation

The calculated impedances are modeled as cascaded transmission line sections in **Sonnet netlist** to observe ideal electrical behavior.

10 sections

: 10-section taper is close to ideal but still shows ripple / higher reflection.

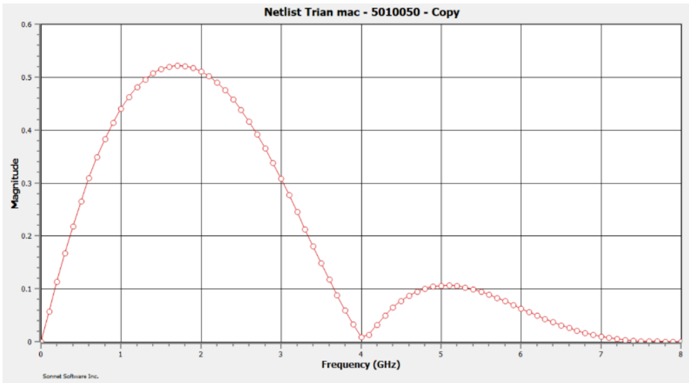
Element	Nodes	Description
Net	1 11	Main Network
TLIN	1 2	Z=50.17 E=36.0 F=4.0
TLIN	2 3	Z=51.58 E=36.0 F=4.0
TLIN	3 4	Z=54.53 E=36.0 F=4.0
TLIN	4 5	Z=59.25 E=36.0 F=4.0
TLIN	5 6	Z=66.2 E=36.0 F=4.0
TLIN	6 7	Z=75.52 E=36.0 F=4.0
TLIN	7 8	Z=84.38 E=36.0 F=4.0
TLIN	8 9	Z=91.7 E=36.0 F=4.0
TLIN	9 10	Z=96.93 E=36.0 F=4.0
TLIN	10 11	Z=99.65 E=36.0 F=4.0



20 sections

: 20-section taper reduces reflection and becomes smoother / closer to ideal.

Element	Nodes	Description
Net	1 21	Main Network
TLIN	1 2	Z=50.17 E=18.0 F=4.0
TLIN	2 3	Z=51.58 E=18.0 F=4.0
TLIN	3 4	Z=54.53 E=18.0 F=4.0
TLIN	4 5	Z=59.25 E=18.0 F=4.0
TLIN	5 6	Z=66.2 E=18.0 F=4.0
TLIN	6 7	Z=75.52 E=18.0 F=4.0
TLIN	7 8	Z=84.38 E=18.0 F=4.0
TLIN	8 9	Z=91.7 E=18.0 F=4.0
TLIN	9 10	Z=96.93 E=18.0 F=4.0
TLIN	10 11	Z=99.65 E=18.0 F=4.0
TLIN	11 12	Z=99.65 E=18.0 F=4.0
TLIN	12 13	Z=96.93 E=18.0 F=4.0
TLIN	13 14	Z=91.7 E=18.0 F=4.0
TLIN	14 15	Z=84.38 E=18.0 F=4.0
TLIN	15 16	Z=75.52 E=18.0 F=4.0
TLIN	16 17	Z=66.2 E=18.0 F=4.0
TLIN	17 18	Z=59.25 E=18.0 F=4.0
TLIN	18 19	Z=54.53 E=18.0 F=4.0
TLIN	19 20	Z=51.58 E=18.0 F=4.0
TLIN	20 21	Z=50.17 E=18.0 F=4.0



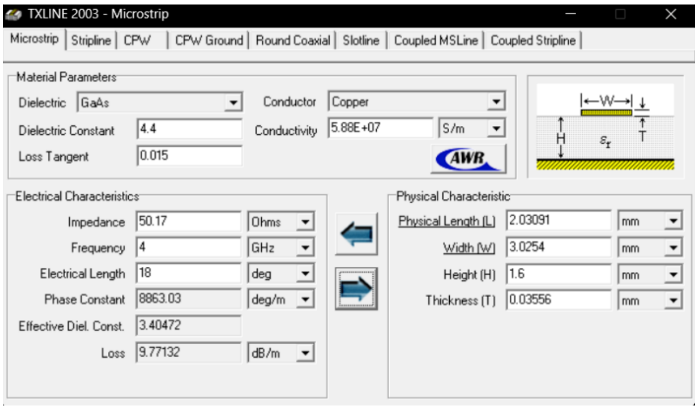
Dimensions + CPW-Ground Spacing

TXLine2003 conversion

The 20-section impedance values are entered into TXLine2003 to obtain physical dimensions under the same substrate settings.

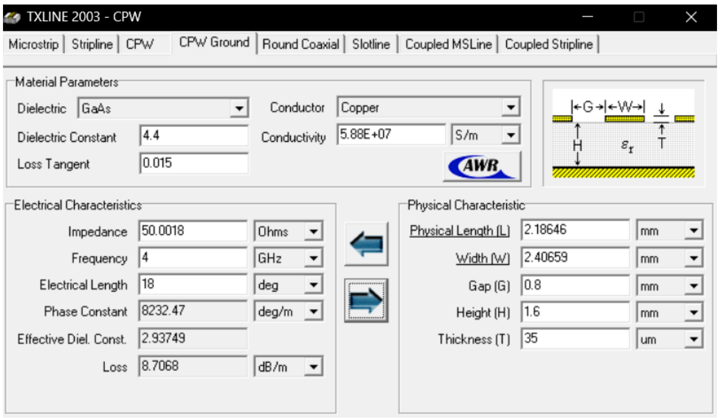
Main outputs used

- Signal width W
- Section length L



Impedance	W	L
50.17	3.0254	2.03091
51.58	2.88555	2.03577
54.53	2.61826	2.04565
59.25	2.25101	2.06064
66.2	1.81633	2.08099
75.52	1.37343	2.10539
84.38	1.05728	2.12572
91.7	0.85265	2.1407
96.93	0.731103	2.1506
99.65	0.674795	2.15554

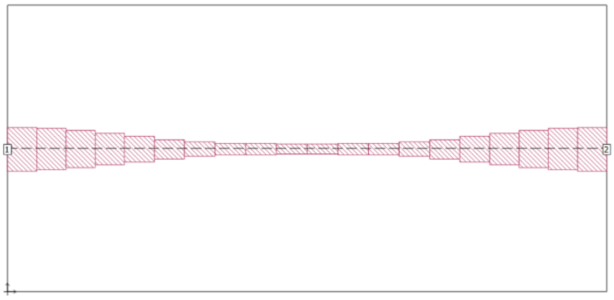
- **For CPW with ground (CPWG): spacing S between the center conductor and both ground conductors (two side grounds)**

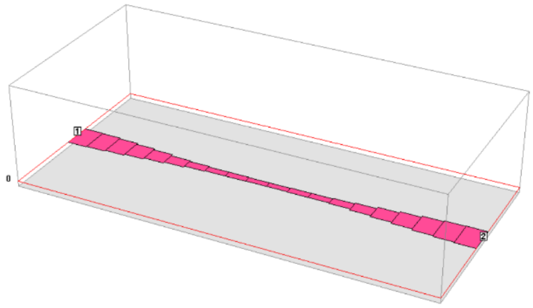


Sonnet Geometry Simulation (20 Sections)

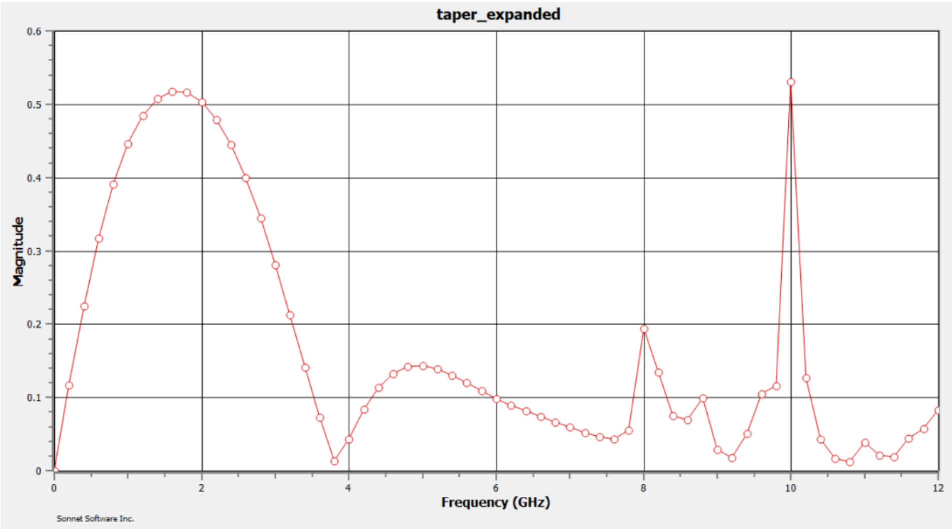
Geometry simulation

The physical widths and lengths from TXLine2003 are used to draw the actual geometry in Sonnet and simulate the EM response.



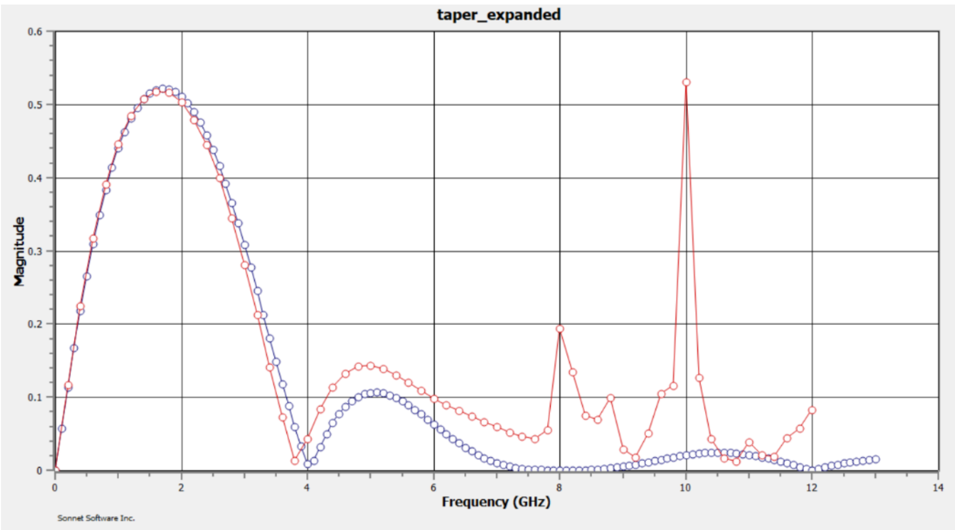


-S-parameter plot from geometry simulation



Comparison

Netlist and geometry results are compared for the 20-section design. The trends are consistent, while small differences are expected due to physical discontinuities and EM effects in real layout.



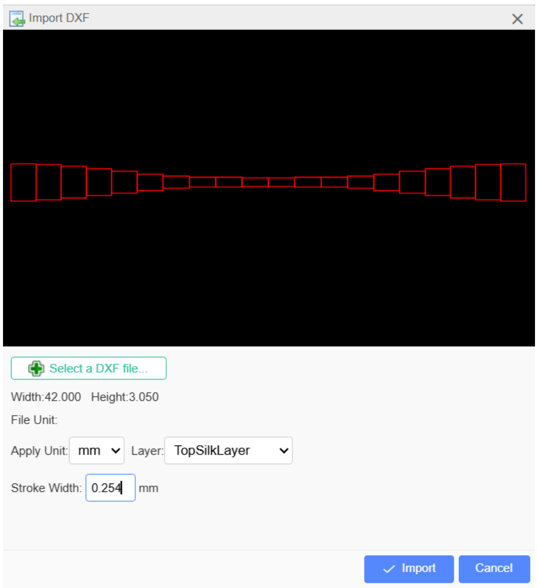
EasyEDA PCB Layout → JLCPCB

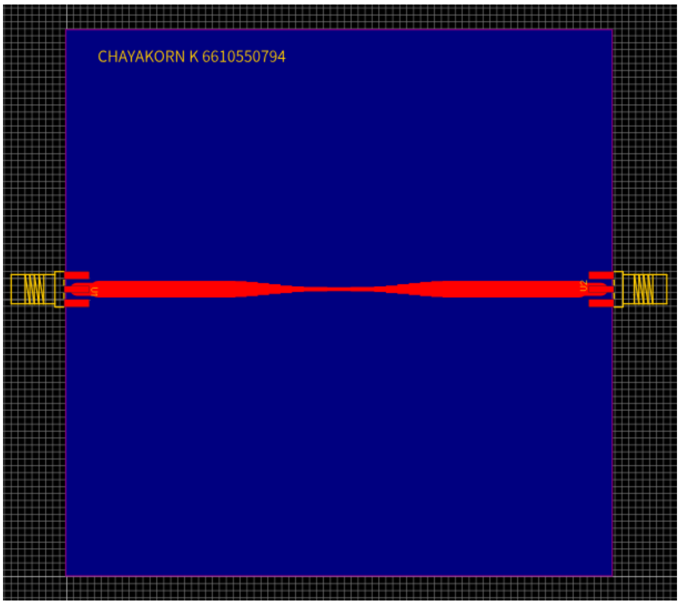
Layout creation

The final shape is exported from Sonnet (DXF) and imported into EasyEDA.

Steps

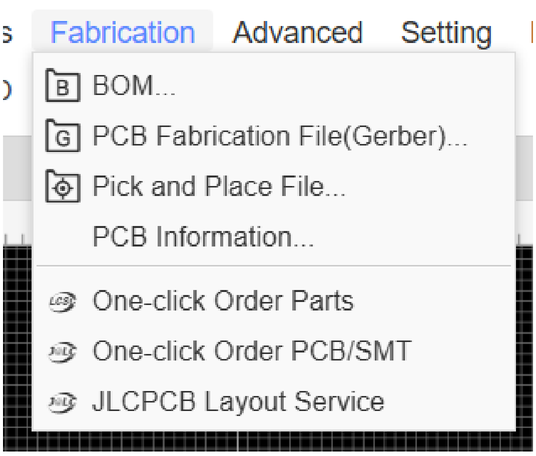
- Import the DXF into **Top Layer**
- Board size: **100 mm Ĭ 100 mm**
- Route copper trace from connector/port into the taper
- Add CPW-ground copper using the spacing from TXLine
- Draw the ground on board

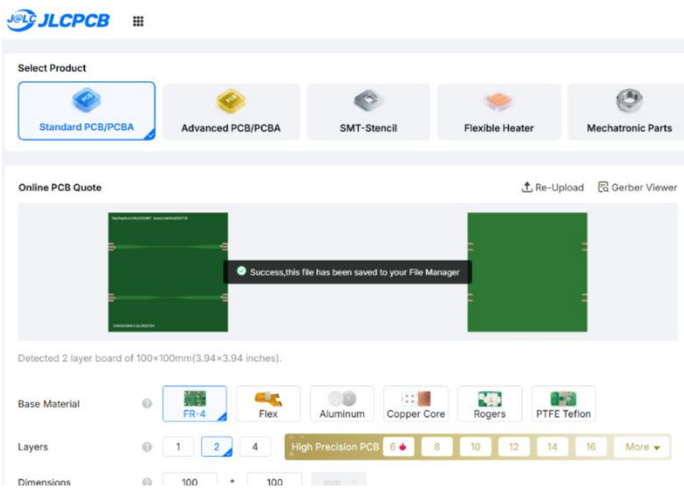




Fabrication

The PCB is sent to fabrication using EasyEDA ŕOne-Click to Fabricationà





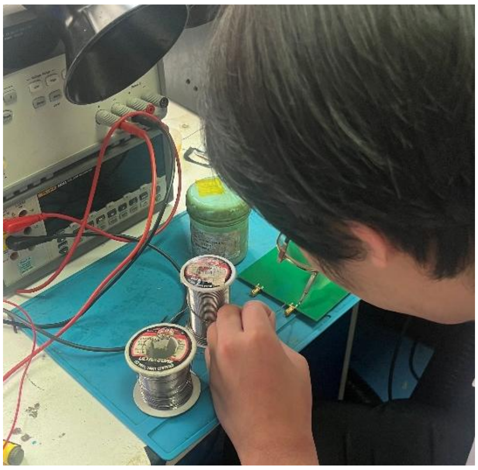
PCB Measurement

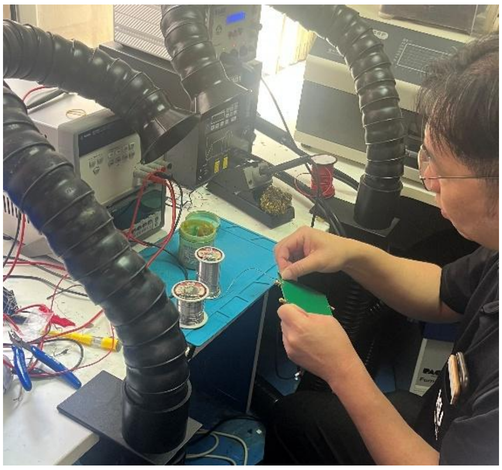
PCB Fabrication

This Figure shows the fabricated PCB of the triangular taper line before soldering the connectors. The tapered transmission line was implemented with a continuous change in line width according to the triangular taper profile. This geometry is consistent with the design used in the Sonnet simulation

Connector Soldering

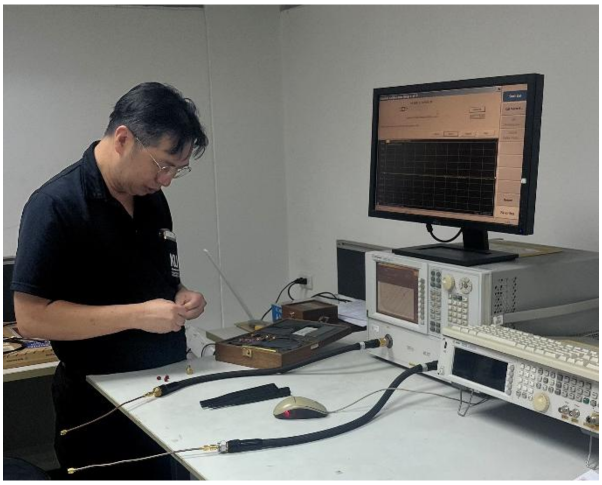
The SMA connectors were soldered onto the PCB under the supervision of the instructor. Proper soldering is important to ensure good electrical contact and to reduce unwanted effects during measurement.





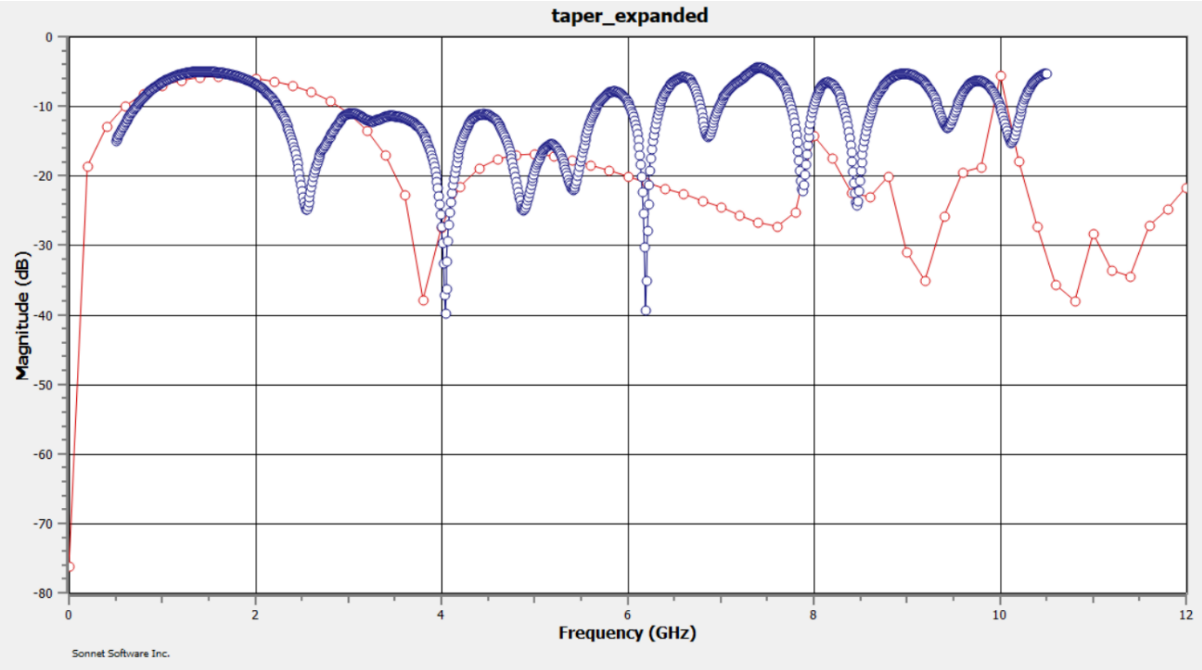
Measurement

The fabricated triangular taper line PCB was measured using a Vector Network Analyzer (VNA). The measurement was performed by connecting coaxial cables to both ports of the PCB. The measured S-parameter magnitude represents the real performance of the taper line, including fabrication and measurement effects.



Comparison

The measured results are compared with the Sonnet geometry simulation results (red curve) for the 20-section design. The overall trends are in good agreement, showing similar frequency response behavior. Small differences in magnitude and frequency shift are observed, which are expected due to fabrication tolerances, connector effects, and other practical factors in the real measurement.



Summary

The comparison confirms that the Sonnet geometry simulation provides a good prediction of the triangular taper line behavior. The measured results show the real performance of the fabricated PCB and include practical effects that are not fully modeled in the simulation.