



Project Report

Title TAPERED LINES Sec 450

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Submitted to

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Preface

This report is prepared as part of the Microwave Engineering (01205322) course. The objective of this report is to present the design, simulation, implementation, and analysis of a symmetric two-port tapered microstrip line transformer, which focuses on impedance matching techniques in microwave frequency applications. The project covers the theoretical background, design methodology, simulation procedures, and the results obtained from both electromagnetic simulation and practical fabrication.

The author would like to express sincere gratitude to Asst. Prof. Dr.Denchai Worasawate ,Ph.D. for his valuable knowledge, guidance, and continuous support throughout the course.

Furthermore, the author hopes that this report will be beneficial to students and readers who are interested in microwave engineering, particularly in the design and implementation of tapered transmission line transformers. Any suggestions, comments, or feedback for improvement are warmly welcomed, and the author apologizes in advance for any unintentional errors or omissions in this report.

Prepared by

Group 1

Project Procedures

This project was carried out by following a structured microwave engineering design workflow, starting from the problem definition and ending with physical PCB implementation. The complete process includes conceptual design, circuit-level modeling, electromagnetic simulation, transmission-line realization, PCB layout, and preparation for fabrication and measurement.

1. Project Specification and Problem Definition

The project requirement, shown in **Figure 1**, specifies the design of a symmetric two-port tapered-line transformer. At Port 1, a taper converts a $50\text{-}\Omega$ impedance to $100\text{-}\Omega$. Instead of terminating the line with a $100\text{-}\Omega$ load, an identical mirrored taper is connected, which transforms the impedance back from $100\text{-}\Omega$ to $50\text{-}\Omega$ at Port 2. As a result, the overall structure can be represented as a $50\text{ }\Omega \rightarrow 100\text{ }\Omega \rightarrow 50\text{ }\Omega$ network.

The most important design constraint is that the **first null of the reflection coefficient (S_{11})** must occur at **3 GHz**, indicating good impedance matching at the target frequency.

Class project:

“The structure is a symmetric two-port tapered-line transformer. At Port 1, a taper converts $50\text{ }\Omega$ to $100\text{ }\Omega$. Instead of a $100\text{-}\Omega$ load, the line is connected to another identical taper that converts the $50\text{-}\Omega$ impedance at Port 2 up to $100\text{ }\Omega$. The two tapers meet at their $100\text{-}\Omega$ ends, so the overall network is a $50\text{-}\Omega$ -to- $100\text{-}\Omega$ taper cascaded with a $100\text{-}\Omega$ -to- $50\text{-}\Omega$ taper.”

The 1st null of S_{11} is at 3GHz.

Figure 1: Project specification showing the symmetric tapered-line transformer structure.

2. Hanning-Windowed Multisection Transmission-Line Design

After understanding the specification, a multisection tapered transmission-line approach was selected instead of a stepped transformer. A tapered structure provides a gradual impedance transition, significantly reducing reflections and improving bandwidth.

To achieve controlled sidelobe behavior and smooth impedance variation, the multisection transmission-line network was designed to behave like a **Hanning-windowed transformer**. The Hanning window is commonly used in signal processing to suppress sidelobes, and the same concept can be applied to microwave impedance matching by properly shaping the impedance profile along the line.

In this design, the characteristic impedance increases gradually from 50Ω toward 100Ω near the center of the structure and then decreases symmetrically back to 50Ω . The impedance values follow an exponential taper modified by Hanning weighting, ensuring smoother transitions near the input and output ports and stronger variation near the center.

Element	Nodes	Description
Net	1 21	Main Network
TLIN	1 2	Z=50.8 E=36.0 F=4.0
TLIN	2 3	Z=53.25 E=36.0 F=4.0
TLIN	3 4	Z=58.3 E=36.0 F=4.0
TLIN	4 5	Z=65.85 E=36.0 F=4.0
TLIN	5 6	Z=74.0 E=36.0 F=4.0
TLIN	6 7	Z=82.35 E=36.0 F=4.0
TLIN	7 8	Z=89.9 E=36.0 F=4.0
TLIN	8 9	Z=95.5 E=36.0 F=4.0
TLIN	9 10	Z=98.45 E=36.0 F=4.0
TLIN	10 11	Z=99.65 E=36.0 F=4.0
TLIN	11 12	Z=99.65 E=36.0 F=4.0
TLIN	12 13	Z=98.45 E=36.0 F=4.0
TLIN	13 14	Z=95.5 E=36.0 F=4.0
TLIN	14 15	Z=89.9 E=36.0 F=4.0
TLIN	15 16	Z=82.35 E=36.0 F=4.0
TLIN	16 17	Z=74.0 E=36.0 F=4.0
TLIN	17 18	Z=65.85 E=36.0 F=4.0
TLIN	18 19	Z=58.3 E=36.0 F=4.0
TLIN	19 20	Z=53.25 E=36.0 F=4.0
TLIN	20 21	Z=50.8 E=36.0 F=4.0

Figure 2: Multisection transmission-line impedance profile designed to behave as a Hanning-windowed transformer.

3. Circuit-Level Simulation and Ideal Transformer Verification

Once the Hanning-windowed multisection impedance profile was defined, the circuit-level model was constructed using a Sonnet netlist. Each section was modeled using a TLIN element with a specific characteristic impedance and a short electrical length.

The reflection coefficient $|S_{11}|$ was simulated to verify that the multisection network behaves similarly to an ideal Hanning-windowed transformer. The simulation results show a smooth reflection response with suppressed sidelobes and a **first null occurring at approximately 3 GHz**, satisfying the project requirement.

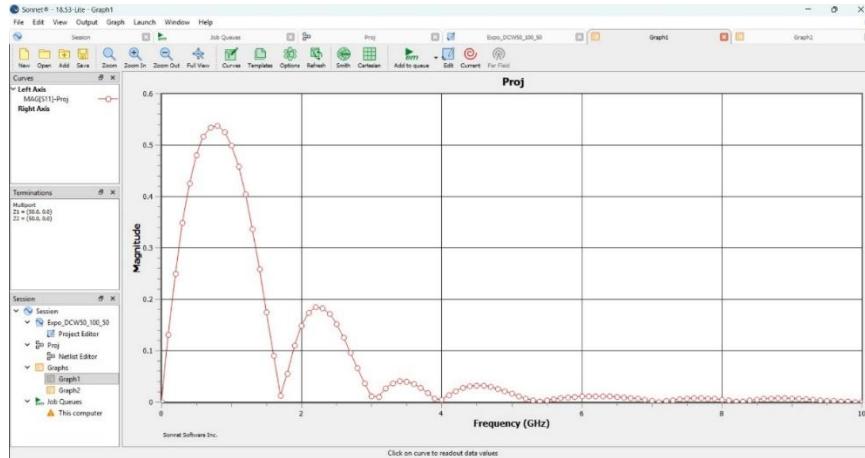


Figure 3: Circuit-level Sonnet simulation showing $|S_{11}|$ response consistent with an ideal Hanning-windowed transformer.

4: Conversion to Physical Microstrip Dimensions

After verifying the netlist results, the TLIN parameters were converted into physical microstrip dimensions using TXLINE 2003.

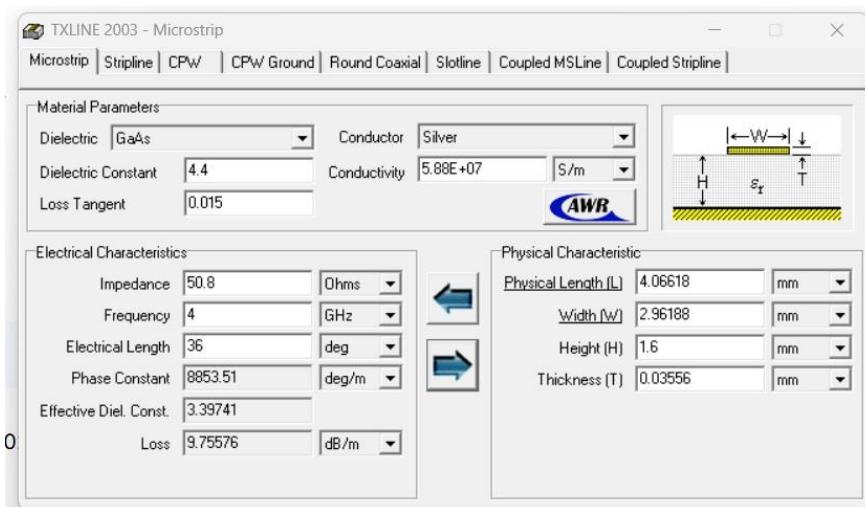


Figure 4: TLIN-to-microstrip conversion using TXLINE.

5. Calculation of Physical Length and Width of Each Section

TXLINE was used to calculate the **physical length and width** of each microstrip section corresponding to the designed characteristic impedance values. Lower-impedance sections resulted in wider microstrip traces, while higher-impedance sections resulted in narrower traces.

Each section was assigned an electrical length of **36 degrees at 4 GHz**, which is sufficiently short to approximate a continuous taper while keeping the total number of sections manageable.

	LENGTH	WIDTH
1	4.06618	2.96188
2	4.08282	2.73028
3	4.1154	2.3196
4	4.16002	1.83576
5	4.20325	1.43691
6	4.24259	1.12238
7	4.2743	0.898954
8	4.2959	0.762527
9	4.30675	0.699094
10	4.31107	0.674795
11	42.05828	15.44218
12	LENGTH	WIDTH

Figure 5: Calculated physical length and width of each microstrip section.

6. Electromagnetic Layout in Sonnet

Using the calculated physical dimensions, the tapered transmission line was drawn in Sonnet's geometry editor. Only half of the structure was drawn initially, after which it was copied and mirrored to form a symmetric layout. A full electromagnetic (EM) simulation was then performed with a frequency sweep from 0 to 8 GHz using a step size of 0.2 GHz. The EM simulation results closely matched the circuit-level netlist results from 0 to 7 GHz, confirming that the physical implementation accurately represents the designed taper.

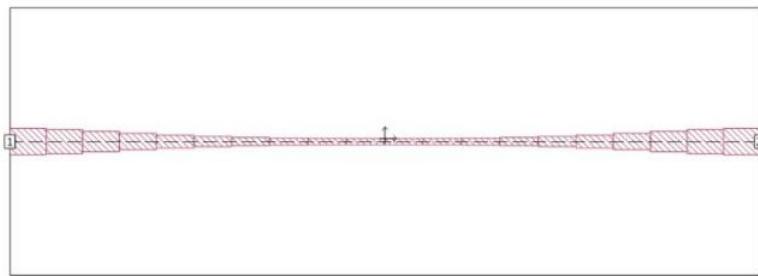


Figure 6: layout of the symmetric tapered microstrip transformer in Sonnet.

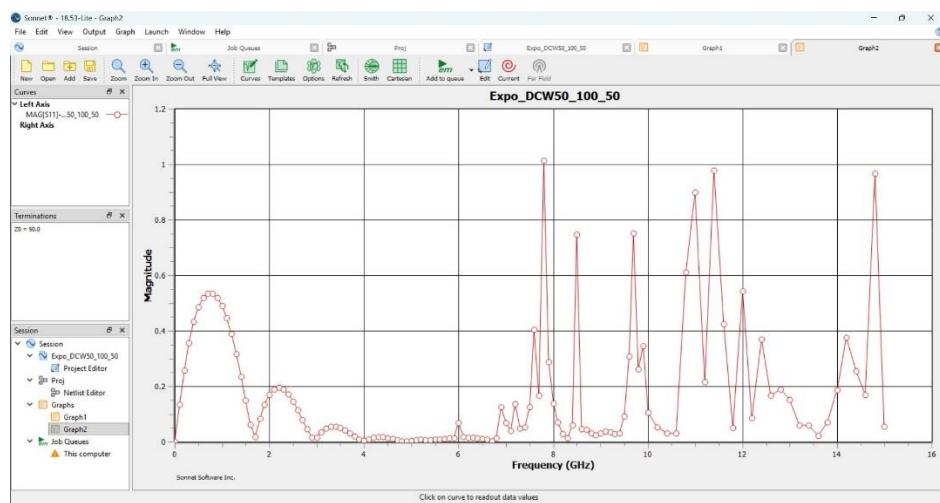


Figure 7: Graph of the symmetric tapered microstrip transformer in Sonnet.

7.PCB Fabrication

Once acceptable simulation results were obtained, the Sonnet geometry was exported as a **DXF file** and imported into **EasyEDA**. The tapered microstrip shape was placed on the top copper layer, and SMA connector pads were added at both ports. The final design was fabricated using **JLCPCB**.

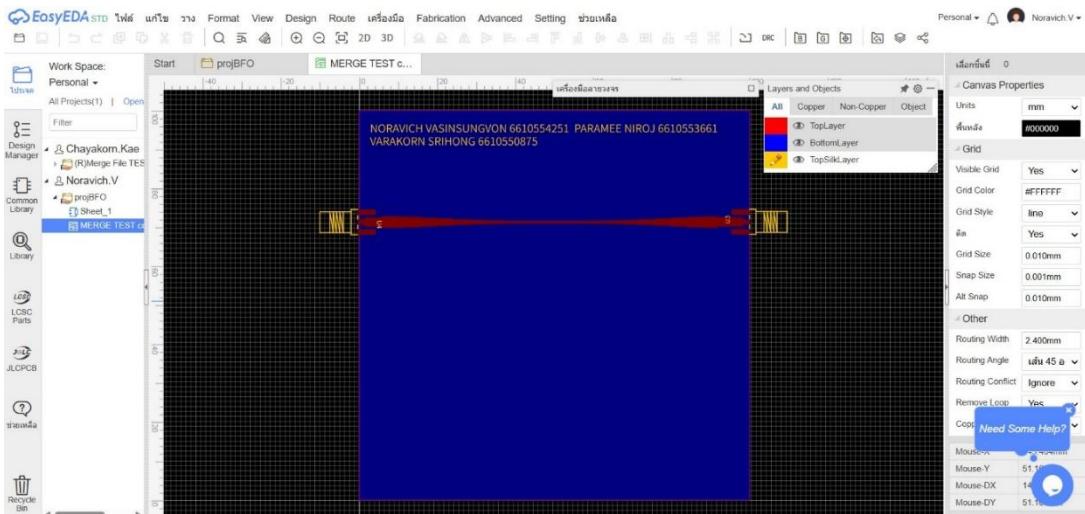


Figure 8: PCB layout of the symmetric tapered transformer implemented in EasyEDA.

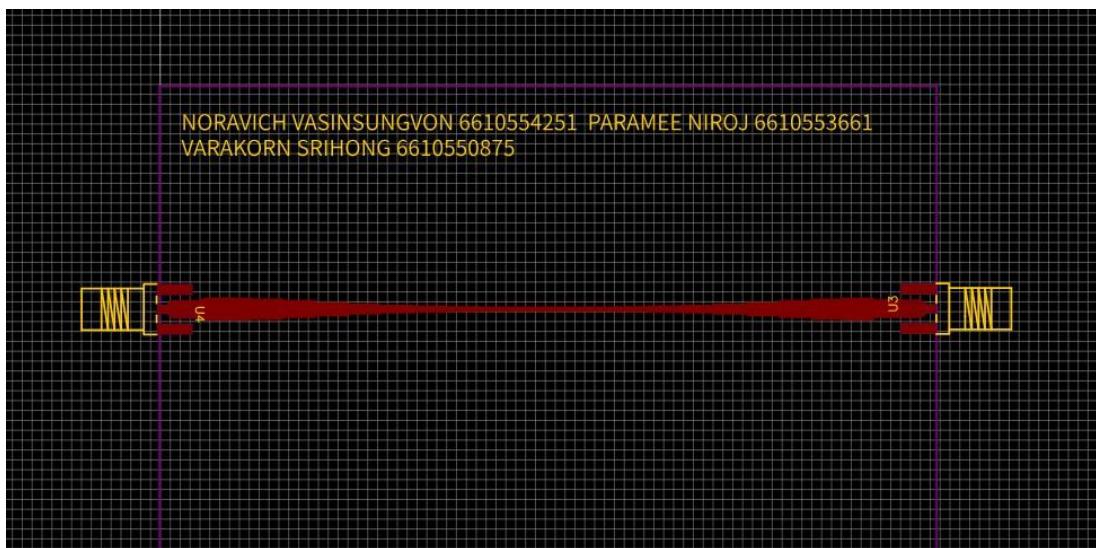


Figure 9: Final PCB realization of the symmetric tapered microstrip transformer.



Figure 10: Fabricated PCB

10. Connector Soldering

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 such as extra loss or reflections during measurement.

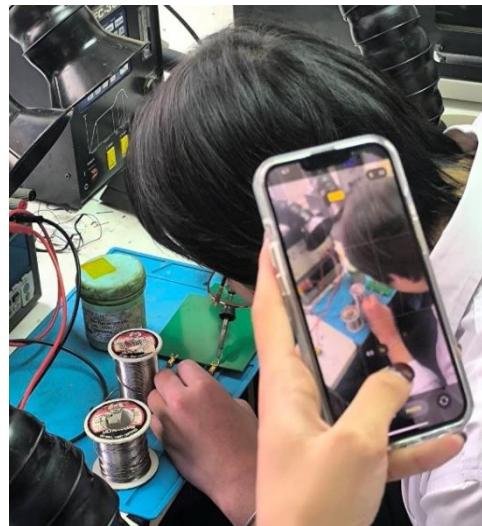


Figure 10: Solder connector to the PCB

11. Measurement

The fabricated PCB was measured using a Vector Network Analyzer (VNA). Coaxial cables were connected to both ports through the SMA connectors. The measured S-parameters represent the real performance of the tapered transmission line.



Figure 11: Solder connector to the PCB

Comparison

The measured results were compared with the Sonnet simulation results. Overall, the measured and simulated responses show similar trends across the frequency range. Small differences in magnitude and frequency are observed.

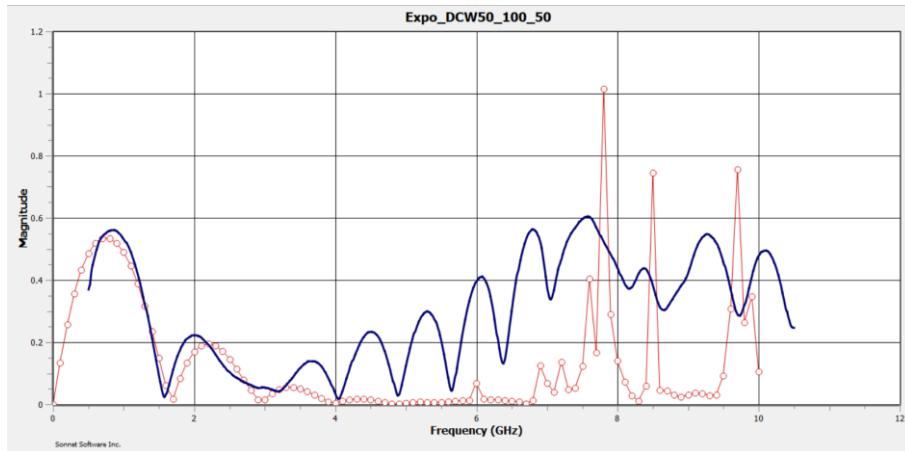


Figure 11: Graph from real and simulated measurement

Summary

The comparison demonstrates that the Sonnet geometry simulation provides a reliable prediction of the tapered transmission line behavior. The measured results confirm the effectiveness of the taper design while also highlighting practical effects introduced during fabrication and measurement. These results validate the overall design methodology and implementation of the tapered transmission line.