

Electromagnetics I

Course Project Report

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EECE – 3600.201

Electromagnetics I Final

Submission Date: 4/27/2026

Due Date: 4/29/2026

I. Abstract

This project focuses on designing a single short-circuited stub impedance matching network using CST Studio at an operating frequency of 4 GHz. The system consists of a 50 Ω transmission line feeding a load impedance of $Z_L = 3 - j10\ \Omega$. The goal is to eliminate reflections by matching the load to the line. Using CST schematic simulation, the optimal stub location and length were determined. The guided wavelength was $\lambda = 5$ cm, and the results confirmed proper matching, as evidenced by Smith Chart visualization and minimal reflections.

II. Introduction

Transmission lines are widely used in RF and microwave systems to transfer power efficiently from a source to a load, such as an antenna. At high frequencies, impedance mismatches between the transmission line and the load cause reflections, reducing power delivery and system efficiency.

The goal of impedance matching is to ensure that:

$$Z_{in} = Z_0 = 50\ \Omega$$

When this condition is satisfied, maximum power is delivered to the load and reflections are eliminated.

In this project, a single shunt short-circuited stub is used for matching. The system operates at 4 GHz, where the guided wavelength is:

$$\lambda = 5\ \text{cm}$$

The load impedance is:

$$Z_L = 3 - j10\ \Omega$$

Because the load has both resistive and reactive components, it cannot be directly matched. A stub is introduced at a specific distance d from the load. The purpose of this stub is to introduce a reactive component that cancels the imaginary part of the admittance at that point.

Equations

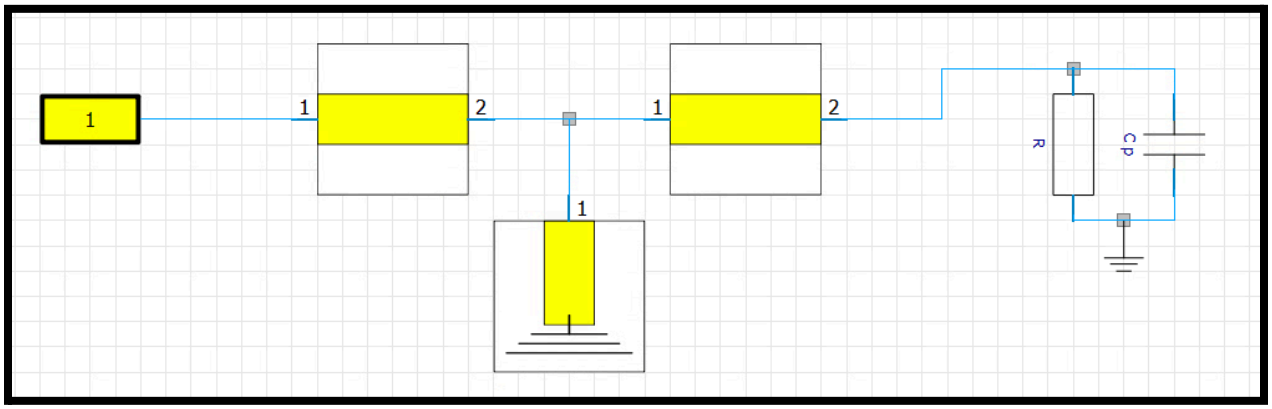
The calculated epsilon of the transmission line was found with the following formulas:

- **Equation 1**: $Vp = f\lambda$
  - *Equation 1* was utilized to calculate the wave speed V_p
- **Equation 2**: $C = \frac{1}{\sqrt{\varepsilon_r}}$
  - *Equation 2* was utilized to solve for ε_r
- **Equation 3**: $\omega = 2\pi f$
  - *Equation 3* was utilized to calculate the angular frequency of the transmission line
- **Relationship 1**: $\varepsilon_r = \left(\frac{c}{f\lambda}\right)^2$

- *Relationship 1* utilizes both *Equation 1* and *Equation 2* to solve for ε_r

III Circuit Description

Transmission Line with Shunt Stub



IV Measurement Results

Table 1. Parameters

Parameter	Measured	Calcualted
Angular Frequency (ω)		$8\pi \times 10^9$ rad/s
Wave Velocity (V_p)		2×10^8 m/s
Load Admittance (Y_L)		$\frac{3+10j}{109}$ S
Load Impedance (Z_L)		$3 + 10j\ \Omega$
Load Capacitance (C_L)	3.65 pF	
Load Resistance (R_L)	$36.\overline{33}\ \Omega$	

Load Distance from Stub (D_{stub})	2.8451 cm	
Length of Stub (L_{stub})	2.3014 cm	

Image 1. Load Only Chart

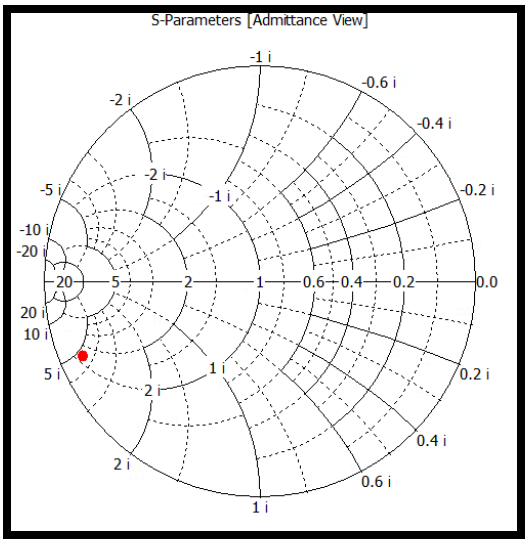


Image 2. D_{stub} Admittance Chart

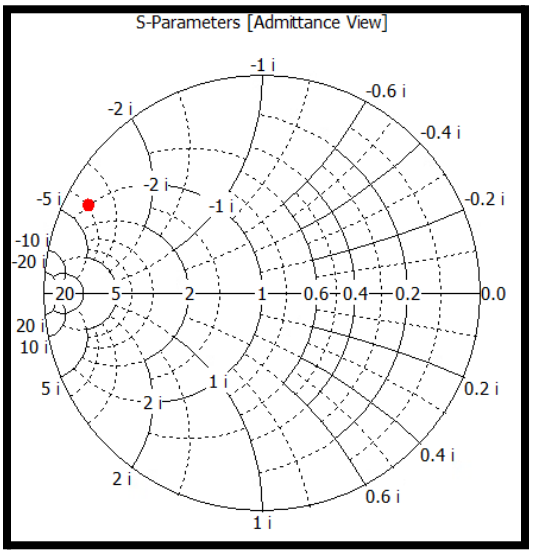


Image 3. L_{stub} Admittance Chart

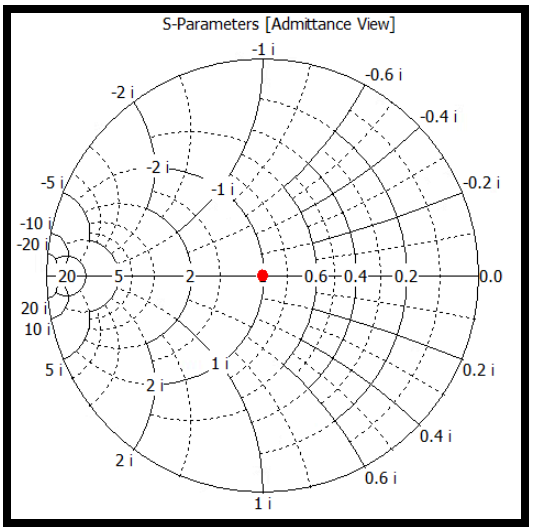


Image 4. All-Section Impedance Chart

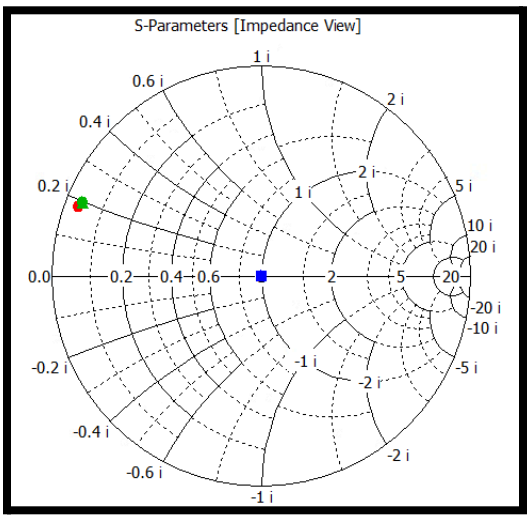


Image 4 shows the Impedences closely matched with some margin of error

V Discussion

Impedance matching is a fundamental concept in high-frequency systems, and in this project, a single-stub matching network was used to achieve this objective. The system began with a clear mismatch between the transmission line and the load, meaning that a portion of the signal would have been reflected back toward the source rather than delivered efficiently. Using CST Studio, this mismatch was systematically corrected by introducing a short-circuited stub at a carefully chosen position along the line.

The process of arriving at the final design shows how transmission lines do more than simply carry signals; they actively transform impedance as a function of distance from the load. As you move along the line, the impedance seen at any given point changes in a predictable way. This allowed the system to be adjusted until the impedance reached a state in which its real component matched that of the transmission line, leaving only a reactive component to address. At that stage, the addition of the stub served a precise purpose: to cancel out that remaining reactive component entirely.

VI Conclusion

Overall, the project demonstrates that impedance matching is not merely a theoretical concept but a practical design process that can be implemented and verified with modern simulation tools. The use of a single stub provides a straightforward yet highly effective method for correcting mismatches in transmission-line systems, underscoring its importance in RF and microwave engineering applications.