

EE3109 Applied Electromagnetics
2024/25 Semester B
Assignment 3

Questions 1 and 2 constitute Assignment 3A; Questions 3-5 constitute Assignment 3B.

1. A low loss transmission line has the following properties: $R' \ll j\omega L'$; $G' \ll j\omega C'$. Find expressions for α , β , v_p and Z_0 for the low loss transmission line; show that these expressions approach the lossless counterparts when $R' \rightarrow 0$ and $G' \rightarrow 0$.
2. A lossless air transmission line has a characteristic impedance of 50Ω and a length of 30mm. The transmission line is terminated with a 100Ω resistor in parallel with a 10 nH inductor. An RF wave of 15 GHz travels along the transmission line.
 - (a) Find Z_L and Γ_L along the transmission line.
 - (b) Find α and β along the transmission line,
 - (c) Write the voltage phasor as a function of distance along the line. Substitute known numerical values into the equation and simplify as much as possible.

Now the input of the transmission line is connected to a microwave source, modelled with an ideal 5V voltage source in series with a generator resistance of $R_g = 75\Omega$.

- (d) Write the voltage phasor as a function of distance along the line. Substitute known numerical values into the equation and simplify as much as possible.

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3. Consider the following circuit, which consists of a 0.4λ air transmission line with a characteristic impedance of $Z_0 = 50\Omega$, connecting a generator with $V_g = 0.5\text{ V}$, $Z_g = 50\Omega$ to the load $Z_L = 30 - j10\Omega$. The generator is tuned to operate at 2.4 GHz.
 - (a) Write the current as a function of position along the transmission line.
 - (b) With the aid of a Smith Chart, design an L-Section which matches the impedance Z_L to the generator impedance of $Z_g = 50\Omega$.
 - (c) Replace the shunt component with a short-circuited transmission line with the aid of a Smith Chart. Determine the electrical length of this transmission line.
 - (d) Due to a change in design, the generator impedance is now changed to $Z_g = 70\Omega$. Add a component (L, C or transmission line section) to transform the input impedance of your match network in (b) to achieve matching to the new generator impedance.
 4. The goal of this question is to design a co-axial transmission line, with an inner and outer conductor radii of a and b respectively.
 - (a) Derive the per-unit-length capacitance and inductance of the co-axial transmission line. (Most of this is done for you in the course notes.)
 - (b) Find the characteristic impedance and phase velocity of the lossless co-axial transmission line.
 - (c) For a dielectric material with $\epsilon_r = 2.2$, design a co-axial TL with $Z_0 = 75\Omega$. Choose the outer conductor radius to be the same as that for an RG-59 cable.
 5. **(10% BONUS)** Prove that one can find the admittance point on the Smith Chart at a location diametrically opposite (same distance from the origin, but in the opposite direction) to the impedance point. Hint: remember the Smith Chart's relationship with the reflection coefficient.