Assignment - 1
EE340: Electromagnetic Theory

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1. You are asked to design a two-wire transmission line operating at a clock frequency of 2 GHz. The line has the following per-unit-length parameters at the operating frequency:

$$R = 1.5\,\Omega/\text{m}$$
$$L = 350\,\text{nH/m}$$
$$G = 20\,\mu\text{S/m}$$
$$C = 120\,\text{pF/m}$$

   (a) Compute the exact propagation constant $\gamma = \alpha + j\beta$ and characteristic impedance Z_0 for this line at 2 GHz. Provide α in Np/m and, β in rad/m, and Z_0 in Ω.

   (b) Check whether this line can be considered a low-loss line at 2 GHz. Justify your answer.

   (c) If the line can be considered to be low-loss, use the approximate formulas to compute α, β, and Z_0. Compare these data with the exact values obtained in Part (b) and comment on the accuracy.

   (d) Now assume that this line is 5 m long, and it is fed by 100 mW power at its input $z = 0$. The actual power recorded at the 5 m distance from the input of this line is 86.5 mW.

   Using the power-attenuation relation $P(z) = P_0 e^{-2\alpha z}$, calculate the attenuation constant of this line in Np/m, and verify the results using its value computed in Part (a).

   In the next step, express the attenuation constant in dB/m. You may use the following expression to convert the attenuation constant from nepers/m to db/m.

$$\alpha_{\text{dB/m}} = 20\log_{10}(e)\,\alpha_{\text{Np/m}}$$

2. The parallel plate transmission line made up of two perfect conductors is filled with lossless dielectric between the plates. The characteristic impedance of the line is 70Ω, and its phase constant is 3 rad/m at 100 MHz. Calculate the inductance per meter and capacitance per meter for this line.

3. A coaxial cable is to be used for transmitting broadband video signals from DC to 1 GHz. To avoid signal distortion, the cable must satisfy the distortionless condition $R/L = G/C$. The cable has following parameters:

$$L = 300\,\text{nH/m}$$
$$C = 100\,\text{pF/m}$$
$$R = 0.5\,\Omega/\text{m}$$

   (a) For the lossless case ($R = 0$, $G = 0$), calculate the characteristic impedance Z_0 and phase velocity v_p.

(b) Determine the value of G (in S/m) required to make the line distortionless.

(c) Compute α in dB/m at 500 MHz and determine whether it is acceptable for a 50 m long cable, assuming the maximum acceptable total attenuation is 3 dB.

(d) Now consider the same line but with a much smaller $G = 2\,\mu\text{S/m}$ (typical for low-loss dielectric).

- Calculate α and β at 500 MHz using the exact formula.
- Compare with the distortionless case and explain qualitatively how this line would distort a short pulse containing multiple frequency components.

4. A two-conductor transmission line operating at 1 GHz has the following parameters: $R = 50\ m\Omega/m$, $L = 150\ nH/m$, $G = 5.2\ \mu S/m$ and $C = 100\ nF/m$. Find the velocity factor (the ratio of phase velocity of the wave in the line to that of the speed of light in vacuum) for this line. Also determine the value of attenuation constant α (dB/km).

5. It is desired to construct various types of uniform transmission lines using polyethylene ($\varepsilon_r = 2.25$) as the dielectric medium, assuming negligible losses.

(a) Find the distance of separation required for a 300 Ω two-wire line, which would be used for this purpose. The radius of the two conducting wires is 0.6 mm (Figure-1 (i)). For two-wire lines, the relationship between the characteristic impedance (Z_0), distance of separation between lines (D), and the wire radius (a) is given as:

$$Z_0 = \frac{1}{\pi}\sqrt{\frac{\mu}{\varepsilon}}\, ln\left[\frac{D}{2a} + \sqrt{\left(\frac{D}{2a}\right)^2 - 1}\right]$$

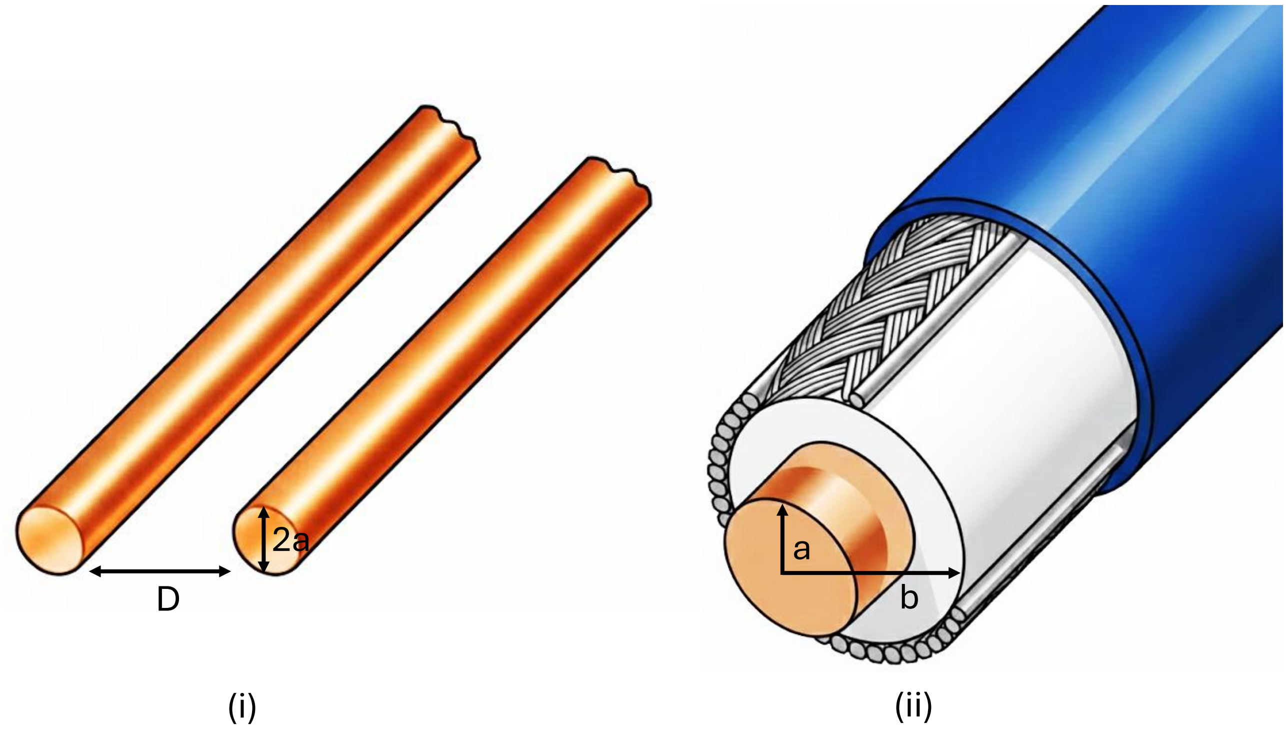

Figure 1: (a) Two Wire Transmission Line; (b) Co-axial Transmission Line

(b) Find the inner radius of the outer conductor (b) for a 75 Ω coaxial line, where the radius of the central conductor (a) is 0.6 mm (Figure-1 (ii)). The formula for Z_0 in terms of its geometrical parameters a and b is:

$$Z_0 = \frac{1}{2\pi}\sqrt{\frac{\mu}{\varepsilon}}\, ln\left(\frac{b}{a}\right)$$

6. Consider a transmission line made of two parallel brass strips ($\sigma_c = 1.6 \times 10^7$ S/m) of width 20 mm and separated by a lossy dielectric slab ($\mu = \mu_0, \varepsilon_r = 3$ and $\sigma = 10^{-3}$ S/m) of thickness 2.5 mm. The operating frequency is 500 MHz. Calculate R, L, G and C per unit length.

7. The parameters of a certain transmission line operating at 6×10^8 rad/s are $L = 0.4\ \mu H/m$, $C = 40\ pF/m$, $G = 80\ mS/m$ and $R = 20\ \Omega/m$.
(a) Find $\gamma, \alpha, \beta, \lambda$ and Z_0. (The symbols have their usual meanings)
(b) If a voltage wave travels 1 m down the line, then by what percent is its amplitude reduced? Also calculate the corresponding shift in phase.