Exam-01 – Transmission Lines (T-lines)[1]

1. A T-line generally has the lumped circuit elements R', G', L', and C'. For a specific T-line considered here, it is $G' = L' = 0$. The propagation constant of a T-line is given by $\gamma = \alpha + j\beta$, where α and β are the loss constant and phase constant, respectively.
   (a) Draw two or three lumped-circuit elements of the T-line and label all objects.
   (b) Calculate α and β.
   (c) Assume $R' = 10^{-3}\ \Omega$ / m and $C' = 1$ pF / m. A sinusoidal signal with amplitude of 10 V and frequency of $f = 1$ MHz is applied to the starting point of the T-line. Calculate the amplitude of the signal at a distance of 10 km.
   (d) The loss constant α depends on frequency f according to $\alpha \propto f^x$. Determine x.
   (e) Provide a narrative explanation (in words) as to why the loss constant α increases with frequency.

2. Assume that the two wires of a T-line are surrounded by only air.
   (a) Can you give an example of such T-line? What are ε_r and μ_r of such T-line?
   (b) What is the phase propagation velocity v_{phase} on such T-line?
   (c) The line frequency of power transmission lines in the US is 60 Hz. Determine the wavelength of a voltage wave with $f = 60$ Hz propagating on the T-line.
   (d) In the laboratory section for this course, we learned that for certain lengths of a T-line, interference effects (standing-wave effects) must be taken into account. For which range of length of a T-line can interference effects be neglected?
   (e) The distance between New York State's Southern tip and Northern tip is about 400 km. Do we need to take into account interference effects of the power T-line within NY State?

3. A voltage signal propagates on a lossless T-line (length = $\ell_{T\text{-line}}$) with a phase velocity of $v_{phase} = 2 f \ell_{T\text{-line}}$, where f is the frequency of the voltage signal.
   (a) Can you express the length of the T-line as a fraction or as a multiple of λ ? (λ = wavelength of voltage signal)
   (b) Assume that the T-line is impedance matched at its input point (starting point). At its output point (ending point), the T-line is (**i**) open circuited (OC), (**ii**) impedance-matched (IM), or (**iii**) short circuited (SC). For these three cases, determine the condition (e.g. virtual OC, virtual SC ...) at the input point of the T-line.

4. Assume that a lossless T-line has a wave impedance of Z_0 and a load impedance of $Z_{Load} = (½)\ Z_0$. A sinusoidal voltage with amplitude V_0^+ is applied to the T-line. Assume that the power applied to the T-line is $(V_0^+)^2 / Z_0$.
   (a) Determine the voltage reflection coefficient at the termination point. Determine the voltage at the load. Determine the power consumed in the load.
   (b) Define the power reflection coefficient. Determine the power reflection coefficient.

[1] Always show your work, always give units, and please write your name on first page.