Homework #10 Solution Set

(25 points - 1 per problem)

1. *List the ways that a transmission line can lose signal. Which of these ways could cause interference with other systems*?

   A transmission line can lose signal through Ohmic loss (conductor loss) and radiation. Radiation loss is caused by poor shielding and could lead to interference with other systems.

2. *Why isn't twisted pair line useful at radio frequencies*?

   Twisted pair has too much capacitance per unit length to be useful at radio frequencies. The capacitance shunts the radio frequencies to ground.

3. *Explain the difference between balanced and unbalanced transmission lines, and give an example for each one.*

   The difference between the two types is that balanced line is symmetrical - the conductors are of equal size and shape. Ladder line is a balanced transmission line. Unbalanced line has unequal (asymmetrical) conductors. Coaxial cable is an unbalanced transmission line.

4. *What type of transmission line is popular at microwave frequencies*?

   Waveguide is popular at microwave frequencies because of its low loss.

5. *Calculate the wavelength of the following signals in free space:*
   a) 2 MHz b) 10 MHz c) 100 MHz

   a) $l = \frac{v}{f} = \frac{3\times10^8 m/s}{2MHz} = \underline{\underline{150m}}$

   b) $l = \frac{v}{f} = \frac{3\times10^8 m/s}{10MHz} = \underline{\underline{30m}}$

   c) $l = \frac{v}{f} = \frac{3\times10^8 m/s}{100MHz} = \underline{\underline{3m}}$

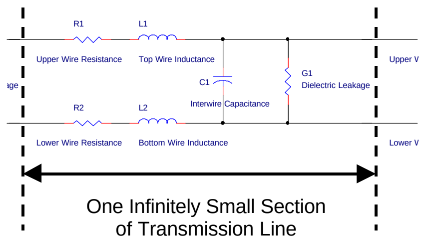
6. *Which of the connectors in figure 11-3 is most useful at UHF? Why*?

   The *N* connector is the most efficient at UHF frequencies. It is a true constant-impedance connector, which means that it does not introduce an impedance mismatch into the circuit it is connected to. N connectors are useful well into the microwave region

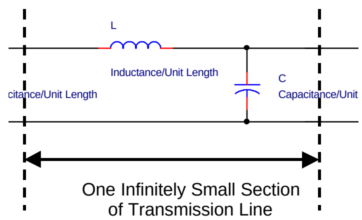
7. *Which of the connectors in figure 11-3 would be cost effective for a 27 MHz CB radio system*?

   The PL-259 ("UHF") connector would be quite effective at 27 MHz.

8. *Draw the schematic diagram showing the equivalent circuit for: a) A lossy transmission line, and b) A lossless line. What types of losses do the two resistors in the lossy model represent*?



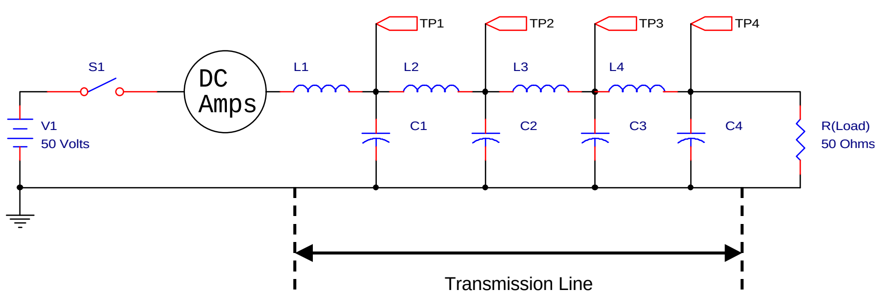
a) [Figure 11-4]



b) [Figure 11-5]

The two resistors in the lossy model represent <u>Ohmic or conductor loss</u>, and <u>dielectric loss</u>.

9. *Explain the charging action that takes place in figure 11-6 after closure of the switch S1. Why doesn't the voltage appear instantly at the 50 Ohm load*?



[Figure 11-6]

When *S1* is closed, C1 charges through L1, and as C1 charges, C2 begins charging through L2, and so on. This is very much like toppling a line of dominos. The voltage can't appear instantaneously across the 50 Ohm load because the capacitors and inductors on the line can not charge instantaneously.

10. *What is the velocity of propagation for a length of RG59U cable having L=298 nH/meter and C=52.5 pF/meter*?

$$v_p = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(298nH/m)(52.5pF/m)}} = \underline{\underline{2.528 \times 10^8 m/s}}$$

11. *What is the velocity factor (VF) for a cable whose velocity of propagation v_p is 2 x 10^8 m/s*?

$$VF = \frac{v_p}{C} = \frac{2 \times 10^8 m/s}{3 \times 10^8 m/s} = \underline{\underline{0.666}}$$

12. *RG62 as manufactured by General Cable is specified has having a velocity factor of 84%, and a capacitance of 44.3 pF/m. Find the equivalent inductance per meter for this cable.*

This problem is solved by manipulating the equation for velocity of propagation:

$$v_p = \frac{1}{\sqrt{LC}}$$

Solving for *L*, we get:

$$L = \frac{1}{v_p^2 C}$$

The velocity of propagation is 84% of the speed of light, or (0.84)(3 x 10^8 m/s) or <u>2.52 x 10^8m/s</u>. Substituting:

$$L = \frac{1}{v_p^2 C} = \frac{1}{(2.52 \times 10^8 m/s)^2 (44.3pF/m)} = \underline{\underline{355.5nH/m}}$$

14. *How long will it take for a signal to travel through a 10 meter length of cable with a velocity factor (VF) of 0.7*?

$$T = \frac{D}{v_p} = \frac{D}{C \times VF} = \frac{10m}{(3 \times 10^8 m/s)(0.7)} = \underline{\underline{47.6nS}}$$

20. *What is the loss of a 50 foot section of RG62A at 100 MHz*?

According to table 11-2, the specific loss is 2.7 dB/100 ft. The loss is therefore:

dB Loss = (50 ft) X (2.7 dB/100 ft) = *1.35 dB*

21. *An RG174 cable is being driven by a 10 Watt source, and is terminated 25 feet away by a 50 Ohm load. What power will be delivered to the load at (a) 50 MHz, (b) 400 MHz*?

    a) At 50 MHz, the specific loss of RG174 is 8 dB/100 ft. The loss in the cable is therefore (25 ft)(8 dB/100ft) or *2 dB*. The power at the load will be:

    $$Po = Pi \times 10^{(dB/10)} = 10W \times 10^{(-2/10)} = \underline{\underline{6.3 Watts}}$$

    b) At 400 MHz, the specific loss is 20.4 dB/100 ft, and the loss in the cable will be (25 ft)(20.4 dB/100ft) or *5.1 dB*. The power at the load will be:

    $$Po = Pi \times 10^{(dB/10)} = 10W \times 10^{(-5.1/10)} = \underline{\underline{3 Watts}}$$

22. *What is the proper impedance for terminating 50 Ohm transmission line*?

    The proper impedance is 50 Ohms.

23. *If the final power amplifier stage in a transmitter fails, what is a good thing to check before placing the transmitter back in service*?

    The transmission line and antenna system should be checked. Problems here can cause transmitter final PA damage.

24. *What causes reflections on transmission lines? How can reflections be eliminated*?

    Impedance mismatches or discontinuities cause reflections. Reflections can be eliminated by properly terminating transmission lines.

25. *What causes standing waves to develop on transmission lines*?

    Standing waves are the result of the interaction between forward and reflected RF energy waves on a transmission line. Where the waves have the same polarity, the voltage is at a maximum; where they cancel, the line has a node (minimum).

26. *A certain transmission line has standing waves; the maximum voltage on the line is 100 V, and the minimum voltage is 50 V. What is the SWR*?

    $$VSWR = \frac{V_{max}}{V_{min}} = \frac{100V}{50V} = \underline{\underline{2:1}}$$

27. *Find the reflection coefficient, G, that will result when a 75 Ohm line is terminated in the following resistances: a) 100 Ohms ; b) 50 Ohms ; c) 25 Ohms ; d) 75 Ohms.*

a) $\Gamma = \dfrac{Z_R - Z_0}{Z_R + Z_0} = \dfrac{100\Omega - 75\Omega}{100\Omega + 75\Omega} = \underline{\underline{+0.142}}$

b) $\Gamma = \dfrac{Z_R - Z_0}{Z_R + Z_0} = \dfrac{50\Omega - 75\Omega}{50\Omega + 75\Omega} = \underline{\underline{-0.2}}$

c) $\Gamma = \dfrac{Z_R - Z_0}{Z_R + Z_0} = \dfrac{25\Omega - 75\Omega}{25\Omega + 75\Omega} = \underline{\underline{-0.5}}$

d) $\Gamma = \dfrac{Z_R - Z_0}{Z_R + Z_0} = \dfrac{75\Omega - 75\Omega}{75\Omega + 75\Omega} = \underline{\underline{0}}$ (No reflection in this case)

28. *Calculate the SWR of the line for each of the four load resistances of problem 27. Which of the SWR readings would be high enough to require further investigation*?

a) $SWR = \dfrac{(1+|\Gamma|)}{(1-|\Gamma|)} = \dfrac{(1+|0.142|)}{(1-|0.142|)} = \underline{\underline{1.33:1}}$

b) $SWR = \dfrac{(1+|\Gamma|)}{(1-|\Gamma|)} = \dfrac{(1+|-0.2|)}{(1-|-0.2|)} = \underline{\underline{1.5:1}}$

c) $SWR = \dfrac{(1+|\Gamma|)}{(1-|\Gamma|)} = \dfrac{(1+|-0.5|)}{(1-|-0.5|)} = \underline{\underline{3:1}}$

d) $SWR = \dfrac{(1+|\Gamma|)}{(1-|\Gamma|)} = \dfrac{(1+|0|)}{(1-|0|)} = \underline{\underline{1:1}}$

Reading *C* is high enough to require further troubleshooting.

29. *A certain transmitter provides an output voltage of 100 Volts to a 75 Ohm transmission line. The line is driving a mismatched load of 50 Ohms. Determine the following: a) The SWR ; b) The maximum and minimum voltages on the line.*

a) Since the load is purely resistive, the SWR can be calculated as
SWR = (Z0 / Zr) = (75 Ohms / 50 Ohms) = <u>1.5:1</u>

b) The incident voltage is 100 Volts (given) and the reflected voltage is:

$$\Gamma = \frac{Z_R - Z_0}{Z_R + Z_0} = \frac{50\Omega - 75\Omega}{50\Omega + 75\Omega} = -0.2$$

$$V_r = \Gamma V_i = (-0.2)(100V) = \underline{\underline{-20Volts}}$$

The maximum and minimum voltages are:

$$V\max = V_i(1+|\Gamma|) = 100V(1+0.2) = \underline{\underline{120V}}$$

$$V\min = V_i(1-|\Gamma|) = 100V(1-0.2) = \underline{\underline{80V}}$$

30. *You have been given a 100 foot length of transmission line to test. The characteristic impedance of the line is unknown, but according to your measurements, an SWR of 2:1 results when the line is terminated in 50 Ohms, and an SWR of 3:1 results when a 75 Ohm termination is substituted. What is the characteristic impedance of the mystery line? (Hint: Use equations 11-14.)*

    Either 25 or 100 Ohm line will have a 2:1 SWR when terminated in 50 Ohms, according to equation (11-14). Line impedances that would result in a 3:1 SWR with a 75 Ohm termination are either 25 Ohms or 225 Ohms.

    The line impedance is therefore 25 Ohms.

31. A certain directional wattmeter reads 100 W in the forward position, and 10 W in the reverse position while testing a transmission line and antenna for an HF transmitter. What is the SWR on the line, and should it be troubleshot?

$$SWR = \frac{\sqrt{P_f} + \sqrt{P_r}}{\sqrt{P_f} - \sqrt{P_r}} = \frac{\sqrt{100W} + \sqrt{10W}}{\sqrt{100W} - \sqrt{10W}} = \underline{\underline{1.9:1}}$$