- the discussion of transmission line electrical characteristics, emphasizing characteristic impedance and the various line losses
- the explanation of dc voltage propagation, including velocity, delay, and reflections from both short-circuited and open-circuited lines
- the analysis of standing waves for open and shorted lines
- the definition of voltage standing wave ratio (VSWR), electrical length of a line, effects of a mismatched load, and use of a quarter-wavelength matching transformer
- the description of a Smith chart and its use in matching a load to a line
- the application of transmission lines as discrete circuit components, unbalanced-to-balanced transformers (baluns), and filters
- the testing of transmission lines using slotted lines and time-domain reflectometers

Questions and Problems

Section 12-2

1. Define *transmission line*. If a simple wire connection can be a transmission line, why is an entire chapter of study devoted to it?
2. In general terms, discuss the various types of transmission lines. Include the advantages and disadvantages of each type.
3. * What would be the considerations in choosing a solid dielectric cable over a hollow pressurized cable for use as a transmission line?
4. * Why is an inert gas sometimes placed within concentric radio-frequency transmission cables?
5. Where are twisted-pair cables often used?
6. What is meant by the CAT6/5e designation?
7. Define *near-end crosstalk* and *attenuation* relative to testing twisted-pair cable.
8. Describe three additional test considerations for twisted-pair cable with the enhanced data capabilities.
9. Explain how an unbalanced line differs from a balanced line.
10. Explain how the pickup of unwanted signals on a balanced transmission line is attenuated when converted to an unbalanced signal.
11. A balanced transmission line picks up an undesired signal with a 5-mW level. After conversion to an unbalanced signal using a center-tapped transformer, the undesired signal is 0.011μW. Calculate the common mode rejection ratio (CMRR). (56.6 dB)

Section 12-3

12. Draw an equivalent circuit for a transmission line, and explain the physical significance of each element.
13. Provide a physical explanation for the meaning of a line's characteristic impedance (Z_0).
14. Calculate Z_0 for a line that exhibits an inductance of 4 nH/m and 1.5 pF/m. (51.6 Ω)
15. Calculate the capacitance per meter of a 50-Ω cable that has an inductance of 55 nH/m. (22 pF/m)
16. In detail, explain how an impedance bridge can be used to determine Z_0 for a piece of transmission line.
17. * If the spacing of the conductors in a two-wire radio-frequency transmission line is doubled, what change takes place in the surge impedance (Z_0) of the line?
18. * If the conductors in a two-wire radio-frequency transmission are replaced by larger conductors, how is the surge impedance affected, assuming no change in the center-to-center spacing of the conductor?
19. * What determines the surge impedance of a two-wire radio-frequency transmission line?
20. Determine Z_0 for the following transmission lines:
    (a) Parallel wire, air dielectric with $D/d = 3$. (215 Ω)
    (b) Coaxial line, air dielectric with $D/d = 1.5$. (24.3 Ω)
    (c) Coaxial line, polyethylene dielectric with $D/d = 2.5$. (36.2 Ω)
21. List and explain the various types of transmission line losses.
22. * A long transmission line delivers 10 kW into an antenna; at the transmitter end, the line current is 5 A, and at the coupling house (load) it is 4.8 A. Assuming the line to be properly terminated and the losses in the coupling system to be negligible, what is the power lost in the line? (850 W)
23. Define *surge impedance*.

Section 12-4

24. Derive the equation for the time required for energy to propagate through a transmission line [Equation (12-19)].
25. * What is the velocity of propagation for radio-frequency waves in space?
26. A delay line using RG-8A/U cable is to exhibit a 5-ns delay. Calculate the required length of this cable. (3.39 ft)
27. Explain the significance of the velocity factor for a transmission line.
28. Determine the velocity of propagation of a 20-km line if the *LC* product is $7.5 \times 10^{-12}\ s^2$. (7.3×10^9 m/s)
29. What is the wavelength of the signal in Problem 28 if the signal's frequency is 500 GHz? (0.0146)
30. If the velocity of propagation of a 20-ft transmission line is 600 ft/s, how long will it take for the signal to get to the end of the line? (33.3 ms)

Section 12-5

31. Define a *nonresonant transmission line,* and explain what its traveling waves are and how they behave.
32. * An antenna is being fed by a properly terminated two-wire transmission line. The current in the line at the input end is 3 A. The surge impedance of the line is 500 Ω. How much power is being supplied to the line? (4.5 kW)
33. With the help of Figure 12-15, provide a charging analysis of a nonresonant line with an ac signal applied.

Section 12-6

34. Explain the properties of a resonant transmission line. What happens to the

35. A dc voltage from a 20-V battery with $R_s = 75\ \Omega$ is applied to a 75-Ω transmission line at $t = 0$. It takes the battery's energy 10 μs to reach the load, which is an open circuit. Sketch current and voltage waveforms at the line's input and load.
36. Repeat Problem 35 for a short-circuited load.
37. What are *standing waves, standing wave ratio* (SWR), and *characteristic impedance,* in reference to transmission lines? How can standing waves be minimized?
38. With the help of Figure 12-19, explain how standing waves develop on a resonant line.
* 39. If the period of one complete cycle of a radio wave is 0.000001 s, what is the wavelength? (300 m)
* 40. If the two towers of a 950-kHz antenna are separated by 120 electrical degrees, what is the tower separation in feet? (345 ft)

Section 12-7

41. Define *reflection coefficient,* Γ, in terms of incident and reflected voltage and also in terms of a line's load and characteristic impedances.
42. Express SWR in terms of
    (a) Voltage maximums and minimums.
    (b) Current maximums and minimums.
    (c) The reflection coefficient.
    (d) The line's load resistance and Z_0.
43. Explain the disadvantages of a mismatched transmission line.
* 44. What is the primary reason for terminating a transmission line in an impedance equal to the characteristic impedance of the line?
* 45. What is the ratio between the currents at the opposite ends of a transmission line one-quarter wavelength long and terminated in an impedance equal to its surge impedance?
46. An SSB transmitter at 2.27 MHz and 200 W output is connected to an antenna ($R_{in} = 150\ \Omega$) via 75 ft of RG-8A/U cable. Determine
    (a) The reflection coefficient.
    (b) The electrical cable length in wavelengths.
    (c) The SWR.
    (d) The amount of power absorbed by the antenna.
* 47. What should be the approximate surge impedance of a quarter-wavelength matching line used to match a 600-Ω feeder to a 70-Ω (resistive) antenna?

Section 12-8

48. Calculate the impedance of a line 675 electrical degrees long. $Z_0 = 75\ \Omega$ and $Z_L = 50\ \Omega + j75\ \Omega$. Use the Smith chart *and* Equation (12-30) as separate solutions, and compare the results.
49. Convert an impedance, $62.5\ \Omega - j90\ \Omega$, to admittance mathematically *and* with the Smith chart. Compare the results.
50. Find the input impedance of a 100-Ω line, 5.35λ long, and with $Z_L = 200\ \Omega + j300\ \Omega$.
* 51. Why is the impedance of a transmission line an important factor with respect to matching "out of a transmitter" into an antenna?

53. The antenna load on a 150-Ω transmission line is $225\ \Omega - j300\ \Omega$. Determine the length and position of a short-circuited stub necessary to provide a match.
54. Repeat Problem 53 for a 50-Ω line and an antenna of $25\ \Omega + j75\ \Omega$.

Section 12-9

55. Calculate the length of a short-circuited 50-Ω line necessary to simulate an inductance of 2 nH at 1 GHz.
56. Calculate the length of a short-circuited 50-Ω line necessary to simulate a capacitance of 50 pF at 500 MHz.
57. Describe two types of baluns, and explain their function.
* 58. How may harmonic radiation of a transmitter be prevented?
* 59. Describe three methods for reducing harmonic emission of a transmitter.
* 60. Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power amplifier stage of a transmitter to a two-wire transmission line, with a method of suppression of second and third harmonic energy.
61. Explain the construction of a slotted line and some of its uses.
62. Explain the principle of TDR and some uses for this technique.
63. A pulse is sent down a transmission line that is not functioning properly. It has a propagation velocity of 2.1×10^8 m/s, and an inverted reflected pulse (equal in magnitude to the incident pulse) is returned in 0.731 ms. What is wrong with the line, and how far from the generator does the fault exist?
64. A fast-rise-time 10-V step voltage is applied to a 50-Ω line terminated with an 80-Ω resistive load. Determine Γ, E_F, and E_r. (0.231, 12.3 V, 2.3 V)

Section 12-10

65. Describe some of the causes of crosstalk and list possible solutions.
66. Explain why cabling should not be run close to ac power lines.
67. List some of the causes of magnetic field losses in a cable.
68. Explain the effects of extreme sunlight (heat radiation) on cables.

Questions for Critical Thinking

69. With the help of Figure 12-12, provide a step-by-step explanation of how a dc voltage propagates through a transmission line.
70. An open-circuited line is 1.75λ. Sketch the incident, reflected, and resultant waveforms for both voltage and current at the instant the generator is at its peak negative value. Sketch and compare the waveforms for a short-circuited line.
71. You are asked to design a line "free of transmission line effects." You design one that is λ/16 long. How would you justify this design?
72. Match a load of $25\ \Omega + j75\ \Omega$ to a 50-Ω line using a quarter-wavelength matching section. Determine the proper location and characteristic impedance of the matching section. Repeat this problem for a $Z_L = 110\ \Omega - j50\ \Omega$ load. Provide *two* separate solutions.