2. Open the file **FigE13-3** on your EWB CD. Determine if the Pierce crystal oscillator is working properly. Correct any faults and retest the circuit. Report on your findings.
3. Open the file **FigE13-4** on your EWB CD. Determine if the Pierce crystal oscillator is working properly. Correct any faults and retest the circuit. Report on your findings.

Summary

In Chapter 13 we studied various considerations of wave propagation. We discovered that electrical energy can be converted to wave energy with many properties in common with light wave propagation. The major topics you should now understand include:

- the definition of an electromagnetic wave, isotropic point source, wavefront, and characteristic impedance of free space
- the understanding of environmental effects on wave propagation, including reflection, refraction, and diffraction
- the explanation of ground- and space-wave propagation
- the description of ionospheric layers and their effects on sky-wave propagation
- the definitions of skipping, critical frequency, critical angle, maximum usable frequency (MUF), skip zone, fading, and tropospheric scatter
- the description and use of satellite communications
- the explanations of multiplexing techniques used in satellite communications, including FDMA, TDMA, and CDMA
- the description of very small aperture terminal (VSAT) and ultrasmall aperture terminal mobile satellite (MSAT) communication
- the power-loss calculations used in satellite communications analysis

Questions and Problems

Section 13-1

1. Explain why an antenna can be thought of as a transducer.
2. List the similarities and dissimilarities between light waves and radio waves.

Section 13-2

3. What are the two components of an electromagnetic wave? How are they created? Explain the two possible things that can happen to the energy in an electromagnetic wave near a conductor.

*4. What is *horizontal and vertical polarization* of a radio wave?

*5. What kinds of fields emanate from a transmitting antenna, and what relationships do they have to each other?

6. Define *wavefront.*
7. Calculate the power density in watts per square meter (on earth) from a 10-W satellite source that is 22,000 mi from earth. (6.35×10^{-16} W/m^2)
8. Calculate the power received from a 20-W transmitter, 22,000 mi from earth, if the receiving antenna has an effective area of 1600 mi^2. (2.03×10^{-12} W)
9. Calculate the electric field intensity, in volts per meter, 20 km from a 1-kW source. How many decibels down will that field intensity be if the distance is an additional 30 km from the source? (8.66 mV/m, 7.96 dB)
10. Calculate the characteristic impedance of free space using two different methods.

*11. How does the field strength of a standard broadcast station vary with distance from the antenna?

12. Define *permeability.*

Section 13-3

13. In detail, explain the process of reflection for an electromagnetic wave.
14. With the aid of Snell's law, fully explain the process of refraction for an electromagnetic wave.
15. What is *diffraction* of electromagnetic waves? Explain the significance of the shadow zone and how it is created.
16. Write the equation for the coefficient of reflection. ($\rho = \epsilon_r/\epsilon_i$)
17. Define *refraction.*
18. Define *shadow zone.*

Section 13-4

19. List the three basic modes whereby an electromagnetic wave propagates from a transmitting to a receiving antenna.
20. Describe ground-wave propagation in detail.
21. Explain why ground-wave propagation is more effective over seawater than desert terrain.

*22. What is the relationship between operating frequency and ground-wave coverage?

*23. What are the lowest frequencies useful in radio communications?

24. Fully explain space-wave propagation. Explain the difference between a direct and reflected wave.
25. Explain the phenomenon of *ghosting* in TV reception. What would be the effect if this occurred with a voice transmission?
26. Calculate the ghost width for a 17-in.-wide TV screen when a reflected wave results from an object $\frac{3}{8}$ mi "behind" a receiver. How could this effect be minimized? (1.28 in.)

Section 13-5

27. List the course of events in the process of sky-wave propagation.
28. Provide a detailed discussion of the ionosphere—its makeup, its layers, its variations, and its effect on radio waves.

*29. What effects do sunspots and the aurora borealis have on radio communications?

30. Define and describe *critical frequency, critical angle,* and *maximum usable frequency* (MUF). Explain their importance to sky-wave communications.
31. What is the optimum working frequency, and what is its relationship to the MUF?

33. What radio frequencies are useful for long-distance communications requiring continuous operation?
34. In radio transmissions, what bearings do the angle of radiation, density of the ionosphere, and frequency of emission have on the length of the skip zone?
35. Why is it possible for a sky wave to "meet" a ground wave 180° out of phase?
36. What is the process of tropospheric scatter? Explain under what conditions it might be used.
*37. What is the purpose of a diversity antenna receiving system?
38. List and explain three types of diversity reception schemes.
39. What is skipping?
40. Define *fading.*
41. What happens when a signal is above the critical frequency?

Section 13-6

42. What is *satellite communications*? List reasons for their increasing popularity.
43. Explain the differences between GEO and LEO satellite systems. Describe the advantages and disadvantages of each system.
44. Describe a typical VSAT installation. How does it differ from an MSAT system?
45. Explain the methods of multiplexing in SATCOM systems, and provide the advantages of TDMA over FDMA.
46. Use the satellite footprint of the Telstar 5 provided in Figure 13-17 to determine the expected EIRP for the signal in your area.
47. An earth station is located at 98° W longitude and 35.1° N latitude. Determine the azimuth and elevation angles for the earth station if the antenna is to be pointed at a satellite parked at 92° W longitude.
48. What two signals does a GPS satellite transmit? How are they used, and what frequencies are being used?
49. What is the distance to a satellite parked at 69° W longitude from an earth station located at 29° N latitude and 110° 36′ 20″ W longitude? Calculate the round-trip time delay for a signal traveling from the earth station to the satellite and back.
50. Define *apogee* and *perigee.*
51. What is the altitude and orbital period of the Iridium LEO satellites? How many satellites are there, and what type of orbital pattern is used?

Section 13-7

52. Calculate the noise factor (NF) in dB for a 100° LNA.
53. Determine the figure of merit for a satellite earth station with the following specifications:
    Antenna Gain—48 dBi
    Reflector noise temperature—28 K
    LNA noise temp—55 K
    Noise temp. (various components)—3 K
54. Calculate the free-space path loss for a link between a satellite parked at 89° W longitude and an earth station at 29° N latitude and 110 36′ 20″ W longitude. The downlink frequency is 11.974 GHz.

longitude. A data rate of 6 Mbps using 8-PSK modulation is being used, which requires a bandwidth of 2 MHz (63 dB). The required C/N at the satellite is 8 dB, and the required C/N at the earth station is 15 dB. Comment on the results obtained from the satellite link budget in regard to whether the received C/N is or is not acceptable.

Earth Station

Uplink frequency	14.135 GHz
Antenna Diameter	5.0 meters
Antenna Efficiency	0.65
Earth Station G/T	31.2 dBK
Transmit EIRP	62 dBW (4.5 W)

Satellite

Downlink Frequency	11.752 GHz
Satellite EIRP	38.2 dBW
Satellite G/T	0.9 dBK

Section 13-8

56. Describe the effects of EMI on a receiver.
57. Explain the best methods for reducing EMI.
58. Explain the problems associated with ghosting.
59. Explain the best way to reduce reflection.
60. Your television is exhibiting interference on the picture. How can you determine whether you have an EMI or RFI problem?
61. What are the three ways EMI can be picked up by a receiver? Explain how you can test to determine the source.

Questions for Critical Thinking

62. A user complains about "interference." How can you determine whether this is electromagnetic interference (EMI) or radio-frequency interference (RFI)?
63. Calculate the radio horizon for a 500-ft transmitting antenna and a receiving antenna of 20 ft. Calculate the required height increase for the receiving antenna if a 10 percent increase in radio horizon were required. (37.9 mi, 31.2 ft)
64. In the strictest sense, define *skip distance* and *skip zone.*
65. You will be receiving sky waves. In what ways can you anticipate fading to occur?