Q6-8. Distinguish between multilevel TDM, multiple-slot TDM, and pulse-stuffed TDM.

Q6-9. Distinguish between synchronous and statistical TDM.

Q6-10. Define spread spectrum and its goal. List the two spread spectrum techniques discussed in this chapter.

Q6-11. Define FHSS and explain how it achieves bandwidth spreading.

Q6-12. Define DSSS and explain how it achieves bandwidth spreading.

6.4.3 Problems

P6-1. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with guard bands of 500 Hz using FDM. Calculate the required bandwidth.

P6-2. We need to transmit 100 digitized voice channels using a passband channel of 20 KHz. What should be the ratio of bits/Hz if we use no guard band?

P6-3. In the analog hierarchy of Figure 6.9, find the overhead (extra bandwidth for guard band or control) in each hierarchy level (group, supergroup, master group, and jumbo group).

P6-4. We need to use synchronous TDM and combine 20 digital sources, each of 100 Kbps. Each output slot carries 1 bit from each digital source, but one extra bit is added to each frame for synchronization. Answer the following questions:

- **a.** What is the size of an output frame in bits?
- **b.** What is the output frame rate?
- **c.** What is the duration of an output frame?
- **d.** What is the output data rate?
- **e.** What is the efficiency of the system (ratio of useful bits to the total bits)?

P6-5. Repeat Problem 6-4 if each output slot carries 2 bits from each source.

P6-6. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:

- **a.** What is the size of an output frame in bits?
- **b.** What is the output frame rate?
- **c.** What is the duration of an output frame?
- **d.** What is the output data rate?

P6-7. Ten sources, six with a bit rate of 200 kbps and four with a bit rate of 400 kbps, are to be combined using multilevel TDM with no synchronizing bits. Answer the following questions about the final stage of the multiplexing:

- **a.** What is the size of a frame in bits?
- **b.** What is the frame rate?
- **c.** What is the duration of a frame?
- **d.** What is the data rate?

P6-8. Four channels, two with a bit rate of 200 kbps and two with a bit rate of 150 kbps, are to be multiplexed using multiple-slot TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

P6-9. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

P6-10. Answer the following questions about a T-1 line:

a. What is the duration of a frame?

b. What is the overhead (number of extra bits per second)?

P6-11. Show the contents of the five output frames for a synchronous TDM multiplexer that combines four sources sending the following characters. Note that the characters are sent in the same order that they are typed. The third source is silent.

a. Source 1 message: HELLO

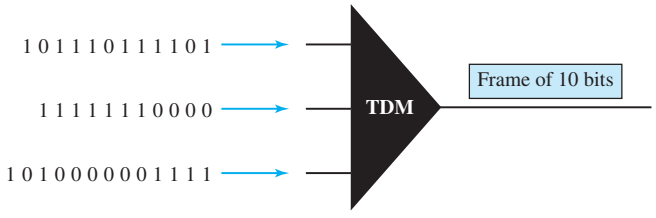
b. Source 2 message: HI

c. Source 3 message:

d. Source 4 message: BYE

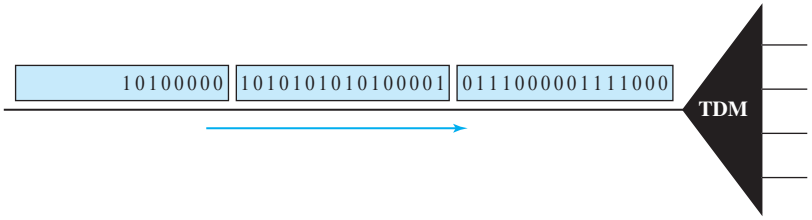
P6-12. Figure 6.34 shows a multiplexer in a synchronous TDM system. Each output slot is only 10 bits long (3 bits taken from each input plus 1 framing bit). What is the output stream? The bits arrive at the multiplexer as shown by the arrows.

Figure 6.34 *Problem P6-12*



P6-13. Figure 6.35 shows a demultiplexer in a synchronous TDM. If the input slot is 16 bits long (no framing bits), what is the bit stream in each output? The bits arrive at the demultiplexer as shown by the arrows.

Figure 6.35 *Problem P6-13*



P6-14. Answer the following questions about the digital hierarchy in Figure 6.23:

a. What is the overhead (number of extra bits) in the DS-1 service?

b. What is the overhead (number of extra bits) in the DS-2 service?

c. What is the overhead (number of extra bits) in the DS-3 service?

d. What is the overhead (number of extra bits) in the DS-4 service?

P6-15. What is the minimum number of bits in a PN sequence if we use FHSS with a channel bandwidth of $B = 4$ KHz and $B_{ss} = 100$ KHz?

P6-16. An FHSS system uses a 4-bit PN sequence. If the bit rate of the PN is 64 bits per second, answer the following questions:

a. What is the total number of possible channels?

b. What is the time needed to finish a complete cycle of PN?

P6-17. A pseudorandom number generator uses the following formula to create a random series:

$$N_{i+1} = (5 + 7N_i) \bmod 17 - 1$$

In which N_i defines the current random number and N_{i+1} defines the next random number. The term *mod* means the value of the remainder when dividing $(5 + 7N_i)$ by 17. Show the sequence created by this generator to be used for spread spectrum.

P6-18. We have a digital medium with a data rate of 10 Mbps. How many 64-kbps voice channels can be carried by this medium if we use DSSS with the Barker sequence?

6.5 SIMULATION EXPERIMENTS

6.5.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.