Problems and Solutions (Chapter 7)

1. What is the difference between the "guard band" and the "guard time" and why are they important in a cellular system? Explain clearly.

   [Solution]

   A "guard band" is used in FDMA where as "guard time" is used in TDMA to reduce interference between adjacent channels in FDMA, and adjacent time slots in TDMA respectively.

2. A TDMA system uses 270.833 kbps data rate to support 8 users per frame.

   (a) What is the raw data rate provided for each user?

   (b) If guard time and synchronization occupy 10.1 kbps, determine the traffic efficiency?

   (c) If (7, 4) code is used for error handling, what is the overall efficiency?

   [Solution]

   (a) Since 8 users are supported per frame the raw data rate is $\frac{270.833}{8} = 33.85$ kbps

   (b) If 10.1 kbps is for guard and synchronization information the traffic efficiency is given by $\frac{33.85-10.1}{33.85} \times 100 = 70.16\%$

   (c) If (7, 4) code is used only 4 out of 7 bits contain the data. Thus the efficiency is $\frac{4}{7} \times \frac{33.85-10.1}{33.85} \times 100 = 40\%$

3. Radio signal travels from the BS to an MS along different paths, some direct, some reflected and some deflected. If the worst case difference in the path length traversed by a signal is 2 km, what is the minimum value of guard time that need to be used? Assume the signal propagation rate of 512 kbps.

   [Solution]

   The difference in time between the reception of the two waves is:

$$s = vt$$

$$t = \frac{2000 \text{ m}}{299792458 \text{ m/sec}} = 6.671 * 10^{-6} \text{ sec}$$

$$\text{Separation in bits} = 6.671 * 10^{-6} \text{ sec} * 512000 \text{ bits/sec} = 3.415 \text{ bits}$$

4. Repeat Problem 7.2 if only four users per frame can be supported.

   [Solution]

   (a) Since 4 users are supported per frame the raw data rate is $\frac{270.833}{4} = 67.7$ kbps

(b) If 10.1 kbps is for guard and synchronization information the traffic efficiency is given by $\frac{67.7-10.1}{67.7} \times 100 = 85.08\%$

(c) If (7, 4) code is used only out of 7 bits contain the data. Thus the efficiency is $\frac{4}{7} \times \frac{67.7-10.1}{67.7} \times 100 = 48.62\%$

5. Repeat Problem 7.3 if the difference in path length is 4 km.

[Solution]

The difference in time between the reception of the two waves is:

$$s = vt$$

$$t = \frac{4000 \text{ m}}{299792458 \text{ m/sec}} = 13.333 * 10^{-6} \text{ sec}$$

$$\text{Separation in bits} = 13.333 * 10^{-6} \text{ sec} * 512000 \text{ bits/sec} = 6.82 \text{ bits}$$

6. Find the Walsh functions for 16-bit code.

[Solution]

We know that

$$\mathbf{H}_0 = [0]$$

$$\mathbf{H}_n = \begin{bmatrix} \mathbf{H}_{n-1} & \mathbf{H}_{n-1} \\ \mathbf{H}_{n-1} & \overline{\mathbf{H}_{n-1}} \end{bmatrix}$$

$$\text{If } \mathbf{H}_n = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \overline{\mathbf{H}_n} = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

$$\mathbf{H}_1 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

$$\mathbf{H}_2 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

$$\mathbf{H}_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$

and so on for $\mathbf{H}_4$.

7. What are the orthogonal Walsh codes? Why is synchronization among the users required for CDMA?

   [Solution]

   The Walsh code is a set of length-64 mutually orthogonal codes, which is used for ensuring orthogonality between the signals for different users receiving from the same base station. The Walsh code is also used for modulation for the reverse channel of IS-95A. In CDMA system, synchronization among the users is required. It is because at the receiver, the received signal is multiply with the Walsh code. If the received signal is not desired, the output is zero. If the users are not synchronized, the output of undesired signal will not be zero.

8. Is it possible to jam CDMA? Explain clearly.

   [Solution]

   In CDMA data signal is spread out over the entire available bandwidth using a unique code assigned to each user during call set up time with base station. Spreading of data signal is achieved using some spread spectrum technique like frequency hopping where data is sent in small pieces over a number of the discrete frequencies available for use at any time in the specified range. Thus jamming such a data signal which is changing its frequency is difficult and impractical.

9. To address the service to be increased in the number of MSs in a CDMA system, it was decided to use TDMA as well. Is it possible to do so? If yes, how; and if no, why not?

   [Solution]

   Even though using TDMA and CDMA together would greatly complicate the transmission process, it is possible to do so. A set of TDMA channels can be multiplexed together using CDMA techniques. A set of CDMA channels can be multiplexed together by giving each channel a TDMA slot.

10. The number of Walsh codes determines the maximum number of MSs that can be serviced simultaneously. Then, why not use a large Walsh code? What are the limitations or disadvantages? Explain clearly (Range of Walsh code is between 28-128 bits).

    [Solution]

    Walsh codes are used in the order of power of 2. A large number may not be used as it will be difficult to maintain the orthogonality among the wave forms and make sure that they are all aligned in time. Also, the power level of the walsh codes needs to be at the required level to measure the code domain power (ratio of power in each of the forward link walsh codes to the total CDMA channel power transmitted) to more accurately monitor the performance.

11. What are the non-military applications of frequency hopping? Why is it selected Bluetooth used in home devices and wireless computer mouse?

    [Solution]

    If any part of the spectrum being used by mobile devices in an area is subject to interference, then all the communication between them is affected. However, if they chose to change (hop) their frequency in a predetermined manner, then only the transmissions in the noisy part of the spectrum are affected. This greatly enhances the communication possibilities between the devices.

    Bluetooth operates in 2.4 GHz ISM band which is shared by number of other wireless standards. Even if there is interference on one frequency channel, it might not be these when it hops to the next frequency selected on a random basis. Hence, frequency hopping ensures minimu interference during transmission by other wireless standards. It also guranttees a high security without requirement of high computation power.

12. What frequency band is used in biomedical devices surgical applications? How does that limit the use of wireless devices?

    [Solution]

    The 2.4 GHz ISM band is used in biomedical devices for surgical applications. A number of wireless standards, such as Bluetooth and the IEEE 802.11b use the same band for communication. Nodes using these standards for communication cannot, therefore, be used in areas where biomedical surgical devices operate.

13. What is FSK/QPSK?

    [Solution]

    FSK is the acronym for frequency shift keying, and QPSK for quadrature phase shift keying. These are techniques to modulate signals onto carrier waves. FSK employs two different frequencies for 0 and 1 bits. QPSK employs a phase shift in multiples of $\frac{\pi}{4}$.

14. Why does the power control become one of the main issues for the efficient operation of CDMA?

    [Solution]

    The power control is critical for efficient operation of CDMA. Because, the sender's transmission power level determines the signal quality at the receiver. There is a need to conserve the limited battery power of the MS for quality signal and also hand off will be smooth with high quality signal. Also, since interference is converted to noise, a strong interference implies a strong noise and degrades the channel for all other users. Therefore, CDMA must use very tight power control for efficient operation.

15. How do you decide the range of a guard channel? Is it a function of the carrier frequency? Explain clearly.

[Solution]

The range of the guard channel depends on the authorized bandwidth per channel and emissions requirement specified by the FCC or monitory commission between adjacent channels.

No, it is not dependent on the carrier frequency.

16. The message signal $x(t) = \sin(100t)$ modulates the carrier signal $c(t) = A\cos(2\pi f_c t)$. Using amplitude modulation. Find the frequency content of the modulated signal.

[Solution]

Since $x(t)$ is a sine wave of frequency $50/\pi$ Hz. Hence, it occupies frequencies are $(f_c - 50/\pi)$ Hz and $(f_c + 50/\pi)$ Hz when transmitted on the carrier wave $A\cos(2\pi f_c t)$ which is centered at the frequency f_c.

17. A signal shown as below amplitude modulates a carrier $c(t) = \cos(50t)$. Precisely plot the resulting modulated signal as a function of time.

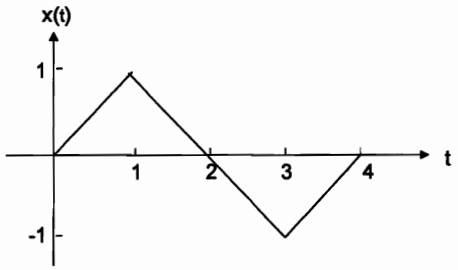
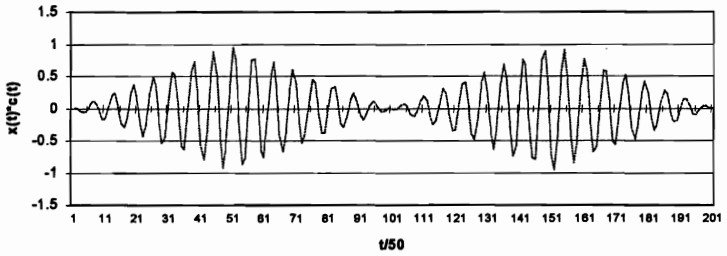


Figure for problem 7.17

[Solution]

The resulting waveform is



18. The message signal is given by $x(t) = \cos(20\pi t)$ and the carrier is given by $c(t) = \cos(2\pi f_c t)$. Using frequency modulation. The modulation index is 5.

    (a) Write an expression for the modulated signal

    (b) What is the maximum frequency deviation of the modulated signal?

    (c) Find the bandwidth of the modulated signal.

    [Solution]

    Since signal $x(t) = \cos(20\pi t)$, $f_m = 10$ Hz.

    Since carrier $c(t) = \cos(2\pi f_c t)$, we have

    $$\beta = \frac{f_\Delta}{f_m} = 5.$$

    Thus,

    $$f_\Delta = 5 f_m = 50 \text{ Hz}.$$

    (a) Mudulated signal is

    $$\begin{aligned} s(t) &= A\cos\left[2\pi f_c t + 2\pi f_\Delta \int_0^t x(\tau)d\tau\right] \\ &= A\cos\left[2\pi f_c t + 2\pi f_\Delta \int_0^t \cos(20\pi\tau)\,d\tau\right] \\ &= A\cos\left[2\pi f_c t + 5\sin(20\pi t)\right]. \end{aligned}$$

    (b) The maximum deviation of modulated signal is

    $$f_\Delta = 5 f_m = 50 \text{ Hz}.$$

    (c) Bandwidth BW is

    $$\text{BW} = 2(\beta + 1) f_m = 120 \text{ Hz}.$$

19. Besides BPSK and QPSK, 8PSK is another kind of phase shift keying. Try to give the constellation for 8PSK.

    [Solution]

    The constellation points will be (0, 0), $(\sqrt{2}, \sqrt{2})$, (0, 1), $(-\sqrt{2}, \sqrt{2})$, $(-1,$ 1), $(-\sqrt{2}, -\sqrt{2})$, (0, -1), and $(\sqrt{2},-\sqrt{2})$ along the unit circle.

20. Use 16QAM to transmit a binary sequence, if the baud rate is 1200 Hz, how many bits can be transmitted in one second?

    [Solution]

    16QAM transmits 16 bits for each symbol. If the baud rate is 1200 Hz, the bit rate will be $16 * 1200 = 19200$ bits per second.

21. Increasing the number of amplitude level and phase shift, we can gain higher level xQAM, such as 64QAM and 256QAM. It seems the transmission rate can be as high as we want by this kind of modulation. Is it true? Explain briefly.

    [Solution]

    We cannot increase the number of points in a signal constellation without increasing the transmitted power. As the number of points increase, the distance between them goes on decreasing, and it is difficult for the receiver to differentiate between them. To increase the distance between them, we must increase the radius of the unit circle, that is, the transmitting power.