23.13: Exercises

1. Develop a formula for the average power of a signal $x(t)$. Consider $x(t)$ to be a voltage across a 1 Ω resistor.
2. What is the PAPR of a 5-tone signal when the amplitude of each tone is the same?
3. What is the PMEPR of a 10-tone signal when the amplitude of each tone is the same?
4. Consider two uncorrelated analog signals combined together. One signal is denoted $x(t)$ and the other $y(t)$, where $x(t)=0.1\sin(10^9 t)$ and $y(t)=0.05\sin(1.01\cdot 10^9 t)$. The combined signal is $z(t)=x(t)+y(t)$. [Parallels Example 2.2.3]
   a. What is the PAPR of $x(t)$ in decibels?
   b. What is the PAPR of $z(t)$ in decibels?
   c. What is the PMEPR of $x(t)$ in decibels?
   d. Is it possible to calculate the PMEPR of $z(t)$? If so, what is it?
5. Consider two uncorrelated analog signals combined together. One signal is denoted $x(t)$ and the other $y(t)$, where $x(t)=0.1\sin(10^8 t)$ and $y(t)=0.05\sin(1.01\cdot 10^8 t)$. What is the PMEPR of this combined signal? Express PMEPR in decibels. [Parallels Example 2.2.3]
6. What is PMEPR of a three-tone signal when the amplitude of each tone is the same?
7. What is PMEPR of a four-tone signal when the amplitude of each tone is the same?
8. A tone $x_1(t)=0.12\cos(\omega_1 t)$ is added to two other tones $x_2(t)=0.14\cos(\omega_2 t)$ and $x_3(t)=0.1\cos(\omega_3 t)$ to produce a signal $y(t)=x_1(t)+x_2(t)+x_3(t),$ where $y(t),\ x_1(t),\ x_2(t)$ and $x_3(t)$ are voltages across a $100\ \Omega$ resistor. Consider that $\omega_1,\ \omega_2,$ and ω_3 are 10% apart and that the signals at these frequencies are uncorrelated.
   a. What is the PMEPR of $x_1(t)$? Express your answer in decibels.
   b. Sketch $y(t)$.
   c. The combined signal appears as a pseudocarrier with a time-varying envelope. What is the power of the largest single cycle of the pseudo-carrier?
   d. What is the average power of $y(t)$?
   e. What is the PMEPR of $y(t)$? Express your answer in decibels.
9. Consider two uncorrelated analog signals summed together. One signal is denoted $x(t)$ and the other $y(t)$, where $x(t)=\sin(10^9 t)$ and $y(t)=2\sin(1.01\cdot 10^9 t)$ so that the total signal is $z(t)=x(t)+y(t)$. What is the PMEPR of $z(t)$ in decibels? [Parallels Example 2.2.3]
10. What is the PMEPR of an FM signal at 1 GHz with a maximum modulated frequency deviation of $\pm 10\text{ kHz}$?
11. What is the PMEPR of a two-tone signal (consisting of two sinewaves at different frequencies that are, say, 1% apart)? First, use a symbolic expression, then consider the special case when the two amplitudes are equal. Consider that the two tones are close in frequency.
12. What is the PMEPR of a three-tone signal (consisting of three equal-amplitude sinewaves, say, 1% apart in frequency)?
13. A phase modulated tone $x_1(t)=A_1\cos[\omega_1 t+\phi_1(t)$. What is the PMEPR of $x_1(t)$? Express your answer in decibels.
14. What is the PMEPR of an AM signal with 75% amplitude modulation?
15. Two FM voltage signals $x_1(t)$ and $x_2(t)$ are added together and then amplified by an ideal linear amplifier terminated in $50\ \Omega$ with a gain of 10 dB and the output voltage of the amplifier is $y(t)=\sqrt{10}[x_1(t)+x_2(t)]$.
   a. What is the PMEPR of $x_1(t)$? Express your answer in decibels?
   b. What effect does the amplifier have on the PMEPR of the signal?
   c. If $x_1(t)=A_1\cos[\omega_1(t)t]$ and $x_2(t)=A_2\cos[\omega_2(t)t]$, what is the PMEPR of the output of the amplifier, $y(t)$? Express PMEPR in decibels. Consider that $\omega_1(t)$ and $\omega_2(t)$ are within 0.1% of each other.
16. An FM signal has a maximum frequency deviation of 20 kHz and a modulating signal between 300 Hz and 5 kHz. What is the bandwidth required to transmit the modulated RF signal when the carrier is 200 MHz? Is this considered to be narrowband FM or wideband FM?
17. A high-fidelity stereo audio signal has a frequency content ranging from 50 Hz to 20 kHz. If the signal is to be modulated on an FM carrier at 100 MHz, what is the bandwidth required for the modulated RF signal? The maximum frequency deviation is 5 kHz when the modulating signal is at its peak value.
18. Consider FM signals close in frequency but whose spectra do not overlap. [Parallels Example 2.4.1]
   a. What is the PMEPR of just one PM signal? Express your answer in decibels.
   b. What is the PMEPR of a signal comprised of two uncorrelated narrowband PM signals with the same average power?
19. Consider two nonoverlapping equal amplitude FM signals having center frequencies within 1%.

a. What is the PMEPR in dB of just one FM modulated signal?
b. What is the PMEPR in dB of a signal comprising two FM signals of the same power?

20. Consider a signal $x(t)$ that is the sum of two uncorrelated signals, a narrowband AM signal with 50% modulation, $y(t)$, and a narrow-band FM signal, $z(t)$. The center frequencies of $y(t)$ and $z(t)$ are within 1%. The carriers have equal amplitude. Express answers in dB.
    a. What is the PAPR of the AM signal $x(t)$?
    b. What is the PAPR of the FM signal $z(t)$?
    c. What is the PAPR of $x(t)$?
    d. What is the PMEPR of the AM signal $x(t)$?
    e. What is the PMEPR of the FM signal $z(t)$?
    f. What is the PMEPR of $x(t)$?
21. Two phase modulated tones $x_1(t) = A_1 \cos[\omega_1 t + \phi_1(t)$ and $x_2(t) = A_2 \cos[\omega_2 t + \phi_2(t)$ are added together as $y(t) = x_1(t) + x_2(t)$. What is the PMEPR of $y(t)$ in decibels. Consider that ω_1 and ω_2 are within 0.1% of each other.
22. A radio uses a channel with a bandwidth of 25 kHz and a modulation scheme with a gross bit rate of 100 kbits/s that is made of an information bit rate of 60 kbits/s and a code bit rate of 40 kbits/s.
    a. What is the modulation efficiency in bits/s/Hz?
    b. What is the spectral efficiency in bits/s/Hz?
23. A cellular communication system uses $\pi/4$- DQPSK modulation with a modulation efficiency of 1.63 bits/s/Hz to transmit data at the rate of 30 kbits/s. This would be the spectral efficiency in the absence of coding. However, 25% of the transmitted bits are used to implement a forward error correction code.
    a. What is the gross bit rate?
    b. What is the information bit rate?
    c. What is the bandwidth required to transmit the information and code bits?
    d. What is the spectral efficiency in bits/s/Hz?
24. A radio uses a channel with a 5 MHz bandwidth and uses 256-QAM modulation with a modulation efficiency of 6.33 bits/s/Hz. The coding rate is $3/4$ (i.e. of every 4 bits sent 3 are data bits and the other is an error correction bit).
    a. What is gross bit rate in Mbits/s?
    b. What is information rate in Mbits/s?
    c. What is the spectral efficiency in bits/s/Hz?
25. The following sequence of bits 0100110111is to be transmitted using QPSK modulation. Take these data in pairs, that is, as 0100110111 These pairs, one bit at a time, drive the I and Q channels. Show the transitions on a constellation diagram. [Parallels Example 2.8.1]
26. The following sequence of bits 0100110111is to be transmitted using $\pi/4$-DQPSK modulation. Take these data in pairs, that is, as 0100110111 These pairs, one bit at a time, drive the I and Q channels. Use five constellation diagrams, with each diagram showing one transition or symbol. [Parallels Example 2.7.1]
27. The following sequence of bits 0100110111is transmitted using OQPSK modulation. Take these data in pairs, that is, as 0100110111 These pairs, one bit at a time, drive the I and Q channels. Show the transitions on a constellation diagram.
28. Draw the constellation diagram of OQPSK.
29. Draw the constellation diagrams of $3\pi/8$- 8DPSK and explain the operation of this system and describe its advantages.
30. How many bits per symbol can be sent using $3\pi/8$-8PSK?
31. How many bits per symbol can be sent using 8- PSK?
32. How many bits per symbol can be sent using 16- QAM?
33. Draw the constellation diagram of OQPSK modulation showing all possible transitions. You may want to use two diagrams.
34. What is the PMEPR of a 5-tone signal when the amplitude of each tone is the same?
35. Draw the constellation diagram of 64QAM.
36. How many bits per symbol can be sent using 32QAM?
37. How many bits per symbol can be sent using 16QAM?
38. How many bits per symbol can be sent using 2048QAM?
39. Consider a two-tone signal and describe intermodulation distortion in a short paragraph and include a diagram.
40. A 16-QAM modulated signal has a maximum RF phasor amplitude of 5 V. If the noise on the signal has an rms value of 0.2 V, what is the EVM of the modulated signal? [Parallels Example 2.11.1]

41. Consider a digitally modulated signal and describe the impact of a nonlinear amplifier on the signal. Include several negative effects.
42. A carrier with an amplitude of 3 V is modulated using 8-PSK modulation. If the noise on the modulated signal has an rms value of 0.1 V, what is the EVM of the modulated signal? [Parallels Example 2.11.1]
43. Consider a 32-QAM modulated signal which has a maximum I component, and a maximum Q component, of the RF phasor of 5 V. If the noise on the signal has an RMS value of 0.1 V, what is the modulation error ratio of the modulated signal in decibels? Refer to Figure 2.8.21(b). [Parallels Example 2.11.1]

2.14.1 Exercises By Section

§$12.21, 2, 3, 4, 5, 6, 7, 8, 910, 11, 12$

§$12.413, 14, 15, 16, 17, 18, 1920, 21$

§$12.522, 23, 24$

§$12.825, 26, 27, 28, 29, 30, 31$

§$12.932, 33, 34, 35, 36, 37, 38$

§$12.1139, 40, 41, 42, 43$

2.14.2 Answers to Selected Exercises

5. 2.55 dB

7. (e) 3.78 dB
8. 0.00022 W

15. no effect

20. (a) 6 dB

20. (e) 0 dB

22. (a) 4 bits/s/Hz

43. 36.02 dB
