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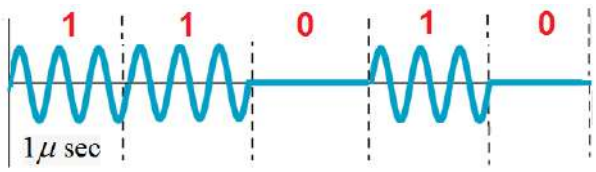
Communication Theory-I, 15 EC 2205

Problems and solutions for CO4:

1. An analog signal carries 4 bits in each signal unit. If 1000 signal units are sent per second, find the baud rate and the bit rate.
   Ans: Baud rate = 1000 bauds per second (baud/s)
   Bit rate = 1000 x 4 = 4000 bps.
2. The bit rate of a signal is 3000. If each signal unit carries 6 bits, what is the baud rate?
   Ans: Baud rate = 3000 / 6 = 500 baud/s.
3. Find the maximum bit rate for a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. Ans: 6 kbps
4. How many signal levels are needed to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. Ans:128 levels, the bit rate is 280 kbps
5. The signal-to-noise ratio is often given in decibels. Assume that SNR_{dB} = 36 and the channel bandwidth is 2 MHz. Find the channel capacity. Ans: 24 Mbps.
6. We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level? Ans: 6Mbps.
7. Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. Find the channel capacity. Ans: This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.
8. A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. Find the channel capacity. Ans: 34.860 kbps
9. Find the minimum bandwidth for an ASK signal transmitting at 2000 bps. The transmission mode is half-duplex.
   Ans: In ASK the ***baud rate and bit rate*** are the same. The baud rate is therefore 2000. An ASK signal requires a minimum bandwidth equal to its baud rate. Therefore, the minimum bandwidth is 2000 Hz.
10. Given a bandwidth of 5000 Hz for an ASK signal, what are the baud rate and bit rate?
11. Consider an ASK modulated signal shown below. Find the bit rate and baud rate.



12. Determine the bandwidth and baud for an FSK signal with a mark frequency of 32 kHz, a space frequency of 24 kHz, and a bit rate of 4 kbps.
13. Determine the maximum bit rate for an FSK signal with a mark frequency of 48 kHz, a space frequency of 52 kHz, and an available bandwidth of 10 kHz.
14. Determine the minimum bandwidth and baud for a BPSK modulator with a carrier frequency of 40 MHz and an input bit rate of 500 kbps. Sketch the output spectrum.
15. Find $\frac{E_b}{N_0}$ required to give $P_e = 10^{-5}$ for the following coherent digital modulation schemes: (a) BASK (b) BPSK (c) BFSK (d) BPSK with a phase error of 5 deg.

Ans: (a) For BASK $Q\left(\sqrt{\frac{E_b}{N_0}}\right) = 10^{-5} \Rightarrow \frac{E_b}{N_0} = 18.19 \text{ or } 12.6 \text{ dB}$

(b) For BPSK $Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = 10^{-5} \Rightarrow \frac{E_b}{N_0} = 9.1 \text{ or } 9.59 \text{ dB}$

(c) For BFSK $Q\left(\sqrt{\frac{E_b}{N_0}}\right) = 10^{-5} \Rightarrow \frac{E_b}{N_0} = 18.19 \text{ or } 12.6 \text{ dB}$

(d) The degradation of BPSK with a phase error of 5 degree is

$$-20\log_{10}\left(\cos 5^{o}\right) = 0.033 \text{ dB}$$

Therefore in this case $\frac{E_b}{N_0} = 9.59 + 0.033 = 9.623 \text{ dB}$

16. BPSK is used for data transmission over an AWGN channel with power spectral density $\frac{N_0}{2} = 10^{-10}$ W/Hz. The transmitted signal energy is $E_b = A^2 T_b / 2$, where T_b is the bit duration and A is the signal amplitude. Determine the value of A needed to achieve an error probability of 10^{-6}, if the data rate is: (a) 10 kbps (b) 100 kbps (c) 1Mbps.

Use $Q(x) = 10^{-6} \Rightarrow x = 4.75$

Ans: $Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = 10^{-6} \Rightarrow \frac{E_b}{N_0} = \frac{A^2 T_b}{N_0} = 4.75 \Rightarrow A^2 T_b = 45.125 \text{ x } 10^{-10}$

(a) For data rate 10kbps, $A = \sqrt{45.125 \text{ x } 10^{-10} \text{x } 10^{4}} = 6.6 \text{ mV}$

(b) For data rate 100kbps $A = \sqrt{45.125 \text{ x } 10^{-10} \text{x } 10^{5}} = 0.0210 \text{V.}$

(c) For data rate 100kbps $A = \sqrt{45.125 \text{ x } 10^{-10} \text{x } 10^{5}} = 0.0664 \text{ V.}$

17. Find the bit error probability for a BPSK system with a bit rate of 1 Mbps. The received waveforms $s_1(t) = A\cos\omega_0 t$ and $s_2(t) = -A\cos\omega_0 t$ are coherently. The value of A is

10 mV. Assume that the single sided noise power spectral density is $N_o = 10^{-11}$ W/Hz. Use $Q(\sqrt{10}) = 8\text{x}10^{-4}$.

18. Compare the SNR / bit and average power required at the demodulator to maintain a BER = 10^{-6} using BPSK and BFSK for data transmission over a radio channel at 56 kbps. Assume that the channel adds white Gaussian noise with power spectral density $N_0 = 10^{-10}$. Use $Q(x) = 10^{-6} \Rightarrow x = 4.75$