MULTI LEVEL MODULATION PROBLEM SHEET

(extracted from *Digital Communications* by Andy Bateman- Addison Wesley pp159-160)

1. An 8-ary ASK scheme makes use of a root raised cosine filter in both the transmitter and the receiver, with an α of 0.33. What is the bandwidth required to support a data rate of 64kbps?

$C = B\log_2 M/(1+\alpha)$
$B = C(1+\alpha)/\log_2 M = 64\times10^3 \times 1.33 / 3 = 28.373$ kHz

2. A digital voice link requires a bit error performance of no worse than 1 error in 10^3. From the bit error plot for M-ary ASK, what is the approximate E_b/N_0 required for binary ASK and an 16-ary ASK modem (both Bipolar)?

Based on the BER plots: 7dB for binary ASK, 21dB for 16-ASK (Note that the BER plots in the notes for M-ASK are all for the case of bipolar signalling – unipolar signalling requires an additional 3dB)

3. An 32-ary ASK modem has a symbol error rate of 2 in 10^5 under worst case conditions. What is the approximate bit error rate assuming Gray coding has been used.

$BER \approx SER/\log_2 M \approx 2\times10^{-5}/5 \approx 4\times10^{-6}$

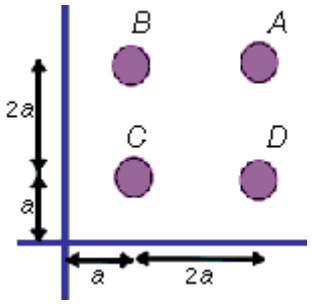
4. An 4-ary orthogonal FSK modem has a symbol rate of 2400 symbols per second. If the lowest symbol frequency is 8kHz, What will the other symbol frequencies be?

Spacing must be half the symbol rate, ie. 1.2kHz. Thus, 9.2kHz, 10.4kHz and 11.6kHz will be the other frequencies.

5. What is the maximum bandwidth efficiency possible for a modem required to operate with an E_b/N_0 of –1.2dB.

$C/B = \log_2(1+E_bC/N_oB)$
$C/B = \log_2(1+0.76C/B)$
This can be solved computationally to be approximately 0.3 bits/s/Hz

6. If the peak signal power for a 16-QAM system is 200 W, measured in a 50Ω load, what are the amplitudes of the different symbol vectors in the transmitted waveform? (Neglect any filtering effects)



Considering one quadrant of the 16-QAM constellation, the average power developed by each of the vectors ***A***, ***B***, ***C***, ***D*** is as follows:

$A^2 = (3a)^2 + (3a)^2 = 18a^2$
$B^2 = (3a)^2 + (a)^2 = 10a^2$
$C^2 = (a)^2 + (a)^2 = 2a^2$
$D^2 = (3a)^2 + (a)^2 = 10a^2$

$A^2 = 200W$ Hence:
$B^2 = D^2 = 111W$
$C^2 = 22W$

The other quadrants of the constellation will have similar powers.

7. A 16-QAM data link operates at 256 kbps. What is the underlying symbol rate on the channel, and what is the occupied bandwidth if 2 root raised cosine filters are employed, one in the transmitter and one in the receiver, each with an α of 0.5?

$C = f_s \log 2M$
$f_s = C/\log_2 M = 256 \times 10^3 / 4 = 64kBaud$
$B = (1+\alpha)f_s = 1.5 \times 64x10^3 = 96kHz$

8. What is the minimum bandwidth required to support a 256 kbps data stream using:
   (a) four-level bipolar baseband signalling
   (b) four level polar baseband signalling
   (c) BPSK
   (d) QPSK
   (e) 64-QAM

For baseband transmission, the bandwidth required is 0.5Hz/Baud.Thus: $B = C/2\log_2 M$
   (a) $B = C/2\log_2 M = 256x10^3/4 = 64kHz$
   (b) $B = C/2\log_2 M = 256x10^3/4 = 64kHz$

For bandpass transmission, the bandwidth required is 1Hz/Baud.Thus: $B = C/\log_2 M$

   (c) $B = C/\log_2 M = 256x10^3/2 = 128kHz$
   (d) $B = C/\log_2 M = 256x10^3/2 = 128kHz$
   (e) $B = C/\log_2 M = 256x10^3/1 = 256kHz$
   (f) $B = C/\log_2 M = 256x10^3/2 = 128kHz$
   (g) $B = C/\log_2 M = 256x10^3/6 = 42.6kHz$

9. A microwave line-of-sight communication link uses 256-QAM to convey 32Mbps. The bandwidth occupied by the signal is 7 MHz.
   (a) What is the value of α used in the raised cosine filter.
   (b) If the signal to noise ratio on the link is 40dB, what is the theoretical maximum capacity for the channel in a 7MHz bandwidth?

   (a) $C = B\log_2 M/(1+\alpha)$
   $\alpha = (B(\log_2 M)/C) - 1 = (8 \times 7x10^6/32x10^6) - 1 = 0.75$
   (b) $C = B\log_2(1+S/N) = 7x10^6 \log_2(10001) = 93.3Mbits/s$

10. A customer requires a microwave radio link to provide a bit rate of 2 Mbps in a bandwidth of 400kHz. The minimum signal to noise ratio on the channel is 30dB.

Can the channel support the require capacity, and how many symbol states would be required?

$C = B\log_2(1+S/N) = 4x10^5\log_2(1001) = 4$Mbits/s. So the channel can support 2Mbits/s.

$M=2^{C/B} = 2^{2000000/400000} = 32$