Solution to Exam in TSKS02 Telecommunication

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1 Question part

1. a) Fading is caused by multi-path transmission. Yes, when a mobile phone moves relative to the base station, the reflection surfaces change, and the received signal becomes stronger and weaker-fading.

   b) The envelope detector can be used for demodulation of AM-SSB: No, see chapter 5.

   c) You need the carrier frequency and the correct phase at the receiver to demodulate standard AM: no, see chapter 5.

   d) Delta modulation can reduce the number of bits required to describe a slowly varying source in comparison with standard quantization: yes, this is the purpose of the delta modulator, see chapter 6.

   e) Kraft's inequality can be used to explain the Hamming bound: No, see chapter 8 and 9.

2. See chapter 4.

3. See chapter 7.

2 Problem part

1. 4-PSK: $k = 2$ bit/symbol, so $E = 2E_b$ and
   $P_\mathrm{b} \approx 0.5P_\mathrm{e} = Q\left(\sqrt{\frac{E}{N_0}}\right) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$
   $P_\mathrm{b} = 10^{-4} \Leftrightarrow Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \approx 10^{-4} \Leftrightarrow \sqrt{\frac{2E_b}{N_0}} \approx 3.72 \Leftrightarrow \frac{E_b}{N_0} \approx 6.92$
   BPSK: $k = 1$ bits/symbol, so $E = E_b$ and
   $P_\mathrm{b} = P_\mathrm{e} = Q\left(\sqrt{\frac{2E}{N_0}}\right) = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$

   This is the same P_b-formula as for 4-PSK. This means that the the bit error probabilities are the same if the bit signal-to-noise ratio is the same!

   We notice that with the same bit signal-to-noise ratio, 4-PSK achieves 2 times higher rate than BPSK, at no bit error probability cost. However, 4-PSK is using one more signaling dimension.

2. a) No, (11011) + (01101)=(10110) is not in the codebook. This means that the code is non-linear.

   b) For example, start with $G' = \begin{pmatrix} 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 \end{pmatrix}$ and use row operations to get

$$G = \begin{pmatrix} 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 \end{pmatrix}.$$

   c) Yes, the code is now described by a generator matrix. A code being described by a generator matrix means that all linear combinations of the generator matrix rows constitutes the codebook. By combining these codewords, we again only get combinations of the generator matrix rows, i.e., we stay in the codebook, and the code is linear (It is enough for full points to note that the code can be described by a generator matrix).

   d)

$$H = (P^{\mathsf{T}}, I_3) = \begin{pmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 \end{pmatrix}$$

   e) There is neither a single column nor sum of two columns of H which equals an all-zero column. Columns 1 and 3 and 4 of H however sum to an all-zero column. This means that the minimum distance is 3.

3. a) $Y(f) = \frac{j}{2}[X(f+f_c) - X(f-f_c)]$ with $X(f) = M(f)H_1(f) = \begin{cases} M(f), & |f| \le f_0 \\ 0, & \text{otherwise.} \end{cases}$

   b) $Z(f) = \frac{1}{2}X(f)$.

   c) $Z(f) = 0$.

   d) This is AM-SC modulation. In (b), we have access to correct phase, and can demodulate. In (c), we do not have accurate phase, and demodulation breaks down.