EXAMINATION

MOBILE RADIO COMMUNCATIONS 121103

April 3, 2006

General guidelines:

- put your name on every page
- number each page
- derivations are more important than final answers
- work accurately
- success

1. In Figure 1, you see a 4-point constellation that is used for modulation schemes QPSK, offset-QPSK and MSK. We receive a signal using this constellation which has a bit rate of 1 Mb/s. The power received is –98dBm. Our receiver has a noise figure of 10dB. The normalized power density spectrum *G(f)* for MSK is:

$$G(f)=\frac{16}{\pi^2}\left(\frac{\cos 2\pi fT}{1-16f^2T^2}\right)^2$$

where *T* is the symbol time.

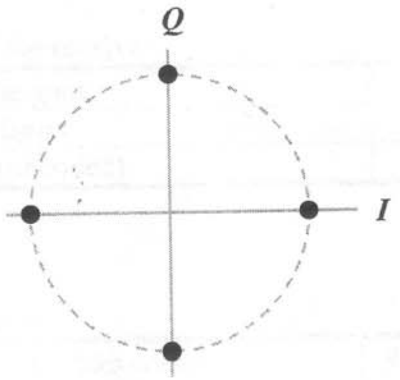

Figure 1. Modulation constellation diagram.

a) Describe the differences in modulation schemes.
b) Determine the double-sided, null-to-null transmission bandwidth for each modulation scheme.
c) Which modulation has the best TX spectrum and why?
d) What are the obtained BER values at the receiver for the different modulation formats assuming an AWGN channel? (Use the Q function and assume a input filter with a noise bandwidth identical to the null-to-null bandwidth).
e) If a class-C amplifier is desired in the transmitter to reduce cost and power consumption, which modulation scheme is preferred? Motivate your answer.
f) If the QPSK is shaped with a raised cosine filter with α=0.5, what will be the null-to-null transmission bandwidth?
g) What will the raised cosine shaping do with the zero crossings of the symbol impulse response in the time domain? (motivate your answer)
h) Instead of a raised cosine TX filter, a root-raised cosine TX and RX filter is used. Why is this done and what is the effect on the inter-symbol interference?

2. A forward-error correction code is applied to improve the robustness of a wireless link. The required user rate is 130 kb/s or larger. A QPSK modulation is used which allows a maximum bit rate of 250 kb/s in a channel bandwidth of 125 kHz. The carrier frequency is 450 MHz. The sender has a 1W transmit power omni-directionally transmitted, whereas the receiver characteristics are shown in the first table below. The range to cover is 25km (assume a 25dB/dec propagation loss).
Several alternative FEC schemes are used; both block coding and convolutional coding are considered. Their characteristics are summarized in the second table below. The encoder for the coding scheme finally selected is shown in Figure 2 below.

The characteristics of the receiver:

Antenna gain	0 dBi
Noise factor	7 dB
E_b/N_0 (uncoded)	10 dB

Different coding schemes:

Coding scheme	*Required E_b/N_0*
½-rate convolutional code A	5.5 dB
1/3-rate convolutional code B	4.2 dB
1/5-rate convolutional code C	3.0 dB
(3,1) Hamming code	7.2 dB
(7,4) Hamming code	9.0 dB
(31,26) Hamming code	9.3 dB
(23,12) Golay code	6.0 dB
(8,4) RM code	6.5 dB
(63,47) RS code	8.5 dB

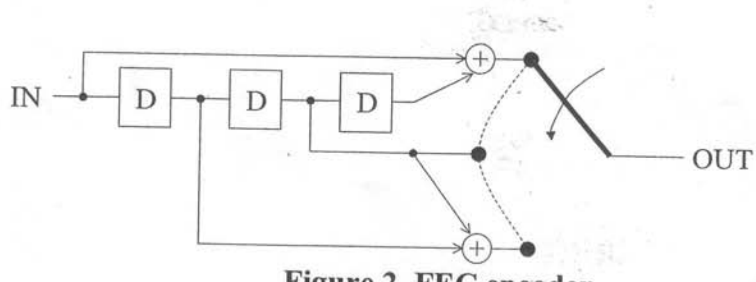

Figure 2. FEC encoder.

a) Will the system without coding give the required range?
b) Which of the coding scheme(s) in table listing all the schemes can be used to fulfill the requirements? Motivate your answer (Tip: consider the required SNR values of the different coding schemes).
c) Which coding scheme gives you the maximum user data rate and what is this user rate?
d) What type of coding scheme is represented by the circuit the Figure 2?
e) What is the constraint length of the FEC code in the figure?
f) The initial state of the circuit the Figure 2 is 000. The input sequence is 0110000. What is the output sequence (suggestion: use a state diagram)?

3. The following shortened BCH code is used:

information	Code #	codeword
000	0	0000000
001	1	1101000
010	2	1110010
011	3	1010001
100	4	0001101
101	5	1001011
110	6	0010111
111	7	1111111

a) Is this code systematic or not?
b) Is this code linear or not?
c) What is the minimum distance?
d) Which code word pairs are orthogonal?
e) How many errors per code word can be detected?
f) How many errors per code word can be corrected?
g) We consider a channel on which the errors are uniformly distributed. If the raw bit error rate (BER) on the channel is 1%, what is then the residual BER after decoding assuming the coding bits are used for correcting bit errors?
h) This code is used in an air interface where bit errors always arrive in bursts. A block interleaving scheme is used as shown in Figure 3. The coded bit stream is written in four rows, from top to bottom. The block is then read from seven columns from left to right and the bits are transmitted. What is the length of the maximum error burst that can be corrected?

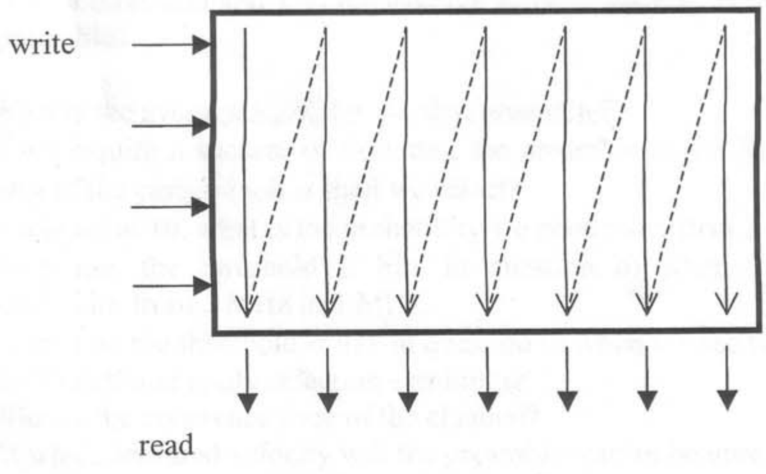

Figure 3. Interleaving scheme

4. A UMTS mobile unit is powered on for the first time. After synchronization to the downlink pilot channel, it sends a random access preamble to the base station (NodeB). The first preamble is sent at a power level of 10 dBm. If the preamble is not detected, a second preamble is sent at 13 dBm. If this one is not detected, a third preamble is sent at 16 dBm, etc. The distance between the mobile and NodeB is 1 km. The mobile velocity if 100 km/hr.

The characteristics of the UMTS base stations and mobile unit are:

Antenna gain base station	14 dBi
Noise factor base station	5 dB
Transmit power base station	10 W
Antenna gain mobile unit	0 dBi
Noise factor mobile terminal	7 dB
Transmit power mobile unit	10 dBm + k.3dB
Receiver sensitivity terminal	-100 dBm
Carrier frequency	2 GHz
Signal bandwidth (after spreading)	5 MHz
RA preamble length	1 ms
Path loss formula PL = $40+35\log_{10}(d)$ d in m	

The probability of missed detection of the preamble is approximated by:

$$\Pr(\text{preamble missed}) = 1 - e^{-\alpha/\Gamma}$$

where α is a threshold and Γ is the average E_p/N_0 wherer E_p is the total energy in the preamble.

a) What is the average E_p/N_0 for the first preamble?
b) If we require a success of detecting the preamble at the first occasion in 99% of the case, which α shall we select?
c) If α is set at 10, what is the probability we need more than 2 attempts?
d) Determine the threshold α like in question b) when we reduce the bandwidth from 5 MHz to 1 MHz.
e) Determine the threshold α like in question b) when we use two antennas at the NodeB and apply selection combining.
f) What is the coherence time of the channel?
g) At which terminal velocity will the preamble start to be unreliable?