參考用

所別： 通訊工程學系碩士班 不分組(一般生)

科目： 通訊系統

本科考試禁用計算器

*請在答案卷內作答

須有計算過程

1. (10%) At the receiver, the received signal is sent into a BPF, and the output of the BPF is $x_r(t) = 10m(t)\cos(\omega_c t) + n(t)$ where the message $m(t)$ is zero-mean and has power 0.5, and $n(t)$ is narrowband white noise with double-sided PSD $N_0/2$. After that, $x_r(t)$ is multiplied by $2\cos(\omega_c t)$ and then sent into a LPF. The bandwidths of BPF and LPF are B and $B/2$ respectively. What is the SNR at the LPF output?

2. (8%) Consider DSB, SSB and coherent AM with efficiency 40%, all have the same transmitted signal power and the same AWGN channel. If the output SNR of DSB is 20 dB, what are the output SNRs of SSB and AM?

3. (10%) Consider the random process with sample functions $X(t) = A\cos(2\pi f_0 t + \Theta)$ where f_0 is a constant.
(a) (5%) Assume that Θ is zero and A is a random variable uniformly distributed in $[-1, 1]$. Write down an expression for the pdf of $X(t)$ at time t_0. Is $X(t)$ stationary? Is $X(t)$ ergodic?
(b) (5%) Assume that A is a constant and Θ is a random variable uniformly distributed in $[0, 2\pi]$. Is $X(t)$ stationary? Is $X(t)$ ergodic in mean? Please explain your answers.

4. (10%) Consider the received FM signal $x(t) = A_c\cos(2\pi f_c t + 2\pi f_d \int^t m(\alpha)d\alpha) + n(t)$ where $n(t)$ is AWGN. Assume that the discriminator SNR is sufficient large to result in operation above threshold. Please explain your answers to the following questions.
(a) (5%) In order to reduce the noise power at the receiver output, what should we do in $x_c(t)$? (i.e., How do we adjust the parameters in $x_c(t)$?)
(b) (5%) In order to increase the signal power at the receiver output, what should we do in $x_c(t)$?

5. (8%) Consider the received FM signal $x(t) = A_c\cos(2\pi f_c t + 2\pi f_d \int^t m(\alpha)d\alpha) + n(t)$ where $n(t)$ is AWGN.
(a) (3%) Please discuss the relation between f_d and the bandwidth of the predetection filter.
(b) (5%) Express $x(t)$ by an alternative form $x(t) = A\cos(2\pi f_c t + \psi(t))$ where $\psi(t)$ consists of modulation phase (due to $m(t)$) and noisy phase. Consider the case of a large f_d. A receiver uses a phase-locked loop to obtain a signal $x'(t) = B\cos(2\pi f_0 t + \beta\psi(t))$ where $\beta << 1$. What is the advantage of detecting $x'(t)$? Please explain your answer.

6. (10%) Consider the modulated signal $x_c(t) = m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t = A(t)\cos(\omega_c t + \theta(t))$. Let $\{\cdots, d_{k-1}, d_k, \cdots\}$ denote a sequence of 1 or -1 decided by data bits. Determine the values of $\Delta\theta_{\max} = \max_t \lim_{\delta\to 0} |\theta(t+\delta) - \theta(t)|$ for the following cases of $m_1(t)$ and $m_2(t)$. We use k to represent an arbitrary **odd** integer.
(a) (2%) $m_1(t) = d_{k-1}$ and $m_2(t) = d_k$ for $(k-2)T \le t < kT$.
(b) (2%) $m_1(t) = d_{k-1}$ for $(k-3)T \le t < (k-1)T$; $m_2(t) = d_k$ for $(k-2)T \le t < kT$.
(c) (3%) $m_1(t) = d_{k-1}\cos\frac{\pi t}{2T}$ for $(k-3)T \le t < (k-1)T$; $m_2(t) = d_k\sin\frac{\pi t}{2T}$ for $(k-2)T \le t < kT$.
(d) (3%) $m_1(t) = d_{k-1}\sin\frac{\pi t}{2T}$ for $(k-3)T \le t < (k-1)T$; $m_2(t) = d_k\cos\frac{\pi t}{2T}$ for $(k-2)T \le t < kT$.

注意：背面有試題

7. (10%) Consider a (3,1) repetition code whose codewords are (0,0,0) and (1,1,1). The modulation is BPSK. For $i = 1, 2, 3$, define $\phi_i(t) = \begin{cases} \sqrt{\frac{2}{T_s}} \cos(\omega_c t), & (i-1)T_s \le t < iT_s \\ 0, & \text{elsewhere} \end{cases}$.

(a) (5%) Show that the set $\{\phi_1(t), \phi_2(t), \phi_3(t)\}$ is an orthonormal basis.

(b) (5%) Consider the three-dimensional Euclidean space with three mutually perpendicular axes labeled by $\phi_1(t), \phi_2(t), \phi_3(t)$. Define two points in the space which correspond to the two codewords. What is the error probability when the optimum receiver is used (expressed by the Q-function and average energy per data bit E_b)?

8. (12%) Consider a signal set containing sixteen signals

$$s_i(t) = \sqrt{\frac{2}{T_s}}[a_i \cos(\omega_c t) + b_i \sin(\omega_c t)], \qquad 0 \le t \le T_s, \qquad i = 1, 2, \cdots, 16$$

where $\{(a_1, b_1), (a_2, b_2), \cdots, (a_{16}, b_{16})\} = \{(\pm\frac{1}{\sqrt{10}}, \pm\frac{3}{\sqrt{10}}), (\pm\frac{3}{\sqrt{10}}, \pm\frac{1}{\sqrt{10}}), (\pm\frac{r_0}{\sqrt{2}}, \pm\frac{r_0}{\sqrt{2}}), (\pm\frac{r_1}{\sqrt{2}}, \pm\frac{r_1}{\sqrt{2}})\}$ $(r_0 < 1 < r_1)$.

(a) (4%) What is the restriction on r_0 and r_1 so that the average energy is 1?

(b) (8%) The minimum Euclidean distance is defined as the minimum value of the Euclidean distance between any two different signal points. What is the value of r_0 which maximizes the minimum Euclidean distance?

9. (22%) Consider a 16QAM signal set containing signals

$$s_i(t) = a_i \cos(\omega_c t) + b_i \sin(\omega_c t), \qquad 0 \le t \le T_s, \qquad i = 1, 2, \cdots, 16$$

where $\{(a_1, b_1), (a_2, b_2), \cdots, (a_{16}, b_{16})\} = \{(\pm 1, \pm 1), (\pm 1, \pm 3), (\pm 3, \pm 1), (\pm 3, \pm 3)\}$. The AWGN channel with two-sided PSD $N_0/2$ is assumed. In (a)-(c), the required data rate is 3 bits/symbol, so only eight signal points are needed. Consider the following two criteria: (i) Choose eight points which have the lowest energy. (ii) Choose eight points which have the largest minimum Euclidean distance.

(a) (5%) Do (i). Find the error probability in terms of the Q-function and E_s (average energy per symbol).

(b) (5%) Do (ii). Find the error probability in terms of the Q-function and E_s.

(c) (2%) Choose the best one from (i) and (ii).

(d) (10%) For the case of data rate 4 bits/symbol, all sixteen points are used. The mapping rule from data bits $b_3b_2b_1b_0$ to signal points is described as follows. The bits b_1b_0 decides which quadrant is used, and then the bits b_3b_2 determine which point in the selected quadrant is used. More specifically, if $(b_1, b_0) = (0,0), (0,1), (1,0), (1,1)$, then the sign of (a_i, b_i) is $(+,+), (-,+), (-,-), (+,-)$, respectively; if $(b_3, b_2) = (0,0), (0,1), (1,0), (1,1)$, then $(|a_i|, |b_i|) = (1,1), (1,3), (3,1), (3,3)$, respectively. Please find the bit error probability in terms of the Q-function and E_b for the optimum receiver.