东 南 大 学 考 试 卷（ A 卷）

课程名称 通信原理 考试学期 06-07-3 得分

适用专业 信息工程 考试形式 闭卷 考试时间长度 120分钟

自觉遵守考场纪律 如考试作弊 此答卷无效

姓名 学号

Section A(30%): True or False (Give your reason if False, 3% for each question)

1. Power and Time are two primary resources in a communication system. (X)
2. Envelop detection can be used in noncoherent receiver. (√)
3. If a Gaussian process is stationary, then the process is also strictly stationary. (√)
4. If two random variables are uncorrelated, they are also statistically independent. (X)
5. Considering DSB modulation, its figure of merit is determined by bandwidth. (X)
6. Performance of a PCM system is ~~only~~ mainly affected by quantization noise. (X)
7. DM requires a sampling rate much higher than the Nyquist Rate. (√)
8. A correlator is equal to a matched filter. (X)
   P284 相关器的输出只有在 t=T 上相等 才等价于匹配滤波器
9. In a QPSK system, bit error rate equals symbol error rate. (X)
   $BER = \frac{Pe}{\log_2 M}$
10. With a same modulation scheme, performance of a coherent receiver is ~~worse~~ better than that of a non-coherent receiver. (X)

Section B(30%): Fill in the Blanks (3% for each question)

1. Suppose the highest frequency component of a message signal m(t) is w Hz, the Nyquist rate of this signal is ___2W___ samples per second.
2. A random process X(t) is applied to a linear time-invariant filter of frequency response H(f), the output process is Y(t). If the power spectral density of X(t) is $S_X(f)$, then the power spectral density of Y(t) is ___$|H(f)|^2 S_X(f)$___.
3. A narrowband signal is $X(t) = 5\cos(2\pi f_c t+0.5)$, where f_c is carrier frequency and f_c = 10 MHz, the in-phase component of X(t) is ___$5\cos 0.5$___.
4. Basic operations performed in the transmitter of a PCM system are ___Sampling___, ___Quantizing___, and ___Coding___.
5. Bandwidth efficiency of QPSK is ___ bits/s/Hz; bandwidth efficiency of BFSK (Sunde's FSK) is ___1___ bits/s/Hz.
6. A carrier wave of frequency 1 MHz is frequency modulated by a message signal m(t) = $2\cos(20\pi t)$ (V), the frequency sensitivity of the modulator is 5 Hz/V, by using Carson's rule, bandwidth of the modulated wave is ___40___ Hz.
7. A 80 kb/s binary data sequence is transmitted using baseband binary PAM. Raised-cosine spectrum with rolloff factors α = 0.5 is adopted by the system. The transmission bandwidth of the system is ___60___ kHz.
8. The autocorrelation function of a stationary process X(t) is $R_X(t)$, then the power spectral density of X(t) is $S_X(f)$ = ___$\int_{-\infty}^{+\infty} R_X(t)\cdot \exp(-j2\pi f t)dt$___
9. A signal m(t) = 10cos (2πt) V is uniformly quantized. If the quantization step is Δ = 0.5 V, then the minimal number of quantization level is L_{min} = ___40___, and the number of bits per sample is at least R_{min} = ___6___.
10. Sampling rate of delta modulator is f_s = 80 KHz, the step size is Δ = 0.1 V. The modulator is tested with a 1 kHz sinusoidal signal. To avoid slope overload, the maximum amplitude of this test signal is ___$\frac{4}{\pi}$___.

$\frac{\Delta}{T_s} \geq \frac{d(A\sin 2\pi f t)}{dt}$

$\Delta f_s \geq A\cdot 2\pi f$

$8k \geq A\cdot 2\pi \times 1k$

$A \leq \frac{8k}{2\pi} = \frac{4}{\pi}$

Section C(40%): Calculations (10% for each question)

1. A random process $Y(t)$ is defined by

$$Y(t) = m(t)\cos(2\pi f_c t + \theta)$$

where $m(t)$ is a stationary process, and the autocorrelation function of $m(t)$ is $R_m(\tau) = \begin{cases} 1 & |\tau| \le 1 \\ 0 & otherwise \end{cases}$. θ is a random variable uniformly distributed over the interval $[0, 2\pi]$. Suppose θ and $m(t)$ are statistically independent.

(1) Show that $Y(t)$ is stationary in wide-sense.

(2) Determine the power spectral density of $Y(t)$?

(3) Determine the AC power contained in $Y(t)$.

$\mu_Y(t) = E[Y(t)] = E[m(t)\cos(2\pi f_c t + \theta)]$

$= E[m(t)] \cdot E[\cos(2\pi f_c t + \theta)]$

$= 0$

$R_Y(\tau) = E[Y(t+\tau)Y(t)]$

$= E[m(t+\tau)\cos(2\pi f_c t + 2\pi f_c \tau + \theta) m(t)\cos(2\pi f_c t + \theta)]$

$= E[m(t+\tau)m(t)] \frac{1}{2} E[\cos(4\pi f_c t + 2\pi f_c \tau + 2\theta) + \cos(2\pi f_c \tau)]$

$= \frac{1}{2} R_m(\tau) \cdot \cos(2\pi f_c \tau)$

$R_Y(\tau)$ is only determined by τ

$\Rightarrow Y(t)$ is stationary in wide-sense

$S_Y(f) = F[R_Y(\tau)] = \frac{1}{2} F[R_m(\tau)\cos(2\pi f_c \tau)]$

$= \frac{1}{2} F[R_m(\tau)] * \frac{1}{2}[\delta(f-f_c) + \delta(f+f_c)]$

$= \frac{1}{4} 2\mathrm{sinc}(2f) * [\delta(f-f_c) + \delta(f+f_c)] = \frac{1}{2}[\mathrm{sinc}[2(f-f_c)] + \mathrm{sinc}[2(f+f_c)]]$

$E[Y^2(t)] = R_Y(0) = \frac{1}{2}R_m(0)$

$= 0.5$

2. Consider an AM modulated signal $s(t)$ produced by modulating signal $m(t)$ with 100 percent modulation. The carrier frequency is f_c and amplitude is Ac. $s(t)$ is transmitted over a white Gaussian noise channel with zero mean and power spectral density $\frac{N_0}{2}$.

(1) Determine the modulated signal $s(t)$.

(2) If the average carrier power is large compared to the average noise power, determine the envelope of $s(t)$.

(3) If the average carrier power is large compared to the average noise power, and the power spectrum density of $m(t)$ is

$$S_m(f) = \begin{cases} \frac{1}{W} & |f| \le W \\ 0 & otherwise \end{cases}$$

Determine the output signal-to-noise ratio of the AM receiver using envelope detection.

(1) $s(t) = (1 + k_a m(t)) A_c \cos(2\pi f_c t)$

(2) $A_c + k_a A_c m(t) + n_I(t)$

(3) $(SNR)_{o,AM} = \frac{\frac{1}{2} A_c^2 P k_a^2}{N_0 W}$ $|k_a m(t)| \le 1$

$P = \frac{1}{2} \times W \times 1 \times 2 = W$

$\therefore (SNR)_{o,AM} = \frac{\frac{1}{2} A_c^2 \cdot W k_a^2}{N_0 \cdot W} = \frac{A_c^2 k_a^2}{2N_0}$

3. Figure P3 shows a pair of signals $s_1(t)$ and $s_2(t)$.

(1) Show that $s_1(t)$ and $s_2(t)$ are orthogonal.

(2) Find a set of orthonormal basis functions and construct the signal constellation for $s_1(t)$ and $s_2(t)$.

(3) Determine the impulse response of the matched filters for the pulses $s_1(t)$ and $s_2(t)$, respectively, and sketch them as a function of time.

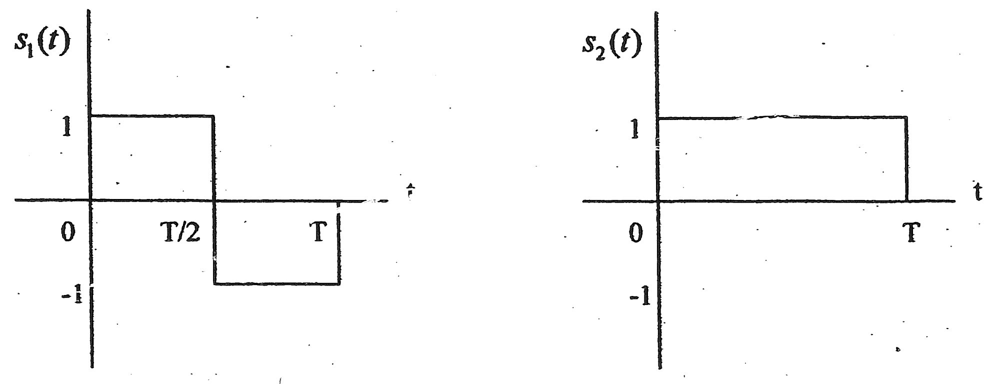
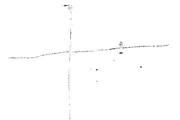


Figure P3

(1) $\int_0^T s_1(t)\, s_2(t)\, dt = 0$

$\Rightarrow$ orthogonal

$s_1(t) = \sqrt{T}\,\phi_1(t)$
$s_2(t) = \sqrt{T}\,\phi_2(t)$



② $E_1 = \frac{T}{2} \cdot 1 + \frac{T}{2} \cdot 1 = T$

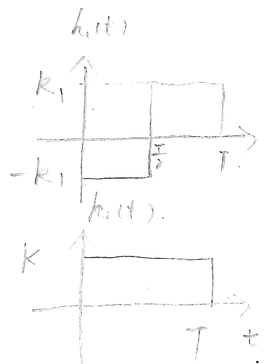
$E_2 = T \times 1 = T$

$\therefore \phi_1(t) = \frac{s_1(t)}{\sqrt{E_1}} = \frac{s_1(t)}{\sqrt{T}}$

$\phi_2(t) = \frac{s_2(t)}{\sqrt{E_2}} = \frac{s_2(t)}{\sqrt{T}}$

③ $h_1(t) = k_1 s_1(T-t)$

$h_2(t) = k_2 s_2(T-t)$



$\phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t)$

$\phi_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t)$

$\sqrt{\frac{2E}{T}}\cos(2\pi f_c t)\cos(2i-1)\frac{\pi}{4} - \sqrt{\frac{2E}{T}}\sin(2\pi f_c t)\sin(2i-1)\frac{\pi}{4}$

4. In a coherent QPSK system, transmitted signals are defined by

$Pe = \text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$

$$s_i(t) = \begin{cases} \sqrt{\dfrac{2E}{T}}\cos\left[2\pi f_c t + (2i-1)\dfrac{\pi}{4}\right], & 0 \le t \le T \\ 0, & \text{otherwise} \end{cases}$$

where $i = 1, 2, 3, 4$, E is the transmitted signal energy per symbol, and T is the symbol duration. The carrier frequency f_c equals n_c/T for some fixed integer n_c.

(1) Find orthonormal basis functions for the transmitted signals.

(2) Plot the signal-space diagram of the coherent QPSK system.

(3) Determine the symbol error probability of the coherent QPSK system.

(4) With Gray encoding used, determine the bit error rate of the coherent QPSK system.

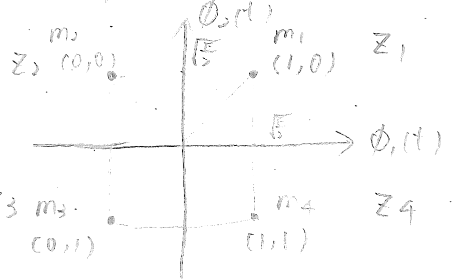
(1) $\phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t)$

$\phi_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t)$

② $s_i(t) = \sqrt{E}\sqrt{\frac{2}{T}}\left[\cos(2\pi f_c t)\cos\frac{(2i-1)\pi}{4} - \sin(2\pi f_c t)\sin\frac{(2i-1)\pi}{4}\right] \quad 0 \le t \le T$

$s_{i1} = \sqrt{E}\cos\frac{(2i-1)\pi}{4}$

$s_{i2} = -\sqrt{E}\sin\frac{(2i-1)\pi}{4}$



i=1 (1,0)
i=2 (0,0)
i=3 (0,1)
i=4 (1,1)

③ QPSK $Pe = \text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$ $\quad BER = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$

$d_{min} = 2\sqrt{\frac{E}{2}} = \sqrt{2E}$

$P_c = (1-p')^2$

$P_e = 1 - P_c = 1-(1-p')^2 = 1-(1+p'^2-2p') = 2p' - p'^2$

$p' = \frac{1}{2}\text{erfc}\left(\frac{d_{min}}{2\sqrt{N_0}}\right) = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E}{2N_0}}\right)$

$P_e \approx 2p' = \text{erfc}\left(\sqrt{\frac{E}{2N_0}}\right) = \text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$ $\quad E = 2E_b$ $\quad BER = \frac{P_e}{\log_2 M}$

④ $BER = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$