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东 南 大 学 考 试 卷（ A 卷）

课程名称	通信原理	考试学期	04-05-3	得分	
适用专业		考试形式	闭卷	考试时间长度	150 分钟

学号　　姓名　　密　封　线

Section A(30%): True or False (Give your reason if False, 2% for each question)

1. 1. A typical mobile radio channel is a free propagation, linear, and time invariant channel. (×)

2. 2. The power spectral density of a stationary process is always nonnegative. (√)

3. 3. In a communication system, noise is unwanted and over which we have incomplete control. (×)

4. 4. If a random process is stationary, it is ergodic; if a Gaussian random process is stationary, then it is also strictly stationary. (×)

5. 5. Double Sideband-Suppressed Carrier (DSB-SC), Single Sideband (SSB), and Frequency Modulation (FM) are all linear modulation schemes. (×)

6. 6. Figure of merit (defined as $(SNR)_O/(SNR)_C$) of AM of DSB-SC is 1/3, and figure of merit of Amplitude Modulation (AM) is less than or equal to 1/3. (×)

7. 7. μ-law is a nonlinear compression law and A-law is a linear compression law. (×)

8. 8. The matched filter at the receiver maximizes the peak pulse signal-to-noise ratio, thus is optimal in a baseband data transmission system with Inter-Symbol Interference (ISI). (×)

9. 9. Correlative-level coding (also known as partial-response signaling) schemes are used to avoid ISI. (×)

10. 10. Time-Division Multiplexing (TDM) is used in Asymmetric Digital Subscriber Lines (ADSL) to separate voice signals and data transmission. (×)

11. 11. If coefficients of an equalizer is adjusted using the Least-Mean-Square (LMS) algorithm adaptively, then the matched filter in front of the equalizer is not necessary. (√)

12. 12. In an M-ary Phase-Shift Keying (M-PSK) system, if the average probability of symbol error is P_e, then the average Bit Error Rate (BER) of the system is $P_e/\log_2 M$. (×)

13. 13. With the same Signal-to-Noise Ratio (SNR), 16-ary Quadrature Amplitude Modulation (16-QAM) has better performance than 16-ary Phase-Shift Keying (16-PSK). The reason is that 16-QAM has constant envelop. (×)

14. 14. With the same SNR, Minimum Shift Keying (MSK) has better performance than

Sunde's Frequency-Shift Keying (FSK). They are both Continuous-Phase Frequency-Shift Keying (CPFSK). (✓)

15. 15. If the largest frequency component of an band-limited signal X(t) is at 100 Hz, then the corresponding Nyquist rate is 200 Hz. (✓)

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

1. 1. The power spectral density of a stationary process X(t) is $S_X(f)$, then the autocorrelation function of X(t) is $R_X(t)$ = $\int_{-\infty}^{\infty} S_X(f)\exp(j2\pi f t)\,df$.

2. 2. A random process Y(t) is defined as $Y(t) = X(t)\cos(2\pi f_c t + \Theta)$, where X(t) is a stationary process, f_c is a constant frequency, and the phase Θ is randomly distributed over the interval $[0, 2\pi]$. Suppose the power spectral density of X(t) is $S_X(f)$, the power spectral density of Y(t) is $S_Y(f)$ = $\frac{1}{4}(S_X(f-f_c)+S_X(f+f_c))$

3. 3. In a Frequency Modulation (FM) system, the modulating signal is $m(t) = 2\cos(6\pi t)$ V, the frequency sensitivity is k_f = 0.3 Hz/V. Using Carson's rule, bandwidth of the FM signal is approximately 7.2 Hz.

4. 4. An analog signal is first encoded into a binary Pulse-Code Modulation (PCM) wave. Sampling rate of the PCM system is 8 kHz, number of representation levels is 64. The binary PCM wave is transmitted over a baseband channel using a 4-ary Pulse-Amplitude Modulation (PAM) (that is, a PAM with 4 amplitude levels). The minimum bandwidth requirement for transmitting the PAM wave is 12 kHz.

5. 5. Basic operations performed in the transmitter of a PCM system include Sampling, Quantization and Encoding.

6. 6. Bandwidth efficiency of 4-ary Quadrature Amplitude Modulation (QAM) is 1; bandwidth efficiency of 8-ary Phase-Shift Keying (8PSK) is 1.5.

7. 7. In a Delta Modulation (DM) system, sampling rate is f_s = 8 kHz and step size is Δ = 0.1 V. If the input to the DM system is a 1 kHz sinusoidal signal, then to avoid slope overload, the maximum amplitude of this input signal is $0.4/\pi$ V.

8. 8. 12 different message signals, each with a bandwidth of 20 kHz, are to be multiplexed and transmitted. If the multiplexing and modulation methods are Frequency-Division Multiplexing (FDM) and Single-Sideband Modulation (SSB), respectively, then the minimum bandwidth required is 240 kHz; if the multiplexing and modulation methods are Time-Division Multiplexing (TDM) and PAM, then the minimum bandwidth required is 240 kHz;

9. 9. The binary data sequence $\{b_k\}$ = 1010110 is applied to a duobinary (class I partial response) system with precoding, as shown in Fig. P1-9 (see next page), where $d_k = b_k \oplus d_{k-1}$, $\oplus$ denotes modulo-two addition, and $a_k = 2\times d_k - 1$. The initial value of d_k is 1. The output of the duobinary encoder is $\{c_k\}$ = 0 -2 0 2 0 0 2. If at the receiving end, the first received digit is 1.25 due to noise, then the receiver output is $\{\hat{b}_k\}$ = 0010110.

bk 1010110
dk 10011011
ak 1-1-1111-11
ck 0-202002
1.25
0010110

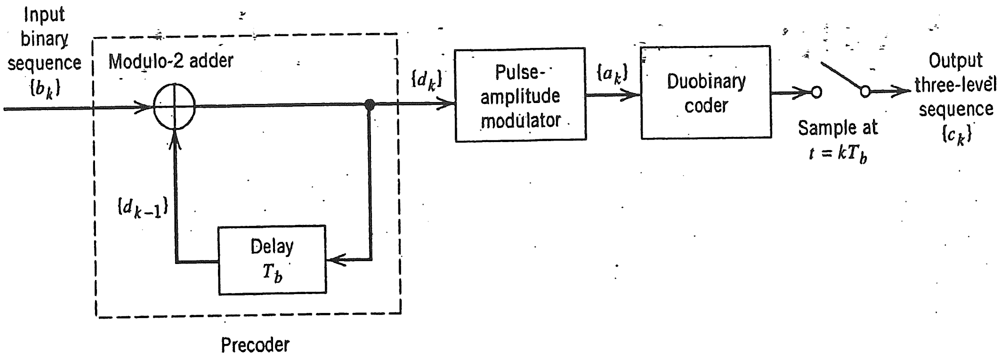


Fig. P1-9

10. 10. A communication system has the signal-space diagram shown in Fig. P1-10, where message points have equal probability of transmitting. Assume communication channel in this system is Additive White Gaussian Noise (AWGN) channel, and E/N_0 is 12, where N_0 is single-sideband power spectral density of the AWGN. Using union band, the average probability of symbol error is overbounded as $P_e \leq$ ________. (Express using complementary error function erfc(·).)

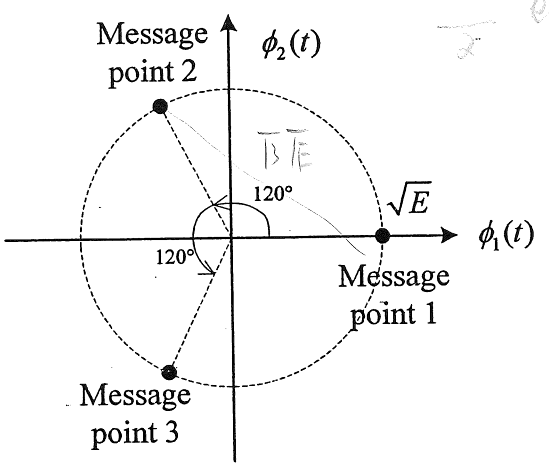


Fig. P1-10

Section C(40%): Calculations (8% for each question)

1. 1. In a coherent Binary Phase-Shift Keying (BPSK) system, symbols 1 and 0 are represented by signals $s_1(t)$ and $s_2(t)$, respectively. The signals are defined by

$$\begin{cases} s_1(t) = \sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t) \\ s_2(t) = \sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t + \pi) \end{cases} \quad 0 \le t \le T_b$$

where E_b is the transmitted signal energy per bit, and T_b is one bit duration.

a) a) Determine the basis function(s) of coherent BPSK signal constellation;

b) b) Plot the signal-space diagram of coherent BPSK system;

c) c) Determine the error probability of BPSK;

d) d) If there is a phase error φ between the phase references of the transmitter and receiver, determine the error probability of BPSK in this condition again.

2. 2. Spectrum of a message signal m(t) is shown in Fig. P3-2. This message signal is Double Sideband-Suppressed Carrier (DSB-SC) modulated with a carrier wave $A_c\cos(2\pi f_c t)$.

W=1k

B_T=2k

1.1k

a) a) If f_c = 2 kHz, plot the spectrum of the modulated signal s(t);

b) b) What is the baseband bandwidth W of the message signal m(t)?

c) c) What is the transmission bandwidth B_T of the DSB-SC modulated signal?

d) d) What is the lowest value of f_c that keeps the DSB-SC modulation from sideband overlap?

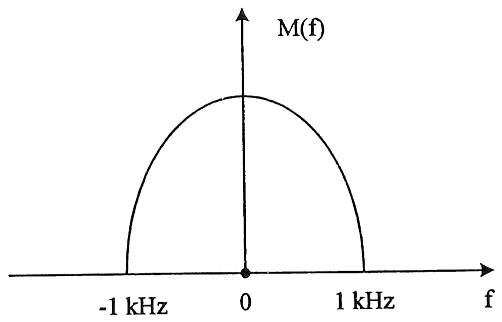


Fig. P3-2

3. 3. Consider a Quadriphase-Shift Keying (QPSK) system. The transmitted signal set is defined as:

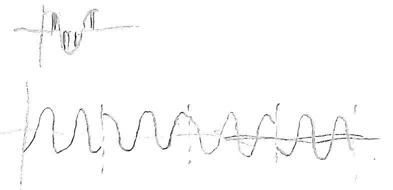
$$s_i(t) = \begin{cases} \cos[2\pi f_c t + (2i-1)\pi/4], & 0 \le t \le T \\ 0, & \text{otherwise} \end{cases}$$

where i = 1, 2, 3, 4. Every two input bits select one of the signals in transmitted signal set to transmit. The rule of mapping is 10 → $s_1(t)$, 00 → $s_2(t)$, 01 → $s_3(t)$, 11 → $s_4(t)$.

$\phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t)$ $0<t<T$

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

$s_i = \begin{bmatrix} \sqrt{E_b}\cos((2i-1)\frac{\pi}{4}) \\ -\sqrt{E_b}\sin((2i-1)\frac{\pi}{4}) \end{bmatrix}$



No.

a) a) Determine the basis function(s) of QPSK signal constellation;

b) b) Express $s_i(t)$ using the basis function(s);

c) c) If the input binary sequence is 01101000, and suppose fc = 2/T, plot the QPSK waveform;

3 7 1 $\frac{\pi}{2}$

d) d) Is the QPSK waveform continuous phase?

4. 4. Consider the signal s(t) shown in Fig. P3-4,

a) a) Assuming h(t) is the matched filter of s (t), plot the impulse response of h (t);

b) b) When s (t) is applied to h (t), plot the matched filter output in the time domain.

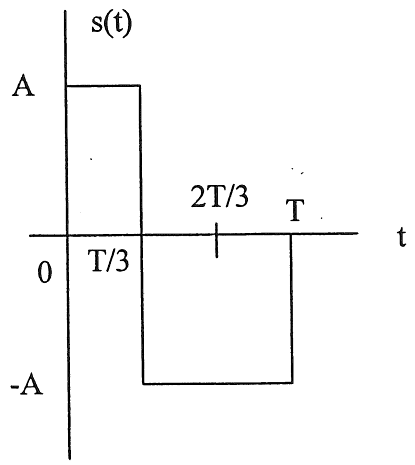


Fig. P3-4

5. 5. Suppose X(t) = Acos(2πft – Θ), where A is a constant, and f and Θ are independent. Θ is uniformly distributed over the interval [0, 2π]. Determine the power spectrum density of X(t) in terms of the probability density function of the frequency f.

$R_X(\tau) = E[X(t+\tau)X(t)]$

$= E[A\cos(2\pi f t + 2\pi f\tau - \Theta) A\cos(2\pi f t - \Theta)]$

$= A^2 E(\frac{1}{2}\cos(4\pi f t + 2\pi f\tau - \Theta) + \frac{1}{2}\cos(2\pi f\tau))$

$= \frac{A^2}{2} E(\cos 2\pi f\tau)$

$= \frac{A^2}{2}\int_{-\infty}^{+\infty} f_f(f)\cos(2\pi f\tau)\,df$

S_X

$S_X(f) = \int_{-\infty}^{+\infty} R_X(\tau)\exp(-j2\pi f t)\,dt$

$= \frac{A^2}{2}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f_f(f)\cos(2\pi f t)\cos(-2\pi f t)\,dt$

$= \frac{A^2}{2} \iint f_X(f)\,df$

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通信原理期终考试参考答案和评分标准

考试学期：04-05-3

Section A: (30分)

1. × The mobile radio channel is typically time variant.
2. √
3. √
4. × Stationary is not necessary ergodic.
5. × FM is not a linear modulation scheme
6. × Figure of merit of DSB-SC is 1, not 1/3.
7. × A-law is also a nonlinear compression law.
8. × The matched filter is optimal with AWGN channel.
9. × Correlative-level coding is to use ISI to achieve 2W signaling rate in a bandwidth of W Hz.
10. × FDM is used in ADSL.
11. √
12. × The BER is usually not $P_e/\log_2 M$.
13. × 16-QAM is not constant envelop.
14. √
15. √

Section B: （30分）

1. $\int_{-\infty}^{\infty} S_X(f)\exp(j2\pi f\tau)\,df$
2. $\frac{1}{4}[S_X(f-f_c)+S_X(f+f_c)]$
3. 7.2
4. 12
5. Sampling, Quantizing, and Encoding
6. 1, 1.5
7. 1.27
8. 240, 240
9. 0 -2 0 2 0 0 2, 0010110
10. erfc(3)

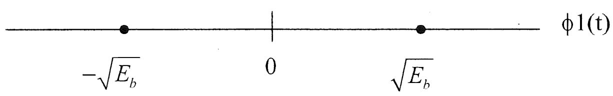
Section C: （40分）

1. (a) The basis function is:

$$\phi_1(t)=\sqrt{\frac{2}{T_b}}\cos(2\pi f_c t),\quad 0\le t\le T_b$$

定义域 (2分)

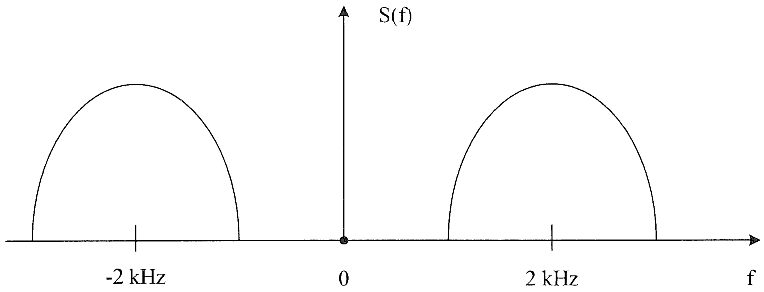
(b) The signal-space diagram is: (2分)



(c) The error probability is $P_e = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$. (2分)

With phase error φ, the error probability becomes $P_e = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E_b}{N_0}}\cos\varphi\right)$. (2分)

2. (a) The spectrum is: (2分)



(b) W = 1 kHz; (2分)

(c) B_T = 2 kHz; (2分)

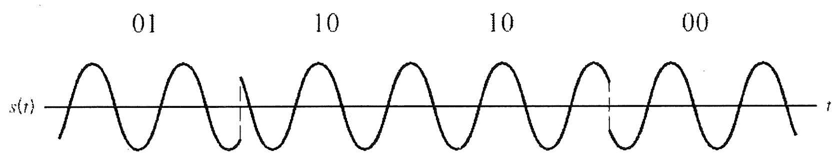
(d) To avoid sideband overlap, the lowest frequency is 1 kHz. (2分)

3. (a) The basis functions are: (2分)

$$\begin{cases} \phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t), & 0 \le t \le T \\ \phi_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t), & 0 \le t \le T \end{cases}$$

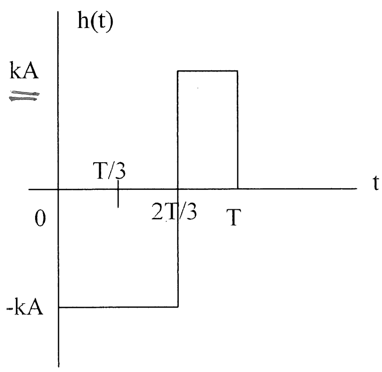
(b) $s_i(t) = \sqrt{\frac{T}{2}}\cos\left[(2i-1)\frac{\pi}{4}\right]\phi_1(t) - \sqrt{\frac{T}{2}}\sin\left[(2i-1)\frac{\pi}{4}\right]\phi_2(t), \quad i = 1,2,3,4$ (2分)

(c) The QPSK waveform is: (2分)

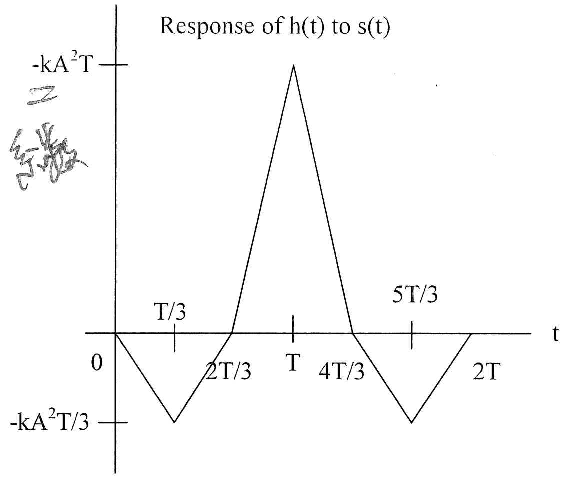


(d) The QPSK waveform is not continuous phase. (2分)

4. (a) h(t) is shown below, where k is a positive constant. (4分)



(b) The filter output is shown below. (4 分)



5. The autocorrelation function of X(t) is: (2分)

$$
\begin{aligned}
R_X(\tau) &= E[X(t+\tau)X(t)] \\
&= A^2 E[\cos(2\pi Ft + 2\pi F\tau - \Theta)\cos(2\pi Ft - \Theta)] \\
&= \frac{A^2}{2} E[\cos(4\pi Ft + 2\pi F\tau - \Theta) + \cos(2\pi F\tau)]
\end{aligned}
$$

Since Θ is uniformly distributed over the interval $[0, 2\pi]$, we get: (2分)

$$
\begin{aligned}
R_X(\tau) &= \frac{A^2}{2} E[\cos(2\pi F\tau)] \\
&= \frac{A^2}{2}\int_{-\infty}^{\infty} f_F(f)\cos(2\pi f\tau)\, df
\end{aligned}
$$

Since X(t) is a real-valued random process, $S_X(f)$ is an even function of frequency, we also have: (2分)

$$
\begin{aligned}
R_X(\tau) &= \int_{-\infty}^{\infty} S_X(f)\exp(j2\pi f\tau)\, df \\
&= \int_{-\infty}^{\infty} S_X(f)\cos(j2\pi f\tau)\, df
\end{aligned}
$$

where $S_X(f)$ is the power spectrum density of X(t). Therefore, we get: (2分)

$$
S_X(f) = \frac{A^2}{2} f_F(f)
$$