东 南 大 学 考 试 卷（A 卷）

课程名称　数 字 通 信　考 试 学 期　11-12-2　得分

适用专业　信息科学与工程学院　考 试 形 式　闭 卷　考试时间长度 120 分钟

Section A : True or False （10%，1% for each question）

1. The channel capacity of a discrete memoryless channel is defined as the maximum mutual information I(X;Y) in any single use of the channel, where the maximization is over all set of possible channel transition probabilities $\{p(y_k|x_j)\}$. （ ）
2. Frequency diversity can be accomplished by choosing frequency spacing equal to or larger than the coherence bandwidth of the channel. （ ）
3. Unlike the entropy of a continuous random variable, the differential entropy of a discrete random variable can be negative. （ ）
4. All error patterns that differ by a code word have the same syndrome. （ ）
5. For additive white Gaussian noise (AWGN) channel, the maximum-likelihood decoder of convolutional code reduces to a minimum Hamming distance decoder. （ ）

6. A prefix code is defined as a in which any code is the prefix of any （ ）

6. A prefix code is defined as a in which any code is the prefix of any other code word. （ ）
7. For fast-frequency hopping, the symbol rate R_s of MFSK signal is an integer multiple of the hop rate R_h. That is, the carrier frequency will change or hop several times during the transmission of one symbol. （ ）
8. Shannon's second theorem specifies the channel capacity C as a fundamental limit on the rate at which the transmission of reliable error-free messages can take place over a discrete memoryless channel and how to construct a good code. （ ）

9. In a satellite communication system, the carrier frequency used on the uplink is always higher than the carrier frequency used on the downlink. ( )

10. A preferred pair of primitive polynomials of degree m whose corresponding shift registers generate m-sequences of period 2^m-1 can be used to generate a Gold sequence. ( )

Section A : True or False （每题 1 分，共 10 分）

1. False	2. True	3. False	4. True	5. False
6. False	7. False	8. False	9. True	10. True

Section B: Fill in the blanks （30%, 1% for each blank）

1. Suppose that X is uniformly distributed over the interval (a, b), i.e., $f(x)=\begin{cases}\frac{1}{b-a} & a<x<b \\ 0 & otherwise\end{cases}$, then the differential entropy h(X) is ______________.
2. Three major sources of degradation in wireless communications are ________________, ________, and __________; the latter two are byproducts of multipath, and large ___________ is responsible for the intersymbol interference.
3. There are the following diversity techniques in our discussion, ____________ diversity, ______ diversity, ______diversity.
4. For Linear block codes, detect all error patterns of Hamming weight $w(e) \le t_1$, *if and only if* $d_{min} \ge$ _______________.
5. The two commonly used types of spread-spectrum modulation are: ______________ and ______________.
6. The satellite communication channel is closely modeled as an ________________ channel.
7. The distortion of D will _____________ as the rate distortion function R(D) is decreased.

... of six symbols $s_0 \sim s_5$ with probabilities 1/2,

8. A source emits one of six symbols $s_0 \sim s_5$ with probabilities 1/2, 1/4, 1/8, 1/16, 1/32, 1/32 respectively. The successive symbols emitted by the source are statistically independent. The entropy of the source is ____________. The average code-word length for any distortionless source encoding scheme for this source is bounded as__________.
9. In a DS/BPSK system, the feedback shift register used to generate the PN sequence has length m=11, than the processing gain is ______ .

Section B: Fill in the blanks （每空 1 分，共 30 分）

1. $\log_2(b-a)$
2. co-channel interference, fading, delay spread, delay spread
3. frequency, time, space
4. $d_{min} \ge t_1 + 1$
5. direct sequence(DS), frequency hopping(FH)
6. AWGN
7. increase
8. 31/16=1.9375bits/symbol, $\bar{L} \ge H(\varphi)$
9. 2^{11}-1 = 2047 (33dB)
10. (n-k) , $(X^n + 1)$
11. minimum Euclidean distance
12. Turbo , LDPC
13. 26.63kbits/second , 4.278(6.3dB)
14. frequency nonselective (or flat), time nonselective (or flat)
15. 2^{13}-1, 0101, 4096, 256, -1/8191

12. Turbo， LDPC
13. 26.63kbits/second， 4.278(6.3dB)
14. frequency nonselective (or flat)， time nonselective (or flat)
15. $2^{13}-1 = 8191$， 4096, 256, -1/8191
16. 5

Section C：Problems （每题 15 分，共 60 分）

1. (a) Free-space loss $L_{freespace} = 10\log_{10}\left(\frac{\lambda}{4\pi d}\right)^2 = 20\log_{10}\left(\frac{3\times10^8/11/10^9}{4\times\pi\times31000\times10^3}\right)$

$=-203.097\text{dB}$ （5 分）

(b) The power gain of each antenna is

$$10\log_{10}G_t = 10\log_{10}G_r = 10\log_{10}\left(\frac{4\times\pi\times A}{\lambda^2}\right) = 10\log_{10}\left(\frac{4\times\pi\times0.65\times\pi}{(3\times10^8/11/10^9)^2}\right)$$

$=45.38\text{dB}$ （5 分）

(c) The received power = transmitted power + G_t + G_r + free-space loss

= 4 .5+ 45.38 + 45.38 + (-203.10)

= -107.84dBW （5 分）

2.

$$p(x=0) = p(x=0,y=0) + p(x=0,y=1) = \frac{1}{3}+\frac{1}{3} = \frac{2}{3}$$

$$p(x=1) = p(x=1,y=0) + p(x=1,y=1) = 0+\frac{1}{3} = \frac{1}{3}$$

$$p(y=0) = p(x=0,y=0) + p(x=1,y=0) = \frac{1}{3}+0 = \frac{1}{3}$$

$$p(y=1) = p(x=0,y=1) + p(x=1,y=1) = \frac{1}{3}+\frac{1}{3} = \frac{2}{3}$$

$$p(x=0|y=0) = p(x=0,y=0)\Big/p(y=0) = \frac{1}{3}\div\frac{1}{3} = 1$$

$$p(x=0|y=1) = p(x=0,y=1)\Big/p(y=1) = \frac{1}{3}\div\frac{2}{3} = 1/2$$

$$p(x=1|y=0) = p(x=1,y=0)\Big/p(y=0) = 0\div\frac{1}{3} = 0$$

$$p(x=1,y=1)\Big/ \ldots = \frac{1}{3}\div\frac{2}{3} = 1/2$$

$$p(x=0|y=0)=p(x=0,y=0)\Big/p(y=0)=\frac{1}{3}\div\frac{1}{3}=1$$

$$p(x=0|y=1)=p(x=0,y=1)\Big/p(y=1)=\frac{1}{3}\div\frac{2}{3}=1/2$$

$$p(x=1|y=0)=p(x=1,y=0)\Big/p(y=0)=0\div\frac{1}{3}=0$$

$$p(x=1|y=1)=p(x=1,y=1)\Big/p(y=1)=\frac{1}{3}\div\frac{2}{3}=1/2$$

$$p(y=0|x=0)=p(x=0,y=0)\Big/p(x=0)=\frac{1}{3}\div\frac{2}{3}=1/2$$

$$p(y=0|x=1)=p(x=1,y=0)\Big/p(x=1)=0\div\frac{1}{3}=0$$

$$p(y=1|x=0)=p(x=0,y=1)\Big/p(x=0)=\frac{1}{3}\div\frac{2}{3}=1/2$$

$$p(y=1|x=1)=p(x=1,y=1)\Big/p(x=1)=\frac{1}{3}\div\frac{1}{3}=1$$

(每式 0.5 分)

(a) $H(X)=-\sum_{j=0}^{1}p(x_j)\log_2 p(x_j)=\frac{2}{3}\times\log_2\frac{2}{3}+\frac{1}{3}\times\log_2\frac{1}{3}=0.9183 bits/sym$

$$H(Y)=-\sum_{k=0}^{1}p(y_k)\log_2 p(y_k)=\frac{1}{3}\times\log_2\frac{1}{3}+\frac{2}{3}\times\log_2\frac{2}{3}=0.9183 bits/sym$$

(每式 1 分)

(b)

$$H(X|Y)=\sum_{k=0}^{1}\sum_{j=0}^{1}p(x_j,y_k)\log_2\left[\frac{1}{p(x_j|y_k)}\right]$$
$$=-\left[1/3\times\log_2(1)+1/3\times\log_2(1/2)+0\times\log_2(0)+1/3\times\log_2(1/2)\right]$$
$$=2/3=0.6667 bits/sym$$

$$H(Y|X)=\sum_{k=0}^{1}\sum_{j=0}^{1}p(x_j,y_k)\log_2\left[\frac{1}{p(y_k|x_j)}\right]$$
$$=-\left[1/3\times\log_2(1/2)+1/3\times\log_2(1/2)+0\times\log_2(0)+1/3\times\log_2(1)\right]$$
$$=2/3=0.6667 bits/sym$$

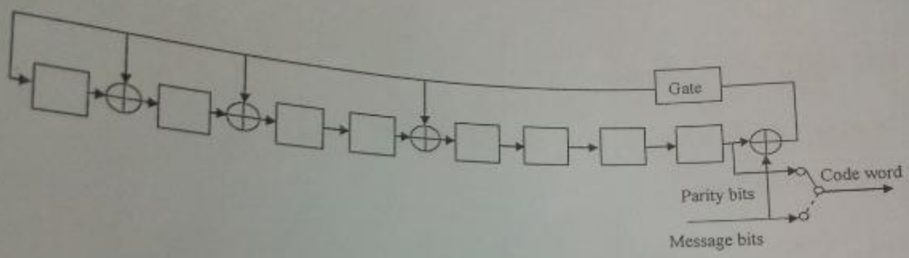
(每式 2 分)

(c)

$$I(X;Y)=H(X)-H(X|Y)=H(Y)-H(Y|X)$$
$$=0.9183-0.6667$$
$$=0.2516 bits/sym$$

(3 分)

3. (a)



（3 分）

(b) generator matrix

$$g(X)=1+X+X^2+X^4+X^8$$

$$Xg(X)=X+X^2+X^3+X^5+X^9$$

$$X^2g(X)=X^2+X^3+X^4+X^6+X^{10}$$

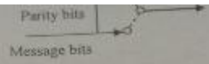
$$X^3g(X)=X^3+X^4+X^5+X^7+X^{11}$$

$$X^4g(X)=X^4+X^5+X^6+X^8+X^{12}$$

$$X^5g(X)=X^5+X^6+X^7+X^9+X^{13}$$

$$X^6g(X)=X^6+X^7+X^8+X^{10}+X^{14}$$

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$



（3 分）

(b) generator matrix

$$g(X)=1+X+X^2+X^4+X^8$$
$$Xg(X)=X+X^2+X^3+X^5+X^9$$
$$X^2g(X)=X^2+X^3+X^4+X^6+X^{10}$$
$$X^3g(X)=X^3+X^4+X^5+X^7+X^{11}$$
$$X^4g(X)=X^4+X^5+X^6+X^8+X^{12}$$
$$X^5g(X)=X^5+X^6+X^7+X^9+X^{13}$$
$$X^6g(X)=X^6+X^7+X^8+X^{10}+X^{14}$$

$$G'=\begin{bmatrix}1&1&1&0&1&0&0&0&1&0&0&0&0&0&0\\0&1&1&1&0&1&0&0&0&1&0&0&0&0&0\\0&0&1&1&1&0&1&0&0&0&1&0&0&0&0\\0&0&0&1&1&1&0&1&0&0&0&1&0&0&0\\0&0&0&0&1&1&1&0&1&0&0&0&1&0&0\\0&0&0&0&0&1&1&1&0&1&0&0&0&1&0\\0&0&0&0&0&0&1&1&1&0&1&0&0&0&1\end{bmatrix}$$

$$G=\begin{bmatrix}1&1&1&0&1&0&0&0&1&0&0&0&0&0&0\\0&1&1&1&0&1&0&0&0&1&0&0&0&0&0\\0&0&1&1&1&0&1&0&0&0&1&0&0&0&0\\0&0&0&1&1&1&0&1&0&0&0&1&0&0&0\\1&1&1&0&0&1&1&0&0&0&0&0&1&0&0\\0&1&1&1&0&0&1&1&0&0&0&0&0&1&0\\1&1&0&1&0&0&0&1&0&0&0&0&0&0&1\end{bmatrix}$$

（4 分）

Parity-check matrix

$$h(X)=1+X+X^3+X^7$$

$$X^{7}h(X^{-1})=1+X^{4}+X^{6}+X^{7}$$
$$X^{8}h(X^{-1})=X+X^{5}+X^{7}+X^{8}$$
$$X^{9}h(X^{-1})=X^{2}+X^{6}+X^{8}+X^{9}$$
$$X^{10}h(X^{-1})=X^{3}+X^{7}+X^{9}+X^{10}$$
$$X^{11}h(X^{-1})=X^{4}+X^{8}+X^{10}+X^{11}$$
$$X^{12}h(X^{-1})=X^{5}+X^{9}+X^{11}+X^{12}$$
$$X^{13}h(X^{-1})=X^{6}+X^{10}+X^{12}+X^{13}$$
$$X^{14}h(X^{-1})=X^{7}+X^{11}+X^{13}+X^{14}$$

$$H'=\begin{bmatrix}
1&0&0&0&1&0&1&1&0&0&0&0&0&0&0\\
0&1&0&0&0&1&0&1&1&0&0&0&0&0&0\\
0&0&1&0&0&0&1&0&1&1&0&0&0&0&0\\
0&0&0&1&0&0&0&1&0&1&1&0&0&0&0\\
0&0&0&0&1&0&0&0&1&0&1&1&0&0&0\\
0&0&0&0&0&1&0&0&0&1&0&1&1&0&0\\
0&0&0&0&0&0&1&0&0&0&1&0&1&1&0\\
0&0&0&0&0&0&0&1&0&0&0&1&0&1&1
\end{bmatrix}$$

$$\begin{bmatrix}
1&0&0&0&0&0&0&0&1&0&0&0&1&0&1\\
0&1&0&0&0&0&0&0&1&1&0&0&1&1&1\\
0&0&1&0&0&0&0&0&1&1&1&0&1&1&0
\end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$$ （4 分）

(c) For the message sequence 1000101, the corresponding message polynomial is

$$m(X) = 1 + X^4 + X^6$$

Firstly, $X^{n-k} m(X) = X^8 + X^{12} + X^{14}$

Secondly, divide $X^{n-k} m(X)$ by $g(X)$,

$$\frac{X^8 + X^{12} + X^{14}}{1 + X + X^2 + X^4 + X^8} = X^6 + X^4 + X^2 + 1 + \frac{1 + X + X^3 + X^4 + X^5 + X^6 + X^7}{1 + X + X^2 + X^4 + X^8}$$

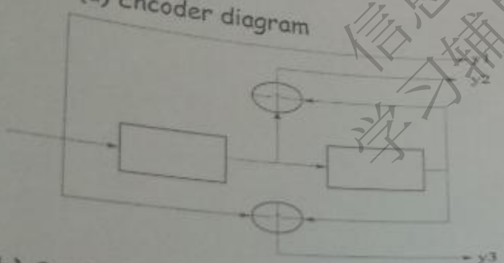
The remainder is $b(X) = 1 + X + X^3 + X^4 + X^5 + X^6 + X^7$

Hence, the desired code polynomial is

$$c(X) = b(X) + X^{n-k} m(X) = 1 + X + X^3 + X^4 + X^5 + X^6 + X^7 + X^8 + X^{12} + X^{14}$$ （4 分）

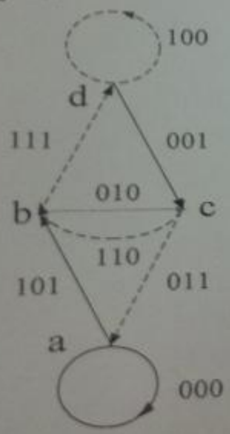
The systematic code word is 11011111,1000101

4. (a) Encoder diagram



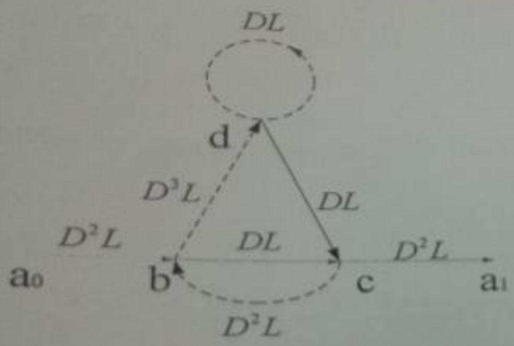
（3 分）

(b) State diagram



（4 分）

(c) （4 分）



$$\begin{cases} b = D^2La_0 + D^2Lc \\ c = DLb + DLd \\ d = D^3Lb + DLd \\ a_1 = D^2Lc \end{cases}$$

(3 分) （2 分）

(d) Encoder output produced by the message sequence 1011000111 is 101, 010, 110, 111, 001, 011, 000, 101, 111, 100, 001, 011 . （3 分）