东 南 大 学 考 试 卷(A 卷)

课程名称 数 字 通 信 考试学期 04-05-2 得分 ______

适用专业 无线电工程系 考试形式 闭 卷 考试时间长度 120 分钟 共 页

Section A：True or False （15%）

1. 1. When the period is exactly 2^m, the PN sequence is called a maximal-length-sequence or simply m-sequence.
2. 2. For a period of the maximal-length sequence, the autocorrelation function is similar to that of a random binary wave.
3. 3. For slow-frequency hopping，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.
4. 4. Frequency diversity can be done by choosing a frequency spacing equal to or less than the coherence bandwidth of the channel.
5. 5. The mutual information of a channel therefore depends not only on the channel but also on the way in which the channel used.
6. 6. 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.
7. 7. The syndrome depends not only on the error pattern, but also on the transmitted code word.
8. 8. Any 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.
9. 9. Any source code satisfies the Kraft-McMillan inequality can be a prefix code.
10. 10. Let a discrete memoryless source with an alphabet φ have entropy $H(\varphi)$ and produce symbols once every T_s seconds. Let a discrete memoryless channel have capacity C and be used once every T_c

seconds. Then , if $\frac{H(\varphi)}{T_s} \geq \frac{C}{T_c}$, there exists a coding scheme for which the source output can be transmitted over the channel and be reconstructed with an arbitrarily small probability of error.

Section B：Fill in the blanks （35%）

1. 1. The two commonly used types of spread-spectrum modulation: ______________ and ______________.
2. 2. A pseudo-noise (PN) sequence is a periodic binary sequence with a ____________waveform that is usually generated by means of a ___________________.
3. 3. Due to ______________, wireless communication is no longer idealized AWGN channel model.
4. 4. There are the following diversity techniques in our discussion ， _________ diversity，________ diversity，_______ diversity.
5. 5. Three major sources of degradation in wireless communications are __________________, ________, and ____________; the latter two are byproducts of multipath.
6. 6. The information capacity of a continuous channel of bandwidth B hertz, perturbed by additive white Gaussian noise of power spectral density $N_0/2$ and limited in bandwidth to B, is given by ______________________.
7. 7. The *error-syndrome vector* (or *syndrome)* is defined as: _______.
8. 8. For Linear Block Codes ，Correct all error patterns of Hamming weight $w(\mathbf{e})\le t_2$, *if and only if* ____________.
9. 9. TCM Combine ________ and _________ as a single entity to attain a more effective utilization of the available __________ and _________.
10. 10. In a DS/BPSK system, the feedback shift register used to generate the PN sequence has length m=19, than the processing gain is _________.
11. 11. Let X represent the outcome of a single roll of a fair die(骰子). The entropy of X is _________________________.
12. 12. A voice-grade channel of the telephone network has a bandwidth of 3.4kHz,the information capacity of the telephone channel for a signal-to-noise ratio of 30dB is _______________________, the minimum signal-to-noise ratio required to support information

transmission through the telephone channel at the rate of 9,600b/s is ________.

13. 13. For a m-sequence generated by a linear feedback shift register of length 5, the total number of runs is _______, number of length-two runs is ______, the autocorrelation R(j)=_______(j≠0).
14. 14. If the coherent bandwidth of the channel is small compared to the message bandwidth, the fading is said to be _______________. If the coherence time of the channel is large compared to the duration of the signal duration, the fading is said to be _______ _______________.
15. 15. A source emits one of five symbols s_0, s_1, s_2 s_3 and s_4 with probabilities 1/2, 1/4, 1/8, 1/16, 1/16, 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 ____________.
16. 16. For a finite variance σ^2, the _________random variable has the largest differential entropy attainable by any random variable, and the entropy is uniquely determined by the ___________.
17. 17. Set partitioning design partitions the M-ary constellation of interest successively and has progressively larger increasing _______________________ between their respective signal points.
18. 18. _______ code and ___________________ code have an error performance within a hair's breadth of Shannon's theoretical limit on channel capacity in a physically realizable fashion.
19. 19. When an infinite number of decoding errors are caused by a finite number of transmission errors, the convolutional code is called a ____________________.

Section C：Problems （50%）

1. A radio link uses a pair of 2m dish antennas with an efficiency of 70 percent each, as transmitting and receiving antennas. Other specifications of the link are:

Transmitted power = 2 dBW（not include the power gain of antenna）

Carrier frequency = 12 GHz

Distance of the receiver form the transmitter = 200 m

Calculate (a) the free-space loss,

(b) the power gain of each antenna,

(c)the received power in dBW.

2. A computer executes four instructions that are designated by the code words (00,01,10,11). Assuming that the instructions are used independently with probabilities(1/2,1/8,1/8,1/4).

(a) (a) Construct a Huffman code for the instructions.

(b) (b) Calculate the percentage by which the number of bits used for the instructions may be reduced by the use of a Huffman code.

3. Consider the (15,8) cyclic code defined by the generator polynomial

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

(a) (a) Develop the encoder for this code.

(b) (b) Get the generator matrix and the parity-check matrix.

(c) (c) Construct a systematic code word for the message sequence 10110011.

(d) (d) The received word is 110001000000001, determine the syndrome polynomial *s(X)* for this received word.

4. Consider the rate *r* = 1/3, constraint length *K* = 3 convolutional encoder. The generator sequences the encoder are as follows:

$g^{(1)}=(1,0,0)$, $g^{(2)}=(1,0,1)$, $g^{(3)}=(1,1,1)$

(a) (a) Draw the block diagram of the encoder.

(b) (b) Construct the code tree

(c) (c) Construct the signal-flow graph and obtain the input-output state equations.

(d) (d) Determine the encoder output produced by the message sequence 10111….

(e) (e) The received sequence is 110,001,101,110,000,011. Use the Viterbi algorithm to compute the decoded sequence.

答案

Section A : True or False （每题 1.5 分，共 15 分）

11. 1. When the period is exactly 2^m, the PN sequence is called a maximal-length-sequence or simply m-sequence. （F）

12. 2. For a period of the maximal-length sequence, the autocorrelation function is similar to that of a random binary wave. （T）

13. 3. For slow-frequency hopping，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.（F）

14. 4. Frequency diversity can be done by choosing a frequency spacing equal to or less than the coherence bandwidth of the channel. （F）

15. 5. The mutual information of a channel therefore depends not only on the channel but also on the way in which the channel used. （T）

16. 6. 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. （F）

17. 7. The syndrome depends not only on the error pattern, but also on the transmitted code word. （F）

18. 8. Any 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. （F）

19. 9. Any source code satisfies the Kraft-McMillan inequality can be a prefix code. （F）

20. 10. Let a discrete memoryless source with an alphabet φ have entropy $H(\varphi)$ and produce symbols once every T_s seconds. Let a discrete memoryless channel have capacity C and be used once every T_c seconds. Then , if $\frac{H(\varphi)}{T_s} \geq \frac{C}{T_c}$, there exists a coding scheme for which the source output can be transmitted over the channel and be reconstructed with an arbitrarily small probability of error. （F）

Section B：Fill in the blanks （每空 1 分，共 35 分）

20. 1. The two commonly used types of spread-spectrum modulation: direct sequence and frequency hopping.

21. 2. A pseudo-noise (PN) sequence is a periodic binary sequence with a noiselike waveform that is usually generated by means of a feedback shift register .

22. 3. Due to multipath, wireless communication is no longer idealized AWGN channel model.

23. 4. There are the following diversity techniques in our discussion， Frequency diversity， Time diversity， Space diversity.

24. 5. Three major sources of degradation in wireless communications are co-channel interference, fading, and delay spread; the latter two are byproducts of multipath .

25. 6. The information capacity of a continuous channel of bandwidth B hertz, perturbed by additive white Gaussian noise of power spectral density $N_0/2$ and limited in bandwidth to B, is given by $C = B\log_2(1+\frac{P}{N_0B})$ bits per second .

26. 7. The *error-syndrome vector* (or *syndrome*) is defined as: $\mathbf{s} = \mathbf{r}\mathbf{H}^T$

27. 8. For Linear Block Codes ，Correct all error patterns of Hamming weight $w(\mathbf{e}) \le t_2$ ， *if and only if* $d_{min} \ge 2t_2 + 1$.

28. 9. TCM Combine coding and modulation as a single entity to attain a more effective utilization of the available bandwidth and power.

29. 10. In a DS/BPSK system, the feedback shift register used to generate the PN sequence has length m=19, than the processing gain is 57dB .

30. 11. Let X represent the outcome of a single roll of a fair die(骰子). The entropy of X is $\log_2(6)$ = 2.586 bits/symbol.

31. 12. A voice-grade channel of the telephone network has a bandwidth of 3.4kHz,the information capacity of the telephone channel for a signal-to-noise ratio of 30dB is 33.9 kbits/second ,the minimum signal-to-noise ratio required to support information transmission through the telephone channel at the rate of 9,600b/s is 7.8dB .

32. 13. For a m-sequence generated by a linear feedback shift register of length 5, the total number of runs is 16 , number of length-two runs is 4 , the autocorrelation R(j)= -1/31 (j≠0).

33. 14. If the coherent bandwidth of the channel is small compared to the message bandwidth, the fading is said to be frequency selective. If the coherence time of the channel is large compared to the duration of the signal duration, the fading is said to be time nonselective or time flat.

34. 15. A source emits one of five symbols s_0, s_1, s_2 s_3 and s_4 with probabilities 1/2, 1/4, 1/8, 1/16, 1/16, respectively. The successive symbols emitted by the source are statistically independent. The entropy of the source is 15/8=1.875bits/symbol. The average code-word length for any distortionless source encoding scheme for this source is bounded as $\bar{L} \ge H(\varphi)$.

35. 16. For a finite variance σ^2, the Guassian random variable has the largest differential entropy attainable by any random variable, and the entropy is uniquely determined by the variance of X.
36. 17. Set partitioning design partitions the M-ary constellation of interest successively and has progressively larger increasing minimum Euclidean distance between their respective signal points.
37. 18. Turbo codes and Low-density parity-check codes have an error performance within a hair's breadth of Shannon's theoretical limit on channel capacity in a physically realizable fashion.
38. 19. When an infinite number of decoding errors are caused by a finite number of transmission errors, the convolutional code is called a catastrophic code.

Section C: Problems

1. A radio link uses a pair of 2m dish antennas with an efficiency of 70 percent each, as transmitting and receiving antennas. Other specifications of the link are:

Transmitted power = 2 dBW （not include the power gain of antenna）
Carrier frequency = 12 GHz
Distance of the receiver form the transmitter = 200 m
Calculate (a)the free-space loss,
(b) the power gain of each antenna,
(c)the received power in dBW. （本题 10 分）

Solution:

(a) Free-space loss $L_{freespace} = 10\log_{10}\left(\frac{\lambda}{4\pi d}\right)^2$

$$= 20\log_{10}\left(\frac{3\times10^8/12/10^9}{4\times\pi\times200}\right) = -100dB$$

(b) The power gain of each antenna is

$$10\log_{10}G_t = 10\log_{10}G_r = 10\log_{10}\left(\frac{4\times\pi\times A}{\lambda^2}\right)$$

$$= 10\log_{10}\left(\frac{4\times\pi\times0.7\times\pi}{\left(3\times10^8/12/10^9\right)^2}\right)$$

$$= 46.46dB$$

(c) The received power = transmitted power + G_t + G_r + free-space loss
= 2 + 46.46 + 46.46 + (-100)
= -5.08dBW

2. A computer executes four instructions that are designated by the code words (00,01,10,11). Assuming that the instructions are used independently with probabilities(1/2,1/8,1/8,1/4).

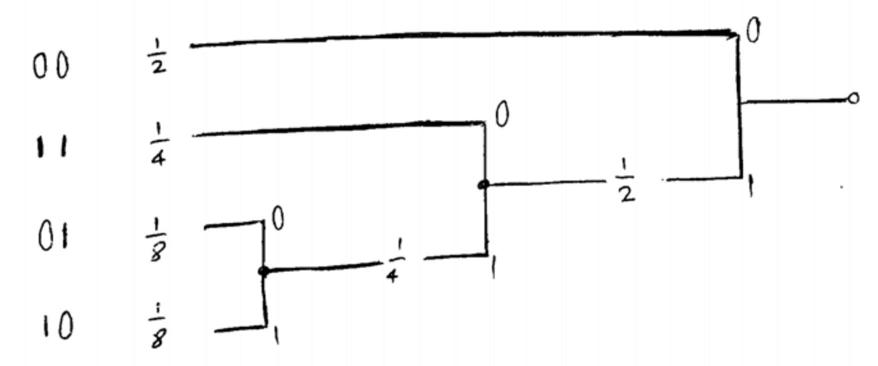
(c)(a) Construct a Huffman code for the instructions.

(d)(b)Calculate the percentage by which the number of bits used for the instructions may be reduced by the use of a Huffman code.

（本题 10 分）

Solution:

(a) As low as possible



Computer code	Probability	Huffman Code
0 0	$\frac{1}{2}$	0
1 1	$\frac{1}{4}$	1 0
0 1	$\frac{1}{8}$	1 1 0
1 0	$\frac{1}{8}$	1 1 1

As high as possible

Computer code	Probability	Huffman Code
00	1/2	1
11	1/4	01
01	1/8	000
10	1/8	001

(e)(c) The number of bits used for the constructions based on the computer code, in a probabilistic sense, is equal to

$$2\left(\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{8}\right)=2 \text{ bits}$$

On the other hand, the number of bits used for instructions based on the Huffman code, is equal to

$$1 \times \frac{1}{2}+2 \times \frac{1}{4}+3 \times \frac{1}{8}+3 \times \frac{1}{8}=\frac{7}{4}$$

The percentage reduction in the number of bits used for instruction, realized by adopting the Huffman code, is therefore

$$100 \times \frac{1/4}{2}=12.5\%$$

3. Consider the (15,8) cyclic code defined by the generator polynomial

$$g(X)=1+X+X^3+X^7 \quad (h(X)=X^8+X^4+X^2+X+1)$$

(e)(a) Develop the encoder for this code.

(f)(b) Get the generator matrix and the parity-check matrix.

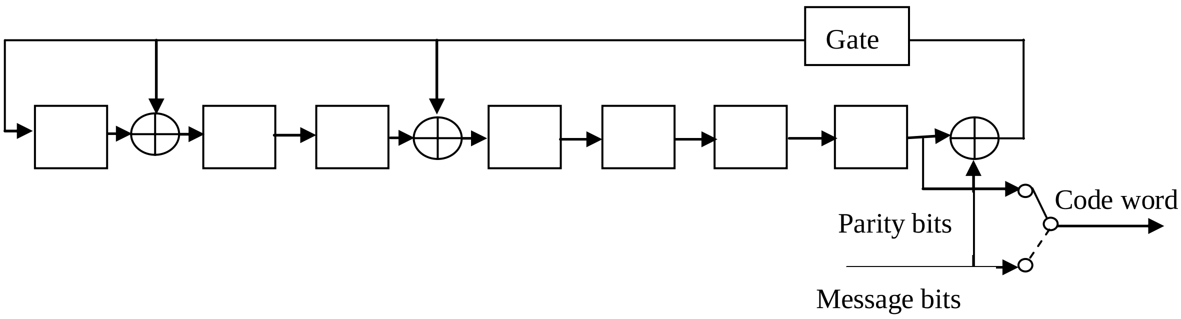
(g)(c) Construct a systematic code word for the message sequence 10110011.

(h)(d) The received word is 110001000000001, determine the syndrome polynomial *s(X)* for this received word.

（本题 15 分）

Solution:

(a)



(b) generator matrix

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

$$Xg(X)=X+X^2+X^4+X^8$$

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

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

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

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

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

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

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

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

Parity-check matrix

$$X^8h(X^{-1})=1+X^4+X^6+X^7+X^8$$

$$X^9h(X^{-1})=X+X^5+X^7+X^8+X^9$$

$$X^{10}h(X^{-1})=X^2+X^6+X^8+X^9+X^{10}$$

$$X^{11}h(X^{-1})=X^3+X^7+X^9+X^{10}+X^{11}$$

$$X^{12}h(X^{-1})=X^4+X^8+X^{10}+X^{11}+X^{12}$$

$$X^{13}h(X^{-1})=X^5+X^9+X^{11}+X^{12}+X^{13}$$

$$X^{14}h(X^{-1})=X^6+X^{10}+X^{12}+X^{13}+X^{14}$$

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

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

(c) For the message sequence 10110011, the corresponding message polynomial is

$$m(X) = 1 + X^2 + X^3 + X^6 + X^7$$

Firstly, $X^{n-k}m(X) = X^7 + X^9 + X^{10} + X^{13} + X^{14}$

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

$$\frac{X^7 + X^9 + X^{10} + X^{13} + X^{14}}{1 + X + X^3 + X^7} = X^7 + X^6 + X + 1 + \frac{1 + X^2 + X^3 + X^4 + X^6}{1 + X + X^3 + X^7}$$

The remainder is $b(X) = 1 + X^2 + X^3 + X^4 + X^6$

Hence, the desired code polynomial is

$$c(X) = b(X) + X^{n-k}m(X) = 1 + X^2 + X^3 + X^4 + X^6 + X^7 + X^9 + X^{10} + X^{13} + X^{14}$$

The systematic code word is 1011101,10110011

(d) The code polynomial corresponding to the received word 110001000000001 is

$$r(X) = 1 + X + X^5 + X^{14}$$

divide $r(X)$ by $g(X)$, we get

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

Hence, the syndrome polynomial *s(X)* for this received word is

$s(X) = X + X^2 + X^5 + X^6$ (0110011)

4. Consider the rate *r* = 1/3, constraint length *K* = 3 convolutional encoder. The generator sequences the encoder are as follows:

$g^{(1)} = (1,0,0)$, $g^{(2)} = (1,0,1)$, $g^{(3)} = (1,1,1)$

(f) (a) Draw the block diagram of the encoder.

(g) (b) Construct the code tree

(h) (c) Construct the signal-flow graph and obtain the input-output state equations.

(i) (d) Determine the encoder output produced by the message sequence 10111….

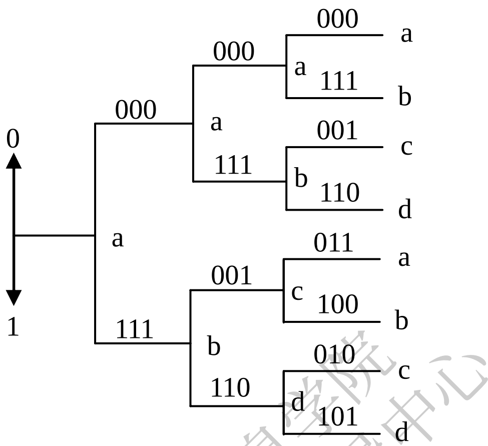
(j) (e) The received sequence is 110,001,101,110,000,011. Use the Viterbi algorithm to compute the decoded sequence.

（本题 15 分）

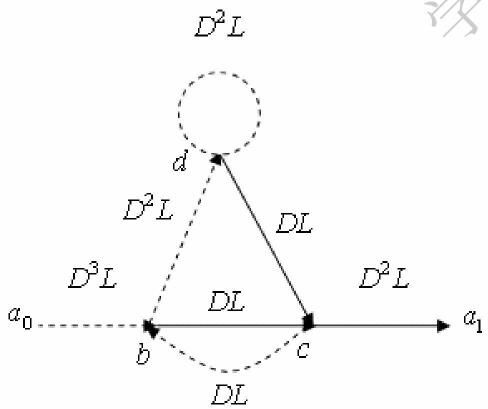
Solution:

(a) Encoder diagram

(b) Code tree



(c) Signal-flow graph



$$\begin{cases} b = D^3 L a_0 + D L c \\ c = D L b + D L d \\ d = D^2 L b + D^2 L d \\ a_1 = D^2 L c \end{cases}$$

(f) (d) Encoder output produced by the message sequence 10111 is 111, 001, 100, 110, 101, 010, 011, 000, …

(g) (e) The received sequence is 110,001,101,110,000,011. The correct sequence is 111, 001, 100, 110, 010, 011. The decoded sequence is 101100.