Tongji University Examination
Year 2012 – 2013 I semester (B)

Signature of preparer: Signature of examiner:

Number of course:102209 Course name: Fundamentals of Communication Systems

Type of examination:Exam

This examination is for: Intermediate exam (__), final exam (__), reexamine (__)

Year_____ Specification _____ number of student _____ Name_____ Marks obtained:_____

The examination consists of three parts, i.e . Part I, questioning & answering; Part II, Computation; and Part II, Calculation and Analysis. The full marks are 100.

Part 1, questioning & answering.

Please answer the following 10 questions. Totally 30 points, each question 3 points.

1. What is the relationship between a signal, a message and an information? Does any signal or message carry information?

   Solution: *A signal is a carrier of a message. The information is related to the probability for the event described by the message to occur. A message is not necessarily carrying any information.*

2. How to measure the information carried by a message?

   Solution: *The information carried by a message is measured by taking the logarithm of 2 or other values of the probability for the event described by the message.*

3. What does an information unit "2 bit" mean?

   Solution: *The information carried by an event which happens with a probability of* $1/4$.

4. Which kind of signal can be called analog signal?

   Solution: *Its voltage or current can be expressed by a continuous function of time. For example, speech signal.*

5. Please describe the advantages of digital communication over the analog communication?

   Solution:

   - *Finite number of possible values of signals*
   - *Correct decision may be achieved*
   - *Error correcting techniques can be used.*
   - *Digital encryption can be used.*
   - *Different kinds of message can be integrated to transmit in one system*
   - *Digital communication equipment:*
     - *Designing and manufacturing are easier*

- *Weight & volume are smaller*

- *Digital signal can be compressed by source coding to reduce redundancy.*
- *Output S/N increases with bandwidth according to exponential law.*

6. What is the unit for symbol rate?

   Solution: *The unit for symbol rate is Baud.*

7. How many basis function is needed for MPAM?

   Solution: *One basis function.*

8. Can the non-coherent detection be adopted for demodulating the MQAM modulated signal?

   Solution: *It is difficult to demodulate the QAM signal without knowing the phases of the received signal.*

9. In the phase-locked loop (PLL) for carrier recovery, the value of the output of integrator, i.e. $z(t) = \int_{T_0} r(t)\sin(2\pi f_c t + \hat{\phi})\mathrm{d}t$ is used to determine the estimate $\hat{\phi}$. When there are multiple propagation paths, whether this estimation still works, and state the reasoning for your opinion.

   Solution: *It only works in the care where the received signal $r(t)$ consists of single propagation path.*

10. What is the "Non decision-feedback PLL"? One kind of "Non decision-feedback PLL" relies on the distribution of the data. Usually the symbol distribution is often assumed to be Gaussian along each signal dimension. Please shortly explain why this assumption is important.

    Solution: *Solution: The structure of a non-decision-directed carrier phase recovery loop depends on the underlying distribution of the data. The constellation of the data would be symmetric.*

Part II, calculating and analysis.

Please answer the following 5 questions. Totally 40 points, each question 8 points.

1. Differential modulation: Please use DQPSK modulation as an example to describe the principle of differential modulation, where the Gray coding is applied for the phase transition. Assuming the initial vector is $[0, 1]$, please find the signal transmitted in vector space for the sequence 0110110001.

   Solution: *Solution: Differential modulation is to use the previous symbol as a phase reference for the current symbol. The information bits are encoded as the differential phase between the current symbol and the previous symbol. 00, phase transition* $\Delta\phi = 0°$*; 01,* $\Delta\phi = 90°$*; 11,* $\Delta\phi = 180°$*;10,* $\Delta\phi = 270°$*. So the phase transition is* $90°, 270°, 180°, 0°, 90°$*. Assuming the initial vector is* $[0, 1]$*, the signal transmitted in vector space are "[1,0], [0,1], [-1,0],[-1,0],[0,-1]".*

2. In order to avoid 180° phase shift, people use $\pi/4$-DQPSK instead of purely DQPSK. The steps of generating the $\pi/4$-DQPSK signals are: 1) Information bits are first differentially encoded as DQPSK, and then 2) every other symbol transmission is shifted in phase by $\pi/4$. Please use the afore-mentioned steps to find the phase transition

of $\pi/4$-DQPSK modulated signals for the bit sequence $01 - 11 - 10 - 00 - 11 - 00$, where "01" to the left of the sequence are transmitted first. The Gray coding is used for information encoding.

Solution: *The phase transition for DQPSK is* $90°, 180°, 270°, 0°, 180°, 0°$. *Initial phase is* $0°$. *Then the phases of the symbol transmitted are* $90°, 270°, 180°, 180°, 0°, 0°$. *The phase transition for* $\pi/4$*-DQPSK is that* $90°, 315°, 180°, 225°, 0°, 45°$.

3. Please describe under the following scenarios, whether the outage probability and error probability are suitable for describing the system performance:

   - $T_c \ll T_s$
   - $T_c \approx T_s$.
   - $T_c \gg T_s$

   Solution:

   - $T_c \ll T_s$: *the fast fading scenario. The probability of symbol errors applies to describing the system performance.*
   - $T_c \approx T_s$: *The average error probability is a reasonably good figure of merit for the channel quality.*
   - $T_c \gg T_s$: *the slow fading scenario. The outage and average error probability are often combined.*

4. For a mixed BPSK and BPAM modulation, the constellations $s_1 = A$ and $s_2 = -2A$ for $A > 0$ are transmitted. Please find the decision regions Z_1 and Z_2 corresponding to the constellations s_1 and s_2, and plot the decision regions.

   Solution: *The signal space is one-dimensional, so* $\boldsymbol{r} = r \in \mathcal{R}$. *The decision region* $Z_1 \subset \mathcal{R}$ *is defined by*

$$Z_1 = \{r : \|r - A\| < \|r - (-2A)\|\} = \{r : r > -A/2\}.$$

   Thus, Z_1 *contains the positive numbers larger than* $A/2$ *on the real line. Similarly*

$$Z_2 = \{r : \|r - A\| < \|r - (-2A)\|\} = \{r : r < -A/2\}.$$

   So Z_2 *contains all numbers less than* $A/2$.

5. The bandwidth of the complex envelope $u(t)$ of $s(t)$ is $B = 200$ KHz. The carrier frequency f_c is 800 MHz. The transmitted signal has the power of 2 w. The transmitter antenna height is $h_t = 30$ meters. The receiver antenna height is $h_r = 3$ meters. The distance between the transmitter and receiver antennas is 100 meters.

   The noise $n(t)$ in the receiver has uniform power spectral density $N_0/2$ with $N_0 = 10^{-5}$ mw/Hz.

   Assuming that the signal propagates in the urban areas of a medium-sized city, where the path loss can be modeled as the Hata model:

$$P_L dB = 69.55 + 26.16 \log_{10}(f_c) - 13.82 \log_{10}(h_t) - a(h_r) + (44.9 - 6.55 \log_{10}(h_t)) \log_{10}(d)$$

   Please calculate the SNR of the received signal.

   Solution: *Solution: it can be calculated that* $a(h_r) = 2.6898$. *Thus,* $33 - 362.6 = -329.6$ *dBm,* $1.09 * 10^{-33}$ *w. So,* $1.09 * 10^{-33}/(10^{-5} \cdot 2 * 10^5) = -232$ *dB.*

Part III, computing.

Please answer the following 3 questions. Totally 30 points.

1. The two -ray model is used when a single ground reflection dominates the multipath effect. Let's consider a system with $h_t = 10$ meters, $h_r = 1.5$ meters, $d \gg h_t + h_r$, the system carrier frequency is 900 MHz. The propagation is as depicted in Figure 1. If the reflection on the ground introduces a phase rotation of $\pi/4$, please find an approximate of the distance where the received power has the second null.

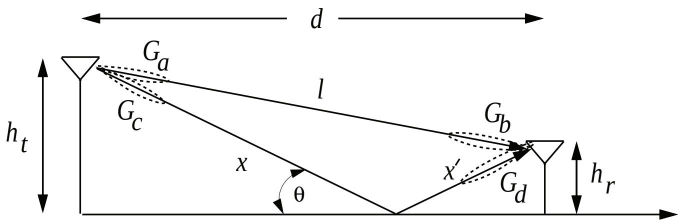

Figure 1: Two-ray model

Solution: *Since the reflection has already introduced $\pi/4$ additional phase, the phase difference $\Delta\phi$ needs to be $\pi - \pi/4 = 3\pi/4$. Thus*

$$\Delta\phi \approx \frac{4\pi h_t h_r}{\lambda d}$$
$$d \approx \frac{4\pi h_t h_r}{\lambda \Delta\phi}$$
$$= \frac{4\pi 10 \cdot 1.5}{3 \times 10^8/(9 \cdot 10^8)(3/4)\pi}$$
$$= 180\frac{4}{3}$$
$$= 240$$

2. Figure 2 illustrates the power delay profiles of the channels measured in Nan Jing Dong Lu in a measurement campaign conducted in December 2012. A sequence of symbols with bandwidth of 3.84 MHz was used to measure the channel, i.e. the symbol was transmitted with a symbol rate of 3.84 MHz. The sample rate in the receiver is 4 times of the symbol rate. The x-axis of Figure 2 represents the delay in samples. It can be observed that from Snapshot no.5 to no. 18, there is only Line-of-sight (LoS) component. For snapshot no. 18 to to no. 25, we can observe multipath effect since there are three dominant peaks in the power delay profiles. Please write the expression of the delay power spectrum for the channels from Snapshot no.5 to no. 18, and for the channel from snapshot no. 18 to no. 25. (Hints: 1) for the period from Snapshot no.5 to no. 18, you may use just one formula; similar for the period from snapshot no. 18 to no. 25; 2) the delay power spectrum can be considered as $|c(\tau, t)|^2$ (please refer to Example 3.1 in the English textbook.))

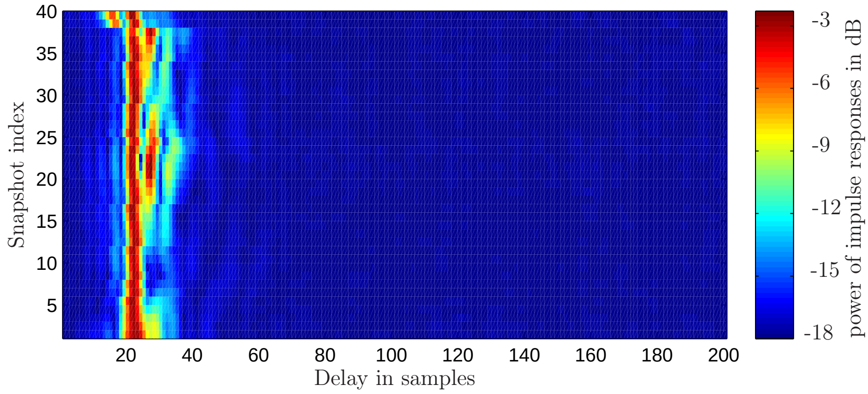

Figure 2: Measured power delay profile

3. Considering a channel with the impulse response of $h(t) = 0.5\delta(t - \tau_0) + 0.5\delta(t - \tau_1)$ where $\tau_0 = 5$ ns is the delay of the line-of-sight (LoS) component, and $\tau_1 = 10$ ns is the delay of a reflected non-line-of-sight component. For a spread spectrum system using maximal linear codes with period $T = 100$ ns and $N = 20$,following two settings, please calculate (1) the required delay offset of the synchronizer in the receiver relative to the line-of-sight component in order to obtain the maximum of received signal power, and (2) the power reduction compared to the case where only the LoS component exist.