UTHM
Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER I
## SESSION 2016/2017

| | | |
|---|---|---|
| COURSE NAME | : | DIGITAL COMMUNICATION |
| COURSE CODE | : | BEB 41803 |
| PROGRAMME CODE | : | BEJ |
| EXAMINATION DATE | : | DECEMBER 2016 / JANUARY 2017 |
| DURATION | : | 3 HOURS |
| INSTRUCTION | : | ANSWERS FIVE (5) QUESTIONS ONLY |



THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

**Q1** (a) Digital communication systems are becoming increasingly attractive because of ever-growing demand for data communications and because of its flexibilities not available in analog transmission. Explain by designing the fundamental features that make a digital communication to take place (from transmitter to the receiver end). You may include the optional features that you need to have in your design.

(5 marks)

(b) The term *noise* refers to *unwanted* electrical signals that always present in digital communication systems. Thermal noise is a natural source of noise that cannot be eliminated. It is often called as 'white noise' and modeled as zero-mean Gaussian random process. Explain why:

(i) thermal noise is defined as white noise; and

(2 marks)

(ii) Gaussian distribution is often used as the system noise model?

(3 marks)

(c) A line at temperature $T_0{}^o = 290$K and loss factor, $L = 2$ is fed from a source with noise temperature $T_g{}^o = 1250$K. The input signal power, $S_i$ is 110pW and the signal bandwidth, $W$ is 100MHz. Calculate:

(i) the input signal to noise ratio, $SNR_i$; and

(4 marks)

(ii) the output signal to noise ratio, $SNR_o$.

(6 marks)

**Q2** (a) A transmitter has an output of 2 W at a carrier frequency of 2 GHz. Assume that the transmitting and receiving antennas are parabolic dishes each 1m in diameter and efficiency of each antenna is 0.55. Calculate:

(i) the gain of each antenna;

(4 marks)

(ii) the Effective Isotropic Radiated Power, EIRP of the transmitted signal in dbW; and

(2 marks)

(iii) the available signal power at the receiving antenna if the receiving antenna is located 21km away from the transmitting antenna over a free-space path.

(4 marks)

(b) A receiver preamplifier has a noise figure of 10 dB, a gain of 80 dB and a bandwidth of 6 MHz. It is a lossless line and the temperature of the antenna is 150K. The input signal power, $S_i$, is $10^{-11}$ W. Calculate:

(i) the effective temperature, $T_R°$;

(2 marks)

(ii) the system temperature, $T_S°$; and

(2 marks)

(iii) output signal to noise ratio, $SNR_o$.

(6 marks)

**Q3** (a) Waveform coding is a technique to transform the waveforms into 'better waveforms' to make the detection process less prone to errors. Waveform coding can be divided into Antipodal and Orthogonal signals. Compare these two signals, by considering the cross-correlation factor, $z_{ij}$.

(6 marks)

(b) In *M*-ary signalling, the processor accepts *k* data bits at a time. As *k* increases, there is an improvement in the error performance ($P_E$). Due to that, there will be a reduction in the required bit energy to noise power spectral density ($E_b/N_o$) and bandwidth efficiency (*BW*). Justify why there is reduction in the *BW* when *k* increases. You may use parameters such as $P_E$ and $E_b/N_o$ to assist your justification.

(6 marks)

(c) Consider a (6,3) code, whose generator matrix, *G*, is :

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

(i) Construct all possible codewords of the code.

(6 marks)

(ii) Formulate the parity-check matrix, *H* of the code.

(2 marks)

**Q4** (a) Produce the orthogonal codeword for 4-bit data set and biorthogonal codeword for 3-bit data set.

(6 marks)

(b) The syndrome, $S$ is the result of parity check performed on $\boldsymbol{r}$ to identify whether $\boldsymbol{r}$ is a valid member of the codeword set. Assume a codeword $U$ = 101110 is transmitted, and the error vector $\boldsymbol{r}$ = 001110 is received. Determine:

(i) the syndrome vector value, $S = \mathbf{r}H^T$; and

(3 marks)

(ii) the corrected vector, $\boldsymbol{U}$.

(3 marks)

Given,

$$H^T = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \end{pmatrix}$$

(c) Among the most popular of the closed-loop symbol synchronizers is the early/late-gate synchronizer. The synchronizer operates by performing two separate integrations of the incoming signal energy over two different portions of symbol interval, as shown in **Figure Q4(b)**. Analyse the statement above by referring to the mentioned figure.

(8 marks)

**Q5** (a) **Figure Q5(a)** shows the Error Probability Plane for orthogonal signalling. Differentiate what are the benefit and trade-off happens at the labelled points **1**, **2** and **3**. You may use terms such as probability of bit error ($P_B$), bit energy to noise power spectral density ($E_b/N_o$), number of bits ($k$) and bandwith ($BW$) to assist you.

(9 marks)

(b) A binary sequence message, X, is to be transmitted over a channel with source probabilities of P(X=1) = 0.6 and P(X=0) = 0.4. Assumed that the channel produce ONE (1) error in a received sequence of 1000 bits. Calculate:

(i) the equivocation H(X|Y) of the transmitted message;

(4 marks)

(ii) the effective information content, $H_{eff}$; and

(4 marks)

(iii) the effective information bit rate, $R_{eff}$, if 2000 binary symbols per second are transmitted over the channel.

(3 marks)

**Q6** (a) Given a bandwidth-limited AWGN radio channel with an available bandwidth of W = 4 kHz. The ratio of received signal power to noise-power spectral density ($P_r/N_0$) = 53 dB-Hz. The data rate, R = 9600 bits/s. In order to have a greater bandwidth efficiency, the modulation scheme's level, M, has been fixed to 8. Calculate:

(i) the symbol energy over noise spectral density ($E_s/N_0$);

(3 marks)

(ii) probability of symbol error, $P_E(M)$; and

(4 marks)

(iii) probability of bit error, $P_B$.

(3 marks)

(b) Two CDMA users (A and B) are transmitting signal at the same time. Given that the output data from speech coder for CDMA user A and B are 1111000000001111 and 1111111111111111 respectively. Walsh Code 1 and 2 (refer to **Table Q6 (b)**) are employed at spreading code A and B respectively. Distinguish that the interference between the users will be minimized, if:

(i) user B is transmitting at user A power level.

(5 marks)

(ii) user B is transmitting at three times user A power level.

(5 marks)



**- END OF QUESTION –**

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**Table Q4: Syndrome Look-Up Table**

| Error Patern | Syndrome |
|---|---|
| 000000 | 000 |
| 000001 | 101 |
| 000010 | 011 |
| 000100 | 110 |
| 001000 | 001 |
| 010000 | 010 |
| 100000 | 100 |
| 010001 | 111 |

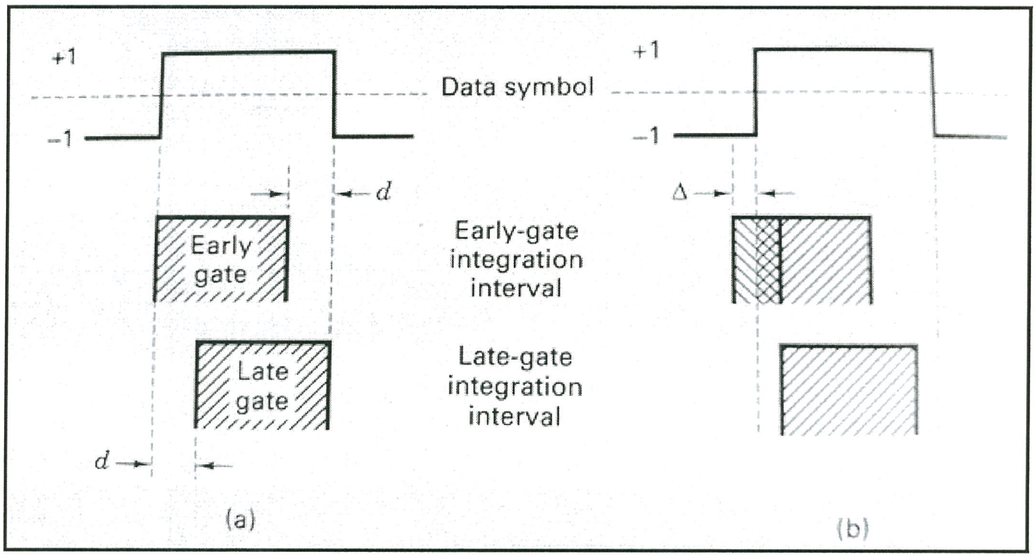


**Figure Q4(b)**

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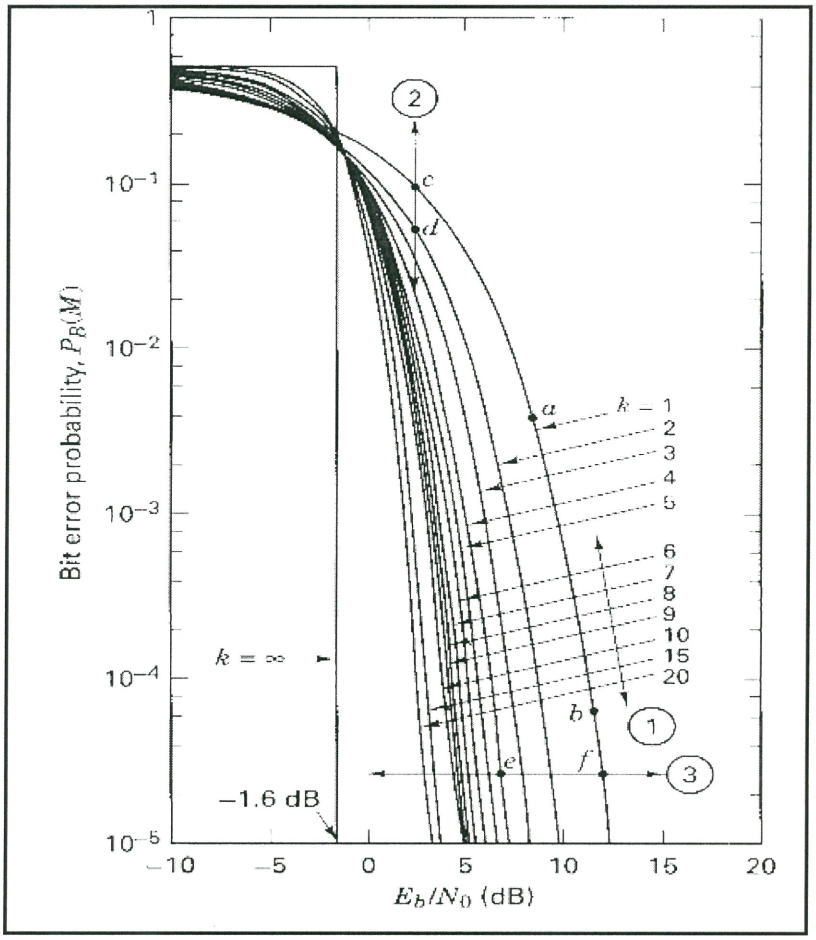


**Figure Q5(a)**

**Table Q6(b)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Code 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Code 1 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 |
| Code 2 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 |
| Code 3 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 |
| Code 4 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 |
| Code 5 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 |
| Code 6 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 |
| Code 7 | 1 | -1 | -1 | 1 | 1 | -1 | 1 | -1 |

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**Table: Probability of Symbol Error and Probability of Bit-Error Equations**

| Modulation Type | Parameter | Equation |
|---|---|---|
| **M-FSK** | Probability of symbol error, $P_E(M)$ | $P_E(M) \le \frac{M-1}{2} \exp\left(-\frac{1}{2}\frac{E_s}{N_0}\right)$ |
| | Probability of bit-error, $P_b$ *(Uncoded system)* | $P_b = \left(\frac{2^{k-1}}{2^k - 1}\right) P_E$ |
| **M-PSK** | Probability of symbol error, $P_E(M)$ | $P_E(M) \approx 2Q\left[\sqrt{\frac{2E_s}{N_0}} \sin\left(\frac{\pi}{M}\right)\right]$ |
| | Probability of bit-error, $P_b$ *(Uncoded system)* | $P_b \approx \frac{P_E}{\log_2 M} \quad (for\ P_E << 1)$ |
| **M-QAM** | Probability of bit-error, $P_b$ *(Uncoded system)* | $P_b \approx \frac{2(1-L^{-1})}{\log_2 L} Q\left[\sqrt{\left(\frac{3\log_2 L}{L^2-1}\right)\frac{2E_b}{N_0}}\right]$ where $L = \sqrt{M}$ |
| **Coded System (All Modulation Type)** | Probability of bit-error, $P_b$ | $P_b \approx \frac{1}{n}\sum_{j=t+1}^{n} j \binom{n}{j} p_c^j (1-p_c)^{n-j}$ |
| **Complementary Error Function (approximation)** | Q(x) | $Q(x) \approx \frac{1}{x\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right)$ where x > 3 |

**Boltzman's Constant, k = 1.38 x $10^{-23}$ W/K-Hz**

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### Table Q6(a): Error function erf($x$)

| $x$ | erf $x$ | $x$ | erf $x$ | $x$ | erf $x$ | $x$ | erf $x$ |
|---|---|---|---|---|---|---|---|
| **1.99 ...** | | **2.49 ...** | | **2.99 ...** | | **3.49 ...** | |
| 2.00 | 0.995322 | 2.50 | 0.999593 | 3.00 | 0.99997791 | 3.50 | 0.999999257 |
| 2.01 | 0.995525 | 2.51 | 0.999614 | 3.01 | 0.99997926 | 3.51 | 0.999999309 |
| 2.02 | 0.995719 | 2.52 | 0.999635 | 3.02 | 0.99998053 | 3.52 | 0.999999358 |
| 2.03 | 0.995906 | 2.53 | 0.999654 | 3.03 | 0.99998173 | 3.53 | 0.999999403 |
| 2.04 | 0.996086 | 2.54 | 0.999672 | 3.04 | 0.99998286 | 3.54 | 0.999999445 |
| 2.05 | 0.996258 | 2.55 | 0.999689 | 3.05 | 0.99998392 | 3.55 | 0.999999485 |
| 2.06 | 0.996423 | 2.56 | 0.999706 | 3.06 | 0.99998492 | 3.56 | 0.999999521 |
| 2.07 | 0.996582 | 2.57 | 0.999722 | 3.07 | 0.99998586 | 3.57 | 0.999999555 |
| 2.08 | 0.996734 | 2.58 | 0.999736 | 3.08 | 0.99998674 | 3.58 | 0.999999587 |
| 2.09 | 0.996880 | 2.59 | 0.999751 | 3.09 | 0.99998757 | 3.59 | 0.999999617 |
| 2.10 | 0.997021 | 2.60 | 0.999764 | 3.10 | 0.99998835 | 3.60 | 0.999999644 |
| 2.11 | 0.997155 | 2.61 | 0.999777 | 3.11 | 0.99998908 | 3.61 | 0.999999670 |
| 2.12 | 0.997284 | 2.62 | 0.999789 | 3.12 | 0.99998977 | 3.62 | 0.999999694 |
| 2.13 | 0.997407 | 2.63 | 0.999800 | 3.13 | 0.99999042 | 3.63 | 0.999999716 |
| 2.14 | 0.997525 | 2.64 | 0.999811 | 3.14 | 0.99999103 | 3.64 | 0.999999736 |
| 2.15 | 0.997639 | 2.65 | 0.999822 | 3.15 | 0.99999160 | 3.65 | 0.999999756 |
| 2.16 | 0.997747 | 2.66 | 0.999831 | 3.16 | 0.99999214 | 3.66 | 0.999999773 |
| 2.17 | 0.997851 | 2.67 | 0.999841 | 3.17 | 0.99999264 | 3.67 | 0.999999790 |
| 2.18 | 0.997951 | 2.68 | 0.999849 | 3.18 | 0.99999311 | 3.68 | 0.999999805 |
| 2.19 | 0.998046 | 2.69 | 0.999858 | 3.19 | 0.99999356 | 3.69 | 0.999999820 |
| 2.20 | 0.998137 | 2.70 | 0.999866 | 3.20 | 0.99999397 | 3.70 | 0.999999833 |
| 2.21 | 0.998224 | 2.71 | 0.999873 | 3.21 | 0.99999436 | 3.71 | 0.999999845 |
| 2.22 | 0.998308 | 2.72 | 0.999880 | 3.22 | 0.99999473 | 3.72 | 0.999999857 |
| 2.23 | 0.998388 | 2.73 | 0.999887 | 3.23 | 0.99999507 | 3.73 | 0.999999867 |
| 2.24 | 0.998464 | 2.74 | 0.999893 | 3.24 | 0.99999540 | 3.74 | 0.999999877 |
| 2.25 | 0.998537 | 2.75 | 0.999899 | 3.25 | 0.99999570 | 3.75 | 0.999999886 |
| 2.26 | 0.998607 | 2.76 | 0.999905 | 3.26 | 0.99999598 | 3.76 | 0.999999895 |
| 2.27 | 0.998674 | 2.77 | 0.999910 | 3.27 | 0.99999624 | 3.77 | 0.999999903 |
| 2.28 | 0.998738 | 2.78 | 0.999916 | 3.28 | 0.99999649 | 3.78 | 0.999999910 |
| 2.29 | 0.998799 | 2.79 | 0.999920 | 3.29 | 0.99999672 | 3.79 | 0.999999917 |
| 2.30 | 0.998857 | 2.80 | 0.999925 | 3.30 | 0.99999694 | 3.80 | 0.999999923 |
| 2.31 | 0.998912 | 2.81 | 0.999929 | 3.31 | 0.99999715 | 3.81 | 0.999999929 |
| 2.32 | 0.998966 | 2.82 | 0.999933 | 3.32 | 0.99999734 | 3.82 | 0.999999934 |
| 2.33 | 0.999016 | 2.83 | 0.999937 | 3.33 | 0.99999751 | 3.83 | 0.999999939 |
| 2.34 | 0.999065 | 2.84 | 0.999941 | 3.34 | 0.99999768 | 3.84 | 0.999999944 |
| 2.35 | 0.999111 | 2.85 | 0.999944 | 3.35 | 0.999997838 | 3.85 | 0.999999948 |
| 2.36 | 0.999155 | 2.86 | 0.999948 | 3.36 | 0.999997983 | 3.86 | 0.999999952 |
| 2.37 | 0.999197 | 2.87 | 0.999951 | 3.37 | 0.999998120 | 3.87 | 0.999999956 |
| 2.38 | 0.999237 | 2.88 | 0.999954 | 3.38 | 0.999998247 | 3.88 | 0.999999959 |
| 2.39 | 0.999275 | 2.89 | 0.999956 | 3.39 | 0.999998367 | 3.89 | 0.999999962 |
| 2.40 | 0.999311 | 2.90 | 0.999959 | 3.40 | 0.999998478 | 3.90 | 0.999999965 |
| 2.41 | 0.999346 | 2.91 | 0.999961 | 3.41 | 0.999998582 | 3.91 | 0.999999968 |
| 2.42 | 0.999379 | 2.92 | 0.999964 | 3.42 | 0.999998679 | 3.92 | 0.999999970 |
| 2.43 | 0.999411 | 2.93 | 0.999966 | 3.43 | 0.999998770 | 3.93 | 0.999999973 |
| 2.44 | 0.999441 | 2.94 | 0.999968 | 3.44 | 0.999998855 | 3.94 | 0.999999975 |
| 2.45 | 0.999469 | 2.95 | 0.999970 | 3.45 | 0.999998934 | 3.95 | 0.999999977 |
| 2.46 | 0.999497 | 2.96 | 0.999972 | 3.46 | 0.999999008 | 3.96 | 0.999999979 |
| 2.47 | 0.999523 | 2.97 | 0.999973 | 3.47 | 0.999999077 | 3.97 | 0.999999980 |
| 2.48 | 0.999547 | 2.98 | 0.999975 | 3.48 | 0.999999141 | 3.98 | 0.999999982 |
| 2.49 | 0.999571 | 2.99 | 0.999977 | 3.49 | 0.999999201 | 3.99 | 0.999999983 |