1. Noisy Channel Data Rates

(a) $N_{db} = 10 \log_{10} (P_2/P_1)$ $N_{db} = -40$ db $P_1 = 0.80$ watt

→ $P_2 = 8 * 10$^-5 watt = 80 μwatt

$N_{db} = 10 \log_{10} (P_2/P_n) = 10 \log_{10} (80/5) =$ <u>12.041 db</u>

(b) Shannon's formula: $C = B \log_2 (1 + S/N)$ B = 5500 Hz – 500 Hz = 5000Hz

$S/N = P_2/P_n = 80/5 = 16$

→ C = 5000 Hz * $\log_2 (1 + 16)$ = <u>20437.314 bps</u>

(c) $N_{db} = 10 \log_{10} (P_2/P_1)$ $P_2 = P_{min} = 0.004$ watt $P_1 = 0.8$watt

→ $N_{db} = 10 \log_{10} (P_2/P_1) = -23.01$db

length = 23 db / 5 db/km = <u>4.6 km</u>

2. Encoding

(a) $\log_2 32 = 5$ --------- So 5 bits can represent 32 different types of signals

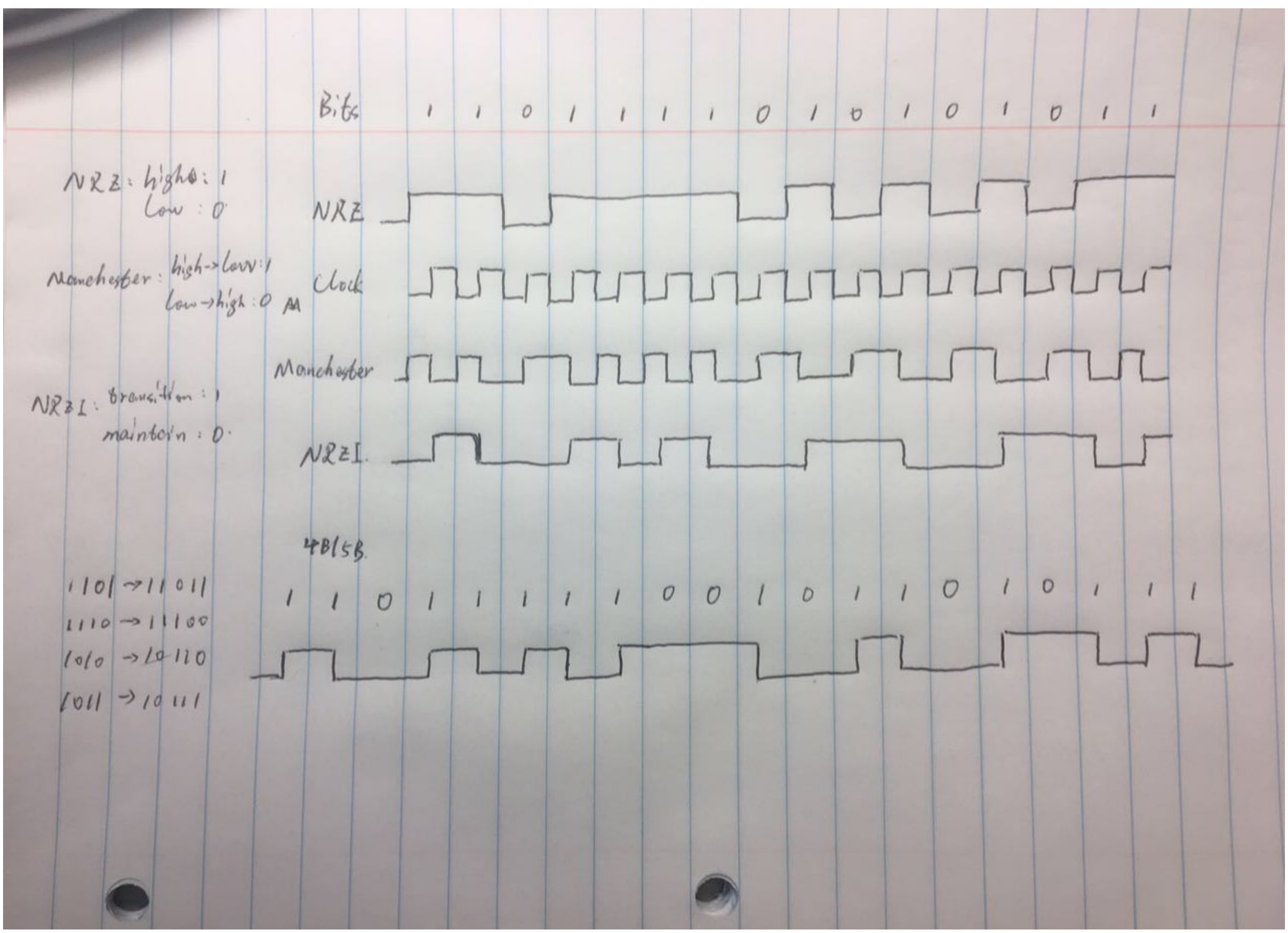
5 * 2000 = <u>10000 bps</u>

(b) $C = B \log_2 (1 + S/N)$ C = 3Gbps = 3*10^9 bps B = 250 * 10^6 Hz

→ S/N = 2^12 – 1

SNR = $10 \log_{10} (S/N)$ = <u>36.123 db</u>

3. Encoding and Channel Capacity



(b) T2, 96 channels → 6.312 Mbps (form http://www.lageman.com/bandwidth.htm)
$C = B \log_2 (1 + S/N)$ $C = 6.312 * 10^6$ bps $B = 25$ MHz $= 25 * 10^6$ Hz
→ $6.312 * 10^6$ bps $= 25 * 10^6$ Hz $* \log_2 (1 + S/N)$
→ $S/N = 0.191$
$SNR = 10 \log_{10} (S/N) = 10 \log_{10} (0.191) = \underline{-7.19 \text{ db}}$

4. Modulation
(a) 8 data points → 8 symbol → $\log_2 8 = 3$ bits
3 bits * 800 baud = <u>2400 bps</u>

(b) This modem uses amplitude modulation. Since these two data points have same phase shift(angle) but different amplitudes.

5. Framing
(a) DLE (16) = 0001 0000 STX (2) = 0000 0010 ETX (3) = 0000 0011
0000 0010 0001 0000 1011 1110 0000 0011 1111 1111 0000 0001 0000 0010 0000 0011

(b) 0111 1110 1011 11100 0000 0011 11101 1111 0000 0001 0000 0010 0111 1110

(c) 01011 11101 00000 00111 01111 11111 00000 00011 00000 00101

(d) data size = 40
for BISYNC: 40/16*4 = 62.5%
for HDLC: 40/58 = 69%
for RS-232: 40/50 = 80%

6. Error Detection
(a) $M(x) = 11100101000$ $C(x) = x^4 + x^3 + 1 = 11001$
So, $T(x) = 11100101000\ 0000$
$R(x) = T(x)/C(x) = 1011$ We append 1011 to M(x) to get the send message
→ $P(x) = 111001010001011$
Assume that bit 4 (counting from the most significant bit) in the code word is in error
→ $Error(x) = 111101010001011$
$Error(x)/C(x) = 10101$, not equals to 0, CRC test failed, there is an error.

(b) $x^4 + x^3 + x + 1 = 11011$
10010110011 / 11011 = 1100, which is $\underline{x^3 + x^2}$. It not equals to 0. Thus, the bit sequence is <u>not</u> correctly encoded with the given generator.

(c) We want to find the largest value of n such that any double bit error can be detected. We can find n by finding the smallest value that double bit error can not be detected. Any error sequence will pass the CRC if it is a multiple of the check bits. So we just need to find the smallest multiple of $x^4 + x + 1$. The highest power of $(x^4 + x + 1)^2$ is 8. Thus, $n = 8-1 = \underline{7}$

7. Networking Utilities
(a) cs.illinois.edu: 4.33 ms
www.illinois.edu: 4.428 ms
www.nps.gov: 10.363 ms
www.cambridge.uk: 62.278 ms
sydney.edu.au: 188.855 ms

(b) cs.illinois.edu: 6
www.illinois.edu: 5
www.nps.gov: 13
www.cambridge.uk: 16
sydney.edu.au: 20

According to the data, the higher number of routers, the higher RTT. It looks the number of hops and RTT is positive correlation. I think the number of hops is not the only factor affecting the RTT. If the number of hops is large but there routers are very close to each other, we can still get a small RTT.