

Name: \_\_\_\_\_

GTID: \_\_\_\_\_

ECE 6390: Satellite Communications and Navigation Systems  
TEST 3 (Fall 2006)

- Please read all instructions before continuing with the test.
  
- This is a **closed** notes, **closed** book, **closed** friend, **open** mind test. On your desk you should only have writing instruments and a calculator.
  
- Show all work. (It helps me to give partial credit.) Work all problems in the spaces below the problem statement. If you need more room, use the back of the page. **DO NOT** use or attach extra sheets of paper for work.
  
- Work intelligently – read through the exam and do the easiest problems first. Save the hard ones for last.
  
- All necessary mathematical formulas are included either in the problem statements or the last page of this test.
  
- You have 75 minutes to complete this examination. When the proctor announces a “last call” for examination papers, he will leave the room in 5 minutes. The fact that the proctor does not have your examination in hand will not stop him.
  
- I will not grade your examination if you fail to 1) put your name and GTID number in the upper left-hand blanks on this page or 2) sign the blank below acknowledging the terms of this test and the honor code policy.
  
- Have a nice day!

Pledge Signature: \_\_\_\_\_

*I acknowledge the above terms for taking this examination. I have neither given nor received unauthorized help on this test. I have followed the Georgia Tech honor code in preparing and submitting the test.*

1. **Short Answer Section (12 points)**

- (a) \_\_\_\_\_  
A BCH code is a type of  code used for forward error correction.
- (b) \_\_\_\_\_  
It is very difficult to jam a  radio signal.
- (c) \_\_\_\_\_  
A forward error correction code can correct errors in an error-prone digital radio signal without retransmission because it introduces  to the original bit stream.
- (d) \_\_\_\_\_  
True or False: A Butterworth filter is the optimum method for detecting a digital pulse.
- (e) \_\_\_\_\_  
Pulse  is the technique that allows engineers to confine a digital radio signal in a fixed bandwidth using realistic electronics.
- (f) \_\_\_\_\_  
 is a digital modulation scheme that can pack many bits per transmitted symbol.

2. **Comparison of Multiple Access Schemes:** Make a table of the 3 types of multiple access schemes we discussed in class. List **one** advantage and **one** disadvantage for each when used in a satellite communication link. (18 points)

3. **Link Comparison:** A GEO video satellite link to an earth station experiences 160 dB of link loss (including all path loss and antenna gain effects). Answer the following questions about the transmitter satellite based on a system noise temperature on earth of 200 K. (70 points)

(a) An analog video signal has 5 MHz of *baseband* bandwidth and must be received with at least 55 dB CNR to be seen as a high-quality image. What is the minimum RF bandwidth and satellite transmit power to send this signal as double-sideband AM? (10 points)

(b) The baseband analog video signal is sampled at the Nyquist rate and quantized with a 10-bit quantizer. This raw digital stream is sent uncoded and uncompressed through the link using QPSK modulation with a minimum BER of  $10^{-6}$ . Assume that ideal sinc pulses are used in the pulse shaping so that  $B_{\text{RF}} = 2R_S$ , where  $R_S$  is the symbol rate. What is the minimum RF bandwidth and satellite transmit power to send this signal? (15 points)

(c) The video signal is coded into the MPEG-2 standard and sent, uncoded, at an average real data rate of 2.4 Mbps using QPSK modulation. Assume ideal sinc pulses are used for digital symbols. If the target BER is  $10^{-6}$ , what is the minimum RF bandwidth and satellite transmit power to send this signal? (15 points)

- (d) The video signal is coded into the MPEG-4 standard and sent, uncoded, at an average real data rate of 2.0 Mbps using QPSK modulation and a rate 1/2-turbo code. Approximate the turbo code as providing near error-free communications at an SNR of 0 dB. Assume ideal sinc pulses are used for digital symbols and do not forget to adjust for the additional coding bits. What is the minimum RF bandwidth and satellite transmit power to send this signal? (15 points)
- (e) You now decide that this particular digital video link must multiplex 16 video signals together with spread spectrum. Your only specification is that, regardless of digital modulation scheme that you choose, you must select an  $m$ -sequence to spread the video signal capable of delivering an uncoded raw BER of  $10^{-3}$ . How many shift registers should you use in the electronics, assuming equal-powered users? (15 points)

# Cheat Sheet

$$\left(\frac{C}{N}\right)_{\text{despread}} = M \left(\frac{C}{N}\right)_{\text{spread}} \quad \left(\frac{C}{N}\right)_{\text{spread}} = \frac{C}{P_N + (Q-1)C} \approx \frac{1}{Q-1}$$

Nyquist Rate  $f_s = 2f_{\text{max}}$       Uniform Quantization Noise = 6N dB

$$\text{Channel Capacity} = B \log_2 \left(1 + \frac{C}{N}\right)$$

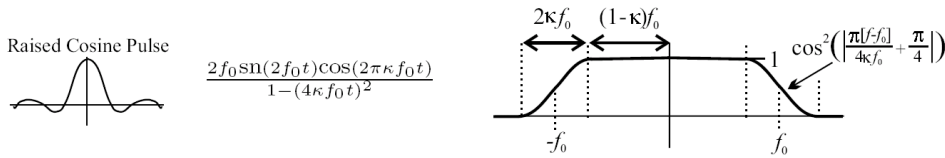
BER for QPSK =  $Q(\sqrt{2\text{SNR}})$       (SNR  $\approx C/N$  in this class)

$$\text{BER for CDMA with } Q\text{-users:} = Q\left(\sqrt{2\left(\frac{C}{N}\right)_{\text{despread}}}\right)$$

m-sequence with  $K$  shift registers:  $M = 2^K - 1$

$$P_N = kTB \quad k = 1.3807 \times 10^{-23} \text{ J K}^{-1}$$

$$Q(x) \approx \frac{1}{x\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \text{ for } x > 3$$



$x$	$Q(x)$	$x$	$Q(x)$	$x$	$Q(x)$	$x$	$Q(x)$	$x$	$Q(x)$
0.00	0.5000	1.00	0.1587	2.00	0.02275	3.00	0.001350	4.00	0.00003167
0.05	0.4801	1.05	0.1469	2.05	0.02018	3.05	0.001144	4.05	0.00002561
0.10	0.4602	1.10	0.1357	2.10	0.01786	3.10	0.0009676	4.10	0.00002066
0.15	0.4404	1.15	0.1251	2.15	0.01578	3.15	0.0008164	4.15	0.00001662
0.20	0.4207	1.20	0.1151	2.20	0.01390	3.20	0.0006871	4.20	0.00001335
0.25	0.4013	1.25	0.1056	2.25	0.01222	3.25	0.0005770	4.25	0.00001069
0.30	0.3821	1.30	0.09680	2.30	0.01072	3.30	0.0004834	4.30	0.000008540
0.35	0.3632	1.35	0.08851	2.35	0.009387	3.35	0.0004041	4.35	0.000006807
0.40	0.3446	1.40	0.08076	2.40	0.008198	3.40	0.0003369	4.40	0.000005413
0.45	0.3264	1.45	0.07353	2.45	0.007143	3.45	0.0002803	4.45	0.000004294
0.50	0.3085	1.50	0.06681	2.50	0.006210	3.50	0.0002326	4.50	0.000003398
0.55	0.2912	1.55	0.06057	2.55	0.005386	3.55	0.0001926	4.55	0.000002682
0.60	0.2743	1.60	0.05480	2.60	0.004661	3.60	0.0001591	4.60	0.000002112
0.65	0.2578	1.65	0.04947	2.65	0.004025	3.65	0.0001311	4.65	0.000001660
0.70	0.2420	1.70	0.04457	2.70	0.003467	3.70	0.0001078	4.70	0.000001301
0.75	0.2266	1.75	0.04006	2.75	0.002980	3.75	0.00008842	4.75	0.000001017
0.80	0.2119	1.80	0.03593	2.80	0.002555	3.80	0.00007235	4.80	0.0000007933
0.85	0.1977	1.85	0.03216	2.85	0.002186	3.85	0.00005906	4.85	0.0000006173
0.90	0.1841	1.90	0.02872	2.90	0.001866	3.90	0.00004810	4.90	0.0000004792
0.95	0.1711	1.95	0.02559	2.95	0.001589	3.95	0.00003908	4.95	0.0000003711
1.00	0.1587	2.00	0.02275	3.00	0.001350	4.00	0.00003167	5.00	0.0000002867