Name: ____________________

GTID: ____________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 3 (Fall 2007)

- 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. **VSAT Communications Link Design:**

You are asked to design the digital data link for a Ku-band VSAT (very small aperture terminal) operating at 14 GHz with a 0.5m diameter dish antenna. The VSAT terminal transmits at 4 Mbit/s (real data rate) to a GEO satellite using 16-QAM. The receiver at the satellite demodulates this signal and relays it back to earth where data is routed through the internet. In the absence of interference, the typical C/N at the satellite receiver is 9 dB. Answer the following questions based on this scenario. (**50 points**)

Note: when a question below asks about an *uncoded* link, you are to analyze the system assuming that the forward error correction block has been removed.

(a) If the system is uncoded, what is the raw BER at the (ideal) receiver? (10 points)

(b) If raised cosine pulses with roll-off factor $\kappa = 0.5$ are used for the link, what is the *uncoded* bandwidth of the transmitted digital system? (5 points)

(c) If the system employed a rate 5/8 turbo coder and all of the other parameters of the link design (real data rate, 16-QAM modulation scheme, .5 roll-off factor, etc.) are held constant, how much additional bandwidth must be used to accommodate the redundant coding bits? (5 points)

(d) If the turbo-code was capable of errorless transmission approaching within 1 dB of the Shannon channel capacity of this system, what would be the minimum coding gain for the system? (10 points)

(e) Sketch a signal constellation for this link design. (10 points)

(f) If 400 MHz were allotted for a satellite's total VSAT capacity, how many users could share the spectrum if FDMA were employed with a 200 kHz guard interval between bands? Assume the same parameters as above with the turbo code used on each link. (10 points)

2. **Radiolocation Analysis:** Use your knowledge of GPS to answer the following radiolocation questions about a *Time Difference Of Arrival* (TDOA) system for a terrestrial mobile wireless network. A TDOA system estimates the 2D position of a handset user by measuring the time it takes for the handset's signal to reach 3 different base stations that are carefully synchronized. Answer the questions below based on this scenario. (**50 points**)

   (a) In the space below, sketch the ideal position of the user relative to the 3 measuring base stations that minimizes the dilution of precision. (10 points)

   (b) If the mobile system is using GSM for its air interface (RF bandwidth of 200 kHz, $T_s = 3.7\mu$s) and the typical power from the handset measured at the base station is -80 dBm, what is the expected position standard deviation error for this system? Assume no dilution of precision and that the error is only due to noise/interference. Assume a system noise temperature of 150 K at the base station's measurement radio and that the typical in-band interference power received from nearby users is -100 dBm in total. Presume that the base station integrates over 1ms worth of digital symbols before making its estimate. (20 points)

   (c) List two other sources of location estimate degradation in this system. (10 points)

   (d) If this same location system were used on a CDMA air interface (3 measurement locations, average measurement SINR of -10 dB, $T_c = 1\mu$s, integration over 1ms), what factor of range improvement/degradation would you expect compared to the GSM system? (10 points)

Cheat Sheet

$$\sigma_r = cT_c\sqrt{\frac{N_{sat}T_b}{\left(\frac{C}{N}\right)_{\text{despread}} T_{int}}} \qquad c = 3.0 \times 10^8 \text{ m/s}$$

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

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

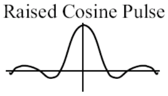
$$\text{BER for } M\text{-QAM} \approx 4\left(1-\frac{1}{\sqrt{M}}\right)\mathrm{Q}\left(\sqrt{3\,\mathrm{CINR}/(M-1)}\right)$$

$$\text{m-sequence with } K \text{ shift registers: } M = 2^K - 1$$

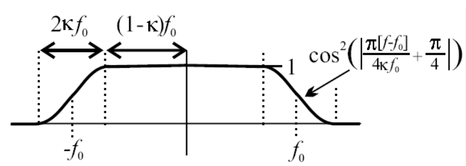
$$P_N = kTB \qquad k = 1.3807\times 10^{-23} \text{ J K}^{-1}$$

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

Raised Cosine Pulse



$$\frac{2f_0 \,\mathrm{sn}(2f_0 t)\cos(2\pi\kappa f_0 t)}{1-(4\kappa f_0 t)^2}$$



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