Name: _____

GTID: _____

ECE 6390: Satellite Communications and Navigation Systems
TEST 3 (Fall 2004)

- 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 50 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** (**20 points**)

(a) ──────────

In a state of emergency, the US government may add selective $\boxed{Answer}$ to degrade the timing precision of GPS satellites.

(b) ──────────

(True or False) Most of the EPIRB emissions are false alarms in the SARSAT system.

(c) ──────────

What type of earth orbit is a GPS satellite?

(d) ──────────

(True or False) The SARSAT system is capable of finding an EPIRB within 100m.

(e) ──────────

The $\boxed{Answer}$ message is a 50 bits/sec signal modulated onto the GPS waveform.

(f) ──────────

A $\boxed{Answer}$ GPS system uses a secondary ground station radio signal to calibrate out common errors within a local area.

(g) ──────────

Small perturbations and uncertainties in the orbital position of a satellite are called $\boxed{Answer}$ errors.

(h) ──────────

A measure of how much a CDMA receiver can reject ("spread out") noise and interference is called $\boxed{Answer}$ gain.

(i) ──────────

A GPS $\boxed{Answer}$ is a group of 4 active satellites in a common orbit with 55° of inclination.

(j) ──────────

No matter how good the time-integration or local corrections are, a stationary D-GPS receiver can never get rid of $\boxed{Answer}$ errors.

2. **Descriptive Answer Section** (**20 points**)
   Write a **concise** answer to each question in the spaces provided beneath each problem state-
   ment. **Note:**   Correct answers that are extremely verbose will be penalized.

   (a) **SARSAT:**   The SARSAT system has 4 satellites with nearly polar inclination orbits.
       Which parts of the earth receive the most frequent scans? Why might this be a poor
       design characteristic for a general search and rescue system? Does GPS have this same
       problem? Why or why not? (10 points)

   (b) **Heavily-Loaded CDMA system:**   The maximum real data capacity (in bits/sec) of a
       single user in a CDMA system with processing gain M, bandwidth B, and an *extremely
       large number* of equal-powered users N is approximately:

$$\text{Capacity} \approx \frac{BM}{N \ln 2}$$

   Derive this expression from first principles, assuming that the CDMA link is interference-
   limited, rather than noise-limited, and that a conventional spread spectrum receiver is
   used (no interference cancellation) with a very long m-sequence. The following relation-
   ship may be used to simplify your answer:

$$\ln(1 + x) \approx x \text{ for } x < 1$$

   (10 points)

3. **Satellite Doppler:**   Doppler shift is at a maximum when a satellite is at the horizon with respect to an earth-based receiver. The altitude of an LEO satellite is 1200 km and the specified operating frequency is 1700.0 MHz. If the radius of the earth is 6380 km, what is the maximum possible Doppler-shift for this satellite? (30 points)

Hints: The total Doppler shift is the sum of the shifts at the transmitter and receiver; do not forget to consider the rotation of the earth in your calculation. Also assume that the satellite orbits in the same direction as the rotation of the earth.

4. **GPS Precision:** You are using a super-resolution differential GPS receiver on the high seas. A marine radiobeacon signal perfectly corrects all local GPS errors so that the dominant contribution to position error is due to received signal quality. At your location, the received $\frac{C}{N}$ is -15 dB (spread). How many seconds will your GPS receiver have to integrate before the position accuracy drops below 1m standard deviation error? (30 points)

Hint: Recall that the spreading gain for GPS is 43.1 dB and that a typical GPS receiver uses 4 satellites for location estimates. Assume no dilution of precision.

Cheat Sheet

$$\lambda f = c \qquad c = 3 \times 10^8 \text{ m/s}$$

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

$$P_R = P_T + G_T + G_R - 20 \log_{10} \left(\frac{4\pi}{\lambda} \right) - 20 \log_{10} (r) - \text{Additional Loss in dB}$$

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

$$\text{Doppler Shifts:} \quad f_{R,Dop} = -\frac{V_R}{\lambda} \cos \theta_R \qquad f_{T,Dop} = \frac{V_T}{\lambda} \cos \theta_T$$

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

$$\sigma_r = c T_c \sqrt{\frac{N_{sat} T_b}{\left(\frac{C}{N} \right)_{\text{despread}} T_{int}}} \qquad T_b = 20 \text{ ms} \quad T_c = 980 \text{ ns}$$

$$\text{Rotation:} \quad V_\theta = R \dot\theta \qquad \text{Orbits:} \quad V = \sqrt{\frac{\mu}{R}}$$