Name: ______________________

GTID: ______________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 2 (Fall 2008)

- 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 80 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 (16 points)**

   (a) ______________ (1) ______________ (2) ______________ (3)
   Name 3 different contributions to GPS location estimate errors that can be corrected using a wide-area augmentation system.

   (b) ______________
   The numerical factor that describes how well a spread spectrum receiver can remove noise and interference from a received signal is called $\boxed{\textit{Answer}}$.

   (c) ______________
   When carrier frequency increases, dish diffraction losses tend to drop, but $\boxed{\textit{Answer}}$ losses increase.

   (d) ______________
   A radio receiver can lower the amount of physical thermal noise taken in by the antenna by reducing $\boxed{\textit{Answer}}$.

   (e) ______________
   An $\boxed{\textit{Answer}}$ is a type of pseudo-noise signal that can be generated with a train of shift registers connected with feedback.

   (f) ______________
   True or False: Geostationary antennas often transmit back to Earth with half-wave dipole antennas.

2. **Dish Antennas (8 points):** What are 2 drawbacks of using a dish antenna on a spacecraft as opposed to an electrically small antenna?

3. **Rain Fade (25 points):** An earth station is trying to receive a signal from a Geostationary satellite transmitting at 20 GHz with a look angle of 30-degrees of elevation in a K-type climatological region where average rain altitude is 2 km above the terrain level. Using our simplified class model, estimate how much margin (worst case scenario in dB) must be designed into the RF link budget to keep the system operating with 99.99% reliability.

4. **Doppler Shift (20 points):** There is a satellite-to-satellite link in GPS used for synchronizing all of the spacecraft with the master atomic clock maintained by the Air Force. If this link were to operate at precisely 4.000000000 GHz, **estimate** a **rough upper-bound** for the **maximum possible** Doppler shift in the carrier frequency. Recall that GPS satellites orbit at an *altitude* of 20,200 km.

5. **GPS (31 points):** You are a cell site technician who one day notices that a particular 850 MHz base station transmitter is experiencing slight non-linearities and transmitting a small amount of power into the GPS 1575 MHz band (L1). A typical 3D GPS receiver in the vicinity of this cell tower receives -160 dBW of power from a single GPS satellite, resulting in a total $(C/(N+I))_{\text{spread}} = -20$ dB and 20m of positioning standard deviation error *under ideal conditions*. Answer the following questions based on this scenario.

   (a) What will the location accuracy be if there is -134 dBW of additional in-band interference from the cellular transmitter (15 points)?

   (b) For the scenario discussed in the previous question, would increasing the gain of the omnidirectional GPS receiver antenna help? Why or why not? (6 points)

   (c) Estimate the averaging interval for this typical GPS receiver based on the information provided. Report your answer in terms of bits (bit fractions are OK in this answer). (10 points)

Cheat Sheet

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

GPS Stats: $R_b = 50$ bits/sec $\quad R_c = 1.023$ Mchips/sec

$$A = \gamma_R L_{\text{eff}} \quad \text{(dB)} \qquad \gamma_R = kR^{\alpha} \quad \text{(dB/km)} \qquad L_{\text{eff}} = \frac{h_r}{\sin\theta_{EL}}$$

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

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

Doppler Formula: $f = f_c - \dfrac{v_R}{\lambda}\cos\theta_R + \dfrac{v_T}{\lambda}\cos\theta_T$

$$V = \sqrt{\frac{\mu}{R}} \qquad T^2 = \frac{4\pi^2 a^3}{\mu} \qquad \mu = GM_p \qquad G = 6.672 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \qquad M_E = 5.974 \times 10^{24} \text{ kg}$$

TABLE 8.2 Rainfall Rate Intensities for the Rain Climatic Zones (From TABLE 1 in [19] © ITU, reproduced with permission)

Percentage of Time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
10	<0.1	0.5	0.7	2.1	0.6	1.7	3	2	8	1.5	2	4	5	12	24
0.3	0.8	2	2.8	4.5	2.4	4.5	7	4	13	4.2	7	11	15	34	49
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65	72
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105	96
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200	142
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250	170

Frequency (GHz)	k_H	k_V	α_H	α_V
4	0.000650	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
8	0.00454	0.00395	1.327	1.310
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.200
20	0.0751	0.0691	1.099	1.065
30	0.187	0.167	1.021	1.000
40	0.350	0.310	0.939	0.929
50	0.536	0.479	0.873	0.868