Name: ______________________________

GTID: ______________________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 2 (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 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. **SARSAT:** Explain why an LEO SARSAT satellite has a near-polar orbital inclination (**10 points**).

2. **Rain Attenuation:** Explain (with an accompanying sketch) why vertical and horizontally polarizations attenuate differently through a rain storm. (**10 points**).

3. **FM Radio Station:** WREK has decided to decrease its index of modulation and sell two sub-bands in its 200 kHz spectrum to local talk radio stations. Describe two technical changes that WREK could make to their station that would allow them to maintain their current coverage footprint in metropolitan Atlanta. (**10 points**).

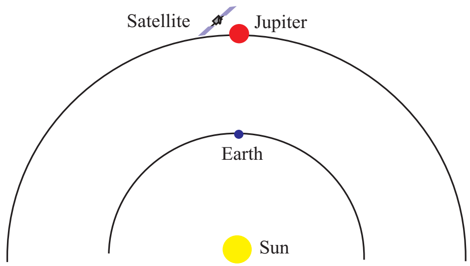
4. **Dish Antennas:** The year is 1996 and NBC is desperate for satellite uplink and downlink earth stations that can be used for its coverage of the summer Olympics in Atlanta. They ask Prof. Steffes if they can borrow the big dish on top of Van Leer for the duration of the Olympics, contingent on its ability to carry 6 GHz, 12 GHz, and 40 GHz video uplinks (with identical modulation schemes and RF bandwidths). The dish has an aperture that is 8m in diameter.

   (a) If the GEO satellite receives a 6 GHz signal from the Van Leer dish with an CNR of 10 dB, what do you estimate the CNR will be at 12 GHz and 40 GHz if it is transmitted by this same Van Leer dish and received by the same satellite with a *common receiving dish antenna*? (**20 points**)

   (b) NBC winds up using the dish and finds that the 6 and 12 GHz links work fine – but the 40 GHz link does not have enough C/N. The weather is clear and the hardware in the RF chain is adequate for all of these frequencies. What is likely the problem? (**5 points**)

5. **Rain Fading:** You are testing a new 20 GHz satellite link system with horizontal polarization that has 10 dB of extra "clear sky" margin built into its link budget. Field trials in major cities across the US have shown that the satellite link works more than $X\%$ of the time in New York, Los Angeles, and Chicago, but fails to do so in Atlanta and Miami. When switched to vertical polarization, the system does actually work more than $X\%$ of the time in Atlanta. *Estimate* the minimum rain rate, R, that knocks out this satellite link as well as the targeted link reliability, X. Assume an average storm height of 1 km and an approximate North American look angle of 45° in all your calculations. (**25 points**)

6. **Deep Space Doppler:** An exploration satellite is in orbit around Jupiter at an altitude of 10,000 km. This satellite is in communication with a dish antenna on earth near the equator (see diagram). The mission data is transmitted over several days when Jupiter and Earth are closest to one another in orbit. Assume all orbits are circular and coplanar.



Useful Planetary Information		
Mass of Earth	5.974×10^{24}	kg
Mass of Jupiter	1.900×10^{27}	kg
Earth distance from Sun	1.496×10^{8}	km
Jupiter distance from Sun	7.779×10^{8}	km
Earth Sidereal Day	86,164	s
Earth Radius	6,378	km
Jupiter Radius	71,400	km

If the spacecraft is designed to transmit at *exactly* 8.000 000 000 GHz, estimate the range of carrier frequencies that you must be prepared to receive on earth during this time (worst-case scenario). (**20 points**)

Cheat Sheet

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

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

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

$$P_N = kTB \qquad k = 1.3807 \times 10^{-23} \text{ J K}^{-1} \qquad G = \eta_A \frac{4\pi A_e}{\lambda^2}$$

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

$$\text{FM SNR (in dB)} = \left(\frac{C}{N}\right)_{\text{dB}} + 10\log_{10}\left(\frac{B_{\text{RF}}}{f_{\text{max}}}\right) + 20\log_{10}\left(\frac{f_{\text{peak}}}{f_{\text{max}}}\right) + 1.8 + P$$

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

$$T_{\text{sys}} = T_{\text{phy}} + T_{\text{d1}} + T_{\text{d2}}\frac{1}{G_1} + T_{\text{d3}}\frac{1}{G_1 G_2}\cdots$$