Name: ______________________________

GTID: ______________________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 2 (Fall 2005)

- 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** (**16 points**)

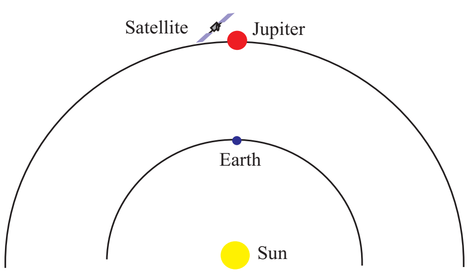
   (a) ________________ (1) ________________ (2) ________________ (3)
   A digital display receives color image information that has been broken into red, green, and blue channels. An analog television display receives color image information that has been broken into *Answer 1*, *Answer 2*, and *Answer 3* channels.

   (b) ________________ (1) ________________ (2)
   According to *Answer 1*'s rule, as the *Answer 2* index increases, the bandwidth of an FM signal expands.

   (c) ________________
   True or False: Horizontally-polarized waves experience more loss through a rain storm than vertically-polarized waves.

   (d) ________________
   Thermal noise received by an antenna is largely due to *Answer* radiation emitted by all matter in the universe.

2. **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.

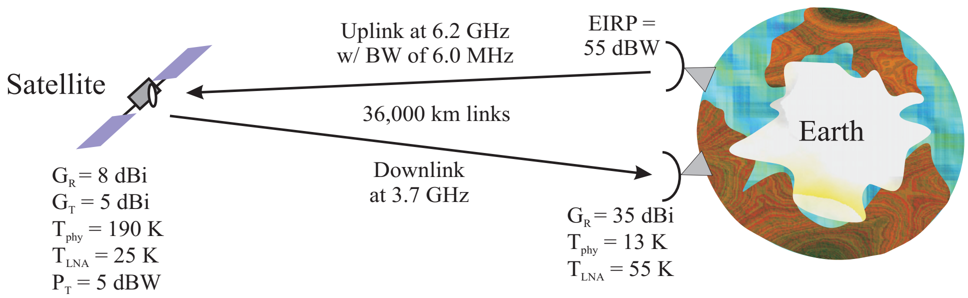


Useful Planetary Information		
Mass of Earth	5.974×10^{24}	kg
Mass of Jupiter	1.900×10^{27}	kg
Earth distance from Sun	1.496×10^{8}	km
Jupiter distance from Sun	7.779×10^{8}	km
Earth Sidereal Day	86,164	s
Earth Radius	6,378	km
Jupiter Radius	71,400	km

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**)

3. **Noise in a Bent-Pipe Transponder:** A transmitting earth station sends an analog video signal of 6.0 MHz bandwidth up to a satellite at a carrier frequency of 6.2 GHz. The ES antenna is a dish with 55 dBW Effective Isotropic Radiated Power (EIRP). The target satellite is in geosynchronous orbit and employs a bent-pipe transponder to relay the signal back to the earth. The satellite has a 20-dB gain LNA with a noise temperature of 25 Kelvin followed by a mixer which downconverts to 3.7 GHz. The final stage of the satellite RF chain is a *gain-controlled* power amplifier capable of transmitting with a 5 dBW average output.

The same horn antenna at the satellite is employed upon transmission and reception; at 6.0 GHz the gain of the dish is 8 dBi and at 3.7 GHz the gain of the dish is 5 dBi. The receiving earth station uses a dish antenna with 35 dBi of gain and a 30-dB gain LNA with a noise temperature of 55 Kelvin. A directional antenna pointing towards the earth sees a physical noise temperature of 190 Kelvin in the microwave bands, while a directional antenna pointing towards space sees a physical noise temperature of 13 Kelvin. Answer the following questions based on this scenario: (**44 points**)



(a) What is the C/N in dB at the *output* of the satellite transmitter amplifier? Remember, this is a bent-pipe transponder where no signal-processing is being performed. (10 points)

(b) Of the 5 dBW transmitted by the satellite back to earth, how much is signal power and how much is noise power? (5 points)

(c) What is the sensitivity (G/T, linear scale) of the ES receiver? Consider only thermal and device noise in this calculation. (5 points)

(d) What is the C/N in dB at the receiving earth station? Do not forget to include the noise broadcasted by the transponder satellite in this calculation. (10 points)

(e) List 4 ways to improve the C/N for the video link between the two earth stations. (8 points)

(f) The satellite passes in front of the sun for several minutes, so that the physical noise temperature as seen by the dish antenna is 10,000 Kelvin. What is the C/N in dB at the receiving earth station? (6 points)

4. **Rain Fading:** A television network from Atlanta has contracted you to design a satellite link at 11.0 GHz for their video feeds. If the average rain height is 1 km above ground and the look angle is 35°, how much link margin must you add onto the minimum "clear-sky" transmit power to ensure at least 99.99% reliability? Recall, Atlanta is an M-type climate. Assume vertical polarization. (**20 points**)

Cheat Sheet

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

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

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

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

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

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

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

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