Name: ______________________

GTID: ______________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 2 (Fall 2009)

- 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. **Dish Antennas and Noise:** An earth station has a sensitivity (G/T or Gain over System Temp) of 1000 K^{-1}. Based on this scenario, calculate the new value for this earth station's G/T if the following change is made: **(15 points)**

   (a) The reflector dish area is doubled.

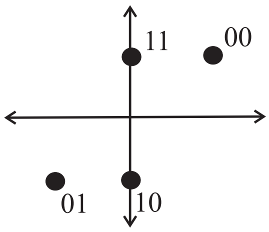
   (b) A radome covering with +1 dB additional signal loss is constructed over the dish antenna (no change in antenna noise temperature).

   (c) The receiver bandwidth is increased by a factor of 10.

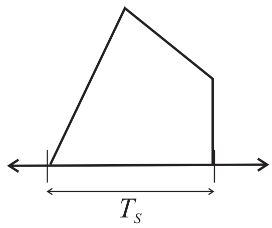
2. **Doppler Shift (25 points):** Say that NASA used a 1000.000000 MHz carrier to communicate with a lunar orbiter circling the moon (mass of 7.3×10^{22} kg) at a radius of 4,000 km. *Estimate* the range of carrier frequencies that an earth-based receiver must handle in order to properly decode the signal. Include earth rotation effects in your calculation (sidereal day = 23 hours 56 minutes).

3. **Digital Transmissions:** A digital alien signal is received from outer space which uses the following (bizarre) signal constellation and symbol shape. **(40 points)**

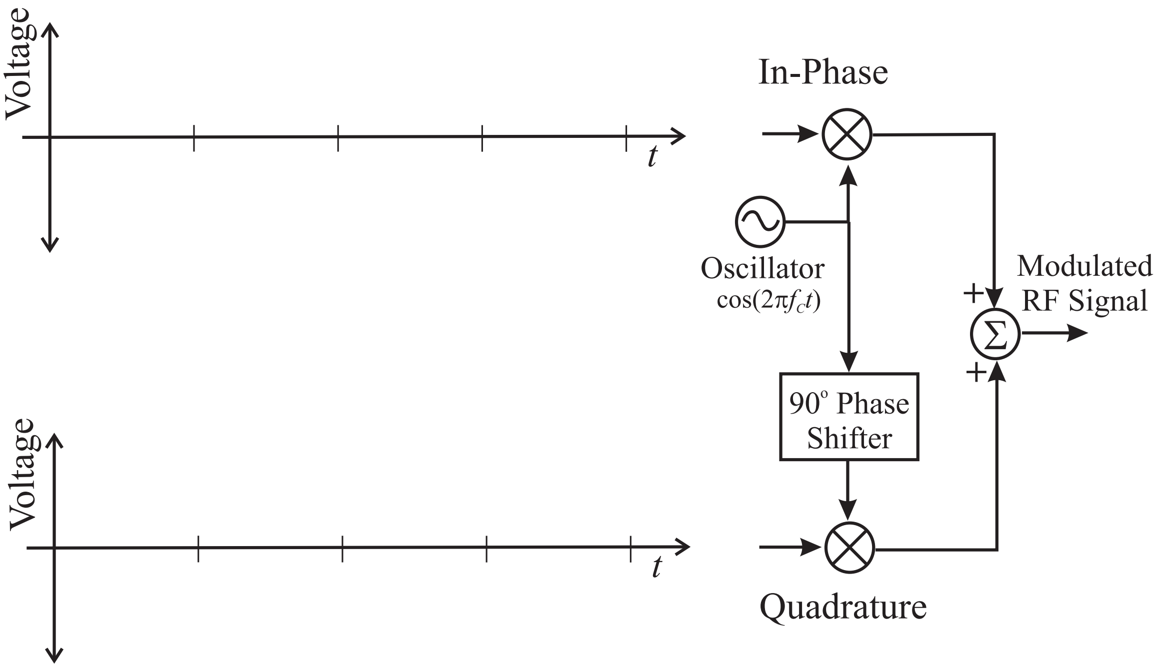
Signal Constellation



Symbol Shape



(a) In the two graphs below, make a rough sketch of the in-phase and quadrature signals that would be sent into the alien's IQ-modulator for the following data sequence: **00100111** (left-to-right is earliest to last bit) **(15 points)**



(b) What might be one of the drawbacks in using a symbol with this type of pulse shape? **(5 points)**

(c) How might you re-arrange the bit assignments on the constellation diagram to improve the overall bit error rate of a digital sequence transmitted using this scheme? **(5 points)**

(d) If baseband analog alien speech has 20 kHz of maximum frequency content, what is the minimum digital symbol period in this scheme that would allow an (uncompressed) alien voice channel to be heard with no less than 60 dB SNR? **(10 points)**

(e) You would like to compress 10 minutes of digitized alien speech. Should you use run-length encoding or Lempel-Ziv compression? Why? **(5 points)**

4. **Rain Fade (20 points):** On average, a linearly-polarized 20 GHz satellite signal travels through 2000 meters of rain when broadcast to a Southeastern city during a moderate storm of 40 mm/hr. Base your answers on this scenario, considering our class's simplified rain model.

(a) If the sense (orientation) of the linear polarization is unpredictable, what do you estimate the difference to be (in dB) between the highest and lowest possible received power in this link? (15 points)

(b) If the climate was M-type according to the ITU classification scale, estimate how often (percent of time) this rain rate would be exceeded in an average year. (5 points)

Cheat Sheet

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

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

$$\ddot{r} = r\dot{\theta}^2 - \frac{GM_P}{r^2} \qquad \ddot{\theta} = -\frac{2\dot{r}\dot{\theta}}{r}$$

$$T^2 = \frac{4\pi^2 a^3}{\mu} \qquad \mu = GM_p \qquad G = 6.672 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \qquad R_E = 6380 \text{ km}$$

$$V = \sqrt{\frac{\mu}{R}} \qquad b = a\sqrt{1-e^2} \qquad \text{perigee} = (1-e)a \qquad \text{apogee} = (1+e)a$$

$$P_N = kT_{sys}B \qquad k = 1.3807 \times 10^{-23} \text{ J K}^{-1} \qquad G = \frac{4\pi A_{em}}{\lambda^2}$$

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

$$\text{Quantization Noise: SNR} = 6 \times \text{ bits/sample}$$

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