Name: ________________________

GTID: ________________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 2 (Fall 2010)

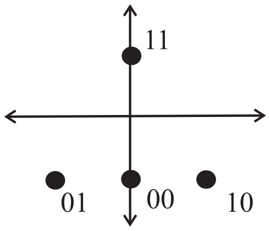
- Please read all instructions before continuing with the test.
- This is a **closed** notes, **closed** book, **closed** friend, **open** mind test. On your desk you should only have writing instruments and a calculator.
- Show all work. (It helps me to give partial credit.) Work all problems in the 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: ____

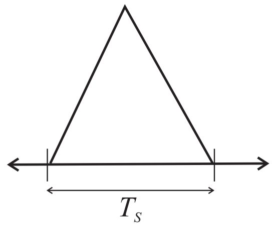
I acknowledge the above terms for taking this examination. I have neither given nor received unauthorized help on this test. I have followed the Georgia Tech honor code in preparing and submitting the test.

1. **Digital Transmissions: (45 points)** A digital modulation scheme is being designed to send compressed video bits with the following signal constellation and pulse shape.

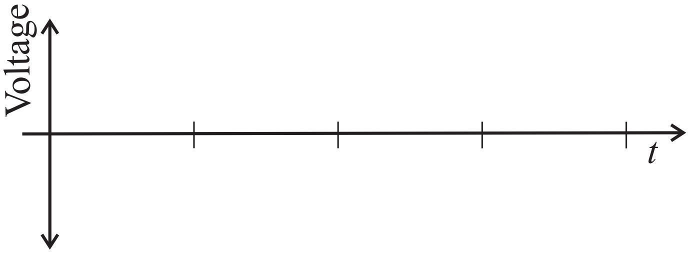
Signal Constellation

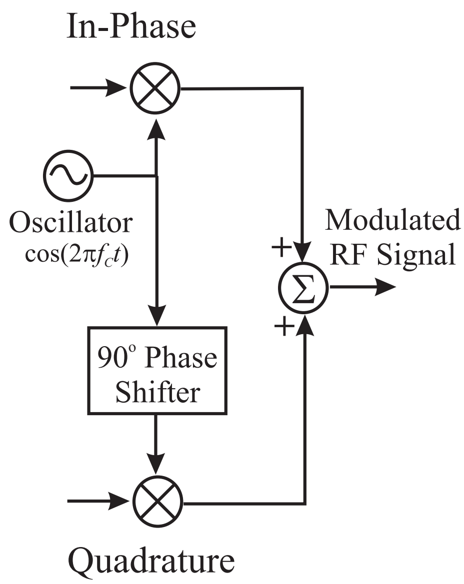


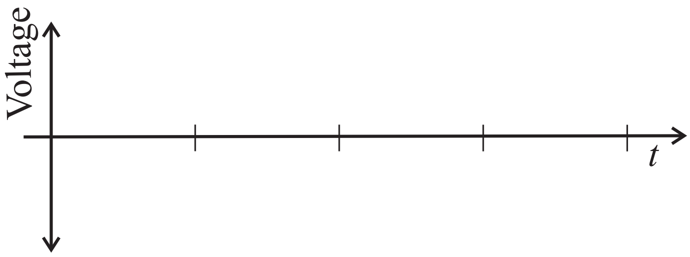
Symbol Shape



   (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: **00 10 01 11** (left-to-right is earliest to last bit) **(15 points)**







   (b) If the analog video stream has three color channels (R, G, and B) each with 10 MHz maximum baseband frequency content and each must be quantized at 8 bits/sample (before compression), what must the total final *uncoded, uncompressed* bit rate be? **(10 points)**

   (c) Based on your previous answer, how wide should T_s be in the time domain for this raw, uncompressed, total video signal to be transmitted using the specified modulation scheme? **(5 points)**

(d) If we assume perfect transmission with the above specifications, what would be the minimum SNR of an individual analog color channel that we could reconstruct at the receiver? **(5 points)**

(e) An engineer proposes using Lempel-Ziv compression on each individual color channel. What are two aspects of this scheme that are suboptimal for video? **(10 points)**

2. **Dish Antennas and Noise: (15 points)** An earth station has a sensitivity (G/T or Gain over System Temp) of 1000 K^{-1}, a peak gain of 50 dBi, and a physical temperature of 30 K when pointed directly overhead at night. Based on this scenario, answer the following questions:

   (a) What do you estimate the device temperature to be for this earth station's receiver LNA?

   (b) Based on your previous answer, what is the *noise figure* of the LNA?

(c) What is the estimated physical temperature if the dish is pointed at the horizon at night instead of directly overhead? (Ground temperature is 290 K)

3. **Rain Fade (40 points):** On average, a linearly-polarized 12 GHz satellite signal travels through 1000 meters of rain when broadcast to a Southeastern city during a moderate storm of 100 mm/hr. Base your answers on this scenario, considering our class's simplified rain model.

   (a) If polarization is vertical, what do you estimate to be the worst case rain attenuation 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)

   (c) Circle the following with either + (increase), - (decrease), or = (unchanged) with regards to how **precipitation attenuation** would change given the following system/scenario changes to the above description. (20 points)

      i. $\boxed{+ \text{ - } =}$ Satellite transmits at horizontal polarization.

      ii. $\boxed{+ \text{ - } =}$ Satellite moves to a higher orbit (look angles are the same).

      iii. $\boxed{+ \text{ - } =}$ Satellite is moved to earth station's zenith (same distance).

      iv. $\boxed{+ \text{ - } =}$ Carrier frequency is decreased.

      v. $\boxed{+ \text{ - } =}$ Temperature drops and rain turns to sleet.

      vi. $\boxed{+ \text{ - } =}$ Doppler shift between spacecraft and earth station increases.

      vii. $\boxed{+ \text{ - } =}$ The earth station's LNA is swapped for a regular amplifier.

      viii. $\boxed{+ \text{ - } =}$ A rain-resistant dish is used at the earth station with more aperture area.

      ix. $\boxed{+ \text{ - } =}$ The altitude of the rain storm clouds increases.

      x. $\boxed{+ \text{ - } =}$ Some joker drops a surfactant in the rain clouds, shrinking the average size of the rain drop for a given rain rate.

Cheat Sheet

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

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

$$\text{NF} = (1 + T_d/T_o) \quad \text{linear (not dB), ref temp } T_o \text{ is 290 K}$$

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

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

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

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

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

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