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

1. **Short Answer Section (16 points)**

   (a) ionospheric delay, tropospheric delay, ephemeris

   (b) processing gain

   (c) surface roughness

   (d) bandwidth

   (e) m-sequence

   (f) false (electrically small antennas are used for coverage, not gain; GEO satellites use dishes and horns to transmit)

2. **Dish Antennas (8 points):** Dish antennas add weight to the spacecraft and require pointing/orientation mechanisms.

3. **Rain Fade (25 points):** The effective length is about 4 km for this problem. The worst case estimate would involve horizontal polarization, which has factors of $k_H = 0.0751$ and $\alpha_H = 1.099$. According to the climatological chart, the average rainfall exceeds 42 mm/hr only 99.99% in a K-type region. Thus,

$$\text{Loss} = (4 \text{ km}) \times 0.0751 \times (42 \text{ mm/hr})^{1.099} = 18.3 \text{ dB}$$

4. **Doppler Shift (20 points):** GPS satellites, at an altitude of 26,580 km, circularly orbit the Earth at a velocity of $V = 3.87$ km/sec. The worst-case scenario would occur if two satellites are traveling in opposite directions from one another (this likely will never happen in a GPS system due to the geometry of the constellations with respect to one another, but this is the best we can calculate with the given information and will at least bound the result). The relative velocity in the worst-case scenario is thus *double* the individual satellite velocity. The Doppler shift in this case is $2V/\lambda$ or 103 kHz.

5. **GPS (31 points):**

(a) The typical noise and interference in the receiver is -140 dBW, which is 10^{-14} Watts in linear scale. With the additional 4×10^{-14} Watts (-134 dBW) of interference from the out-of-band cellular emissions, the total amount of interference+noise is 5×10^{-14} Watts. The GPS receiver will have its $C/(N + I)$ reduced by a factor of 5, resulting in a new location accuracy of 44.7m.

(b) Antenna gain does not help here, because any gain is experienced by C and $N + I$ equally.

(c) Backsolving for T_{int} in the GPS error equation for 4 satellites (it takes 4 satellites to range in 3D GPS), we find that the receiver has the equivalent of 4.3 bits of averaging in its signal correlation.