ECE 6390: Satellite Communications and Navigation Systems
Solutions to TEST 3 (Fall 2008)

1. **Short Answer Section (20 points)**
   (a) Claude Shannon
   (b) false (codecs, not modems)
   (c) lossy
   (d) metamers
   (e) subtractive, additive
   (f) true
   (g) compander
   (h) power, BER

2. **Analog Video:** In terrestrial television broadcasts, bandwidth is at a premium; in satellite television broadcasts, transmit power is at a premium. VSB conserves bandwidth, while FM trades-off extra bandwidth for signal fidelity in a lower-powered channel. Thus, they are matched well to their respective analog television mediums.

3. **Digital Video:** In terrestrial television broadcasts, bandwidth is at a premium; in satellite television broadcasts, transmit power is at a premium. Hence, satellite links typically have lower CNR than broadcast TV links. 16-QAM and 8-VSB are techniques that allow a large number of bits/sec to be transmitted in a restricted bandwidth, while the same overall data rate can be transmitted at broader bandwidth but lower overall CNR with QPSK and BPSK. Thus, these digital modulation schemes are matched well to their respective digital television mediums.

4. **Pulse Shaping:** Using the Fourier Transform pair on the back of the test, we see that sinc pulses have zero crossings every $\frac{1}{2f_o}$; thus, to meet the Nyquist intersymbol interference criterion, these pulses will have a symbol rate of $2f_o$. With a roll-off factor of $\kappa = 0.5$, the Fourier transform of the modulated pulse would take up $3f_o$ of total bandwidth. If the RF channel is 30 MHz, this implies $f_o = 10$ MHz and the symbol rate is 20 Mbaud.

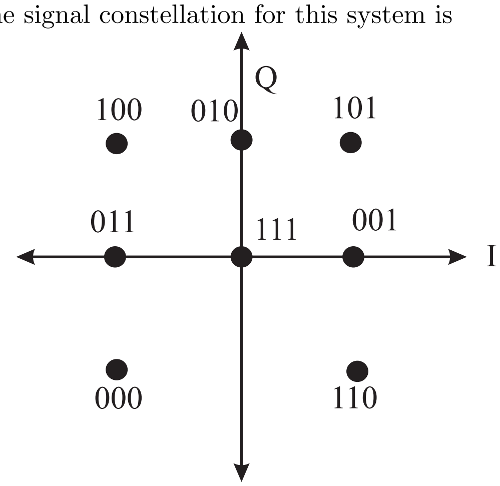
5. **Digital Transmission:** You must sample the 5-MHz baseband analog signal at 10 Msamples/sec to satisfy the Nyquist rate. With 12 bits/sample, this implies a raw data rate of 120 Mbit/sec that compresses to 30 Mbit/sec. A rate 1/2 error correction code doubles the raw bit rate with redundant coding bits, so we're up to 60 Mbit/sec after the FEC coder. If the

final transmitted symbol rate is 6 Msymbols/sec, then we must be able to send 6 bits/symbol. In other words, each symbol must have 2^6 or 1024 amplitude states to keep up with the signal. Thus, 1024-QAM is the appropriate modulation scheme.

6. **Quantization:** Each color channel (R, G, and B) must be allotted 40 Mbit/sec (for a total of 120 Mbit/sec). If the resolution is 500×400 pixels/frame $\times$ 20 frames/sec, then each color channel must encode 4 Msamples/sec. This implies that each color channel is allotted 10 bits/sample, for a quantization SNR of 60 dB.

7. **Forward Error Correction:** The output of this constraint-length 4, rate 1/2 convolutional encoder is: 1011100010101011 (right-most bit is earliest bit).

8. **Constellations:** The signal constellation for this system is



9. **BER:** The previous problem uses an atypical 8-QAM signal constellation, so BER could be approximated as

$$\text{BER for } M\text{-QAM} \approx 4\left(1 - \frac{1}{\sqrt{M}}\right) \mathrm{Q}\left(\sqrt{3\,\mathrm{CINR}/(M-1)}\right) =$$

$$4\left(1 - \frac{1}{\sqrt{8}}\right) \mathrm{Q}\left(\sqrt{30/(8-1)}\right) = 2.74\,\mathrm{Q}\left(2.07\right) = 0.055$$

This estimate is optimistic; the actual BER will be higher because the spacing of the points in the constellation is suboptimal, as are the bit assignments.