S-72.311 ADVANCED ERROR CONTROL SCHEMES

Home assignment #4, submission date: April 3rd 2001

1. **TCM bounds (TCM text)**
   Derive the expression for the *Chernoff upperbound* of the pairwise error probability for a TCM scheme in a Rician flat fading channel *giving all the details*. The fading coefficients for different time intervals are assumed to be independent.

2. **TCM Design**
   Consider 16-PSK 4-state trellis coded modulation scheme.

   a) Perform the set partitioning of the 16-PSK constellations.
   b) Construct the labeled trellis diagram for the above TCM scheme (assuming 4 parallel transitions in each branch).
   c) Determine the asymptotic coding gain of the TCM scheme relative to uncoded 8-PSK system.
   d) Find the Calderbank-Mazo realization of the system.
   e) Using the results obtain in section (d) find the Ungerboeck realization of the system.
   (For part b) Keep the Ungerboeck rules in mind and try to get a symmetrical trellis diagram.

3. **MTCM Design**
   Consider 8-PSK constellation.

   a) Perform the set partitioning using Ungerboeck Rule.
   b) Construct the labeled trellis diagram for 8 PSK 4 state MTCM scheme for n=2 and k=2 (assume 8 transitions paths in each branch).
   c) Find the asymptotic coding gain.

4. **Space time processing**

   (a) Consider the design of 2-space time codes based on QPSK with 4 and 8 states using two transmit and one receive antenna.
   Prove that in each case the code achieves the required diversity advantage -clearly giving details for at least one case.

   (b) Use four transmit antennas and one receive antenna to design a QPSK STCM system. Give the output equations. What diversity advantage you'd expect to achieve? Justify.

5. Iterative Decoding- Max-Log-MAP algorithm

Consider the following encoder. Carry out iterative decoding using the information given for at least two iterations. Writing a MATLAB program may simplify things considerably.

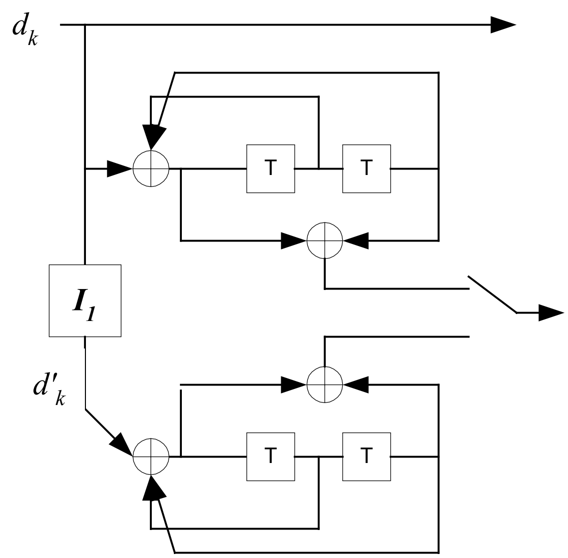

Figure B.1 Turbo encoder with RSC (7,5)

- Assume data sequence $\{d_k\} = \{1,0,0,1,0,1,0,0,1\}$

- The last 2 bits are not the information bits, but the bits inserted in order to termanate the trellis of the RSC1.

- I_1 is a 3×3 block interleaver.

  So that the interleaved sequence $\{d'_k\}$ is $\{1,1,0,0,0,0,0,1,1\}$.

  Verify that the punctured sequence is given by

  (Assuming that the puncturing function initially chooses c_k^1, the punctured sequence c_k^{2x}, x = 1,2)

  $\{c_k^{2x}\} = \{1,0,1,1,0,0,1,0,1\}$.

- Now, the output coded bit sequence consists of c_k^1, c_k^{2x} at time k. They will be modulated using BPSK into x_k^1, x_k^{2x} with the relation:

$$\{x_k^1, x_k^{2x}\} = \{2c_k^1 - 1, 2c_k^{2x} - 1\}.$$

Next, for a discrete memoryless Gaussian channel, noise n_k^1, n_k^{2x} are being added to the transmitted symbol x_k^1, x_k^{2x} at time k. n_k^1 and n_k^{2x} are two independent noise with the same variance σ . Here, we specify σ^2 **= 0.89125** and hence:

$\{n_k^1\}$={1.186691, 0.992661, -1.96959, 1.09031,-1.24656, 0.163554, 2.33662, 2.83439, 0.43984}

$\{n_k^{2x}\}$={0.0795, 0.463952-0.712115, -1.10892, 2.2841, -2.373092, 0.752278,-0.224861, -0.977405}

For each time instant *k,* the receiver input consists of R_k^1, R_k^{2x} which can be stated as:

$$R_k^1 = x_k^1 + n_k^1$$
$$R_k^{2x} = x_k^{2x} + n_k^{2x}$$

check that the values, R_k^1, R_k^{2x} *can be obtained as:*

$\{R_k^1\}$={2.18669,-0.00733882, -2.44162, 2.09031, -2.24656, 1.16355, 1.33662, 1.83439, 1.43984}

$\{R_k^{2x}\}$={2.0795,-0.536048, 0.287885, -0.108924, 1.2841, -3.37309, -1.22486, -1.4892, 0.0225949}

You may use the following decoder configuration.

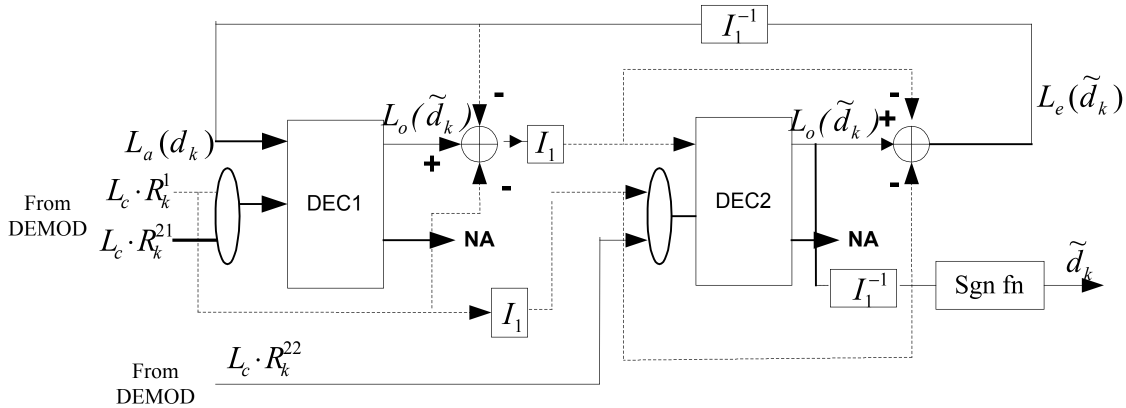

Figure B.2 Iterative Decoding