The Viterbi Algorithm for Trellis Coded Modulation

EECS 869: Error Control Coding

Fall 2009

1 TCM Example

- The trellis coded modulation (TCM) encoder we will use in this project is shown in Figure 1 (it is the same example shown in Moon Figure 13.6). The 4-state trellis diagram for this encoder is shown in Figure 2. A table with all of the trellis labels is given in Table 1. I will let you figure out my labeling formula for the left and right edge indexes. This labeling scheme works fine, but if you don't like it you are free to come up with your own.
- The input to the encoder is a pair of bits m_2 (MSB) and m_1 (LSB). It will be convenient sometimes to use a decimal representation of these two bits (i.e., a 0, 1, 2, or 3), as I have done in Table 1.
- The output of the encoder is a set of three bits: c_2 (MSB), c_1, and c_0 (LSB). It will be convenient sometimes to use a decimal representation of these three bits (i.e., a 0, 1, 2, 3, 4, 5, 6, or 7). You will probably be handling these binary values "by hand" within your implementation, and you must be consistent in the way you handle the LSB and MSB (what I'm saying is that 13 and 31 are both made up of a 1 and a 3, but when you put them together differently you get two different numbers). This same comment applies to m as well.
- The three coded bits are fed to an ordinary 8-PSK modulator, which outputs a complex-valued symbol a according to the function

  $$a(c) = \exp\left\{j\frac{2\pi}{8}c\right\}, \qquad c \in \{0, 1, \cdots, 7\}.$$

  (See also Moon Figure 13.4). As you can see, there is a one-to-one mapping between c and a. I prefer to work with c when I construct tables/diagrams, because it is more "human friendly." However, the modulated symbol a is the actual value that is transmitted, corrupted by noise, and handled by the receiver. The VA actually doesn't need c at all, it just needs a.

2 Project

Complete the following tasks. You should submit an e-mail with two .m file attachments and a separate document with a BER plot (use the e-mail address esp@eecs.ku.edu).

1. **Implement the Viterbi Algorithm for this Example TCM Encoder.** You should implement this as a MATLAB function with the following syntax:

   ```
   m_hat = VaTcmXXX(r, sS, me, ae, sE, eR);
   ```

   where $\mathbf{r}$ is a $1 \times K$ MATLAB vector containing complex-valued unquantized (soft) matched filter (MF) outputs from the PSK demodulator. The metric increment for the TCM VA is

   $$\gamma_k(e) = \mathrm{Re}\big\{r_k a^*(e)\big\}$$

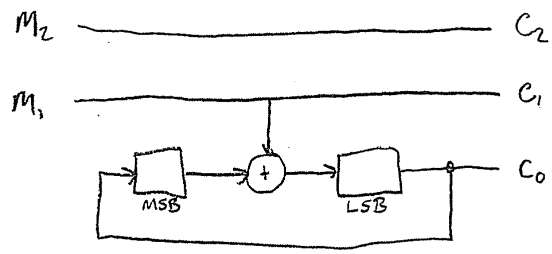

Figure 1: Example TCM encoder.

Table 1: Trellis labels for the example TCM encoder. The labels for $\mathbf{m}(e^{\mathrm{L}})$ are a decimal representation of two bits. The labels for $\mathbf{c}(e^{\mathrm{L}})$ are a decimal representation of three bits.

e^{L}	$s^{\mathrm{S}}(e^{\mathrm{L}})$	$\mathbf{m}(e^{\mathrm{L}})$	$\mathbf{c}(e^{\mathrm{L}})$	$s^{\mathrm{E}}(e^{\mathrm{L}})$	$e^{\mathrm{R}}(e^{\mathrm{L}})$
0	0	0	0	0	0
1	0	1	2	1	5
2	0	2	4	0	2
3	0	3	6	1	7
4	1	0	1	2	8
5	1	1	3	3	13
6	1	2	5	2	10
7	1	3	7	3	15
8	2	0	0	1	4
9	2	1	2	0	1
10	2	2	4	1	6
11	2	3	6	0	3
12	3	0	1	3	12
13	3	1	3	2	9
15	3	2	5	3	14
15	3	3	7	2	11

where $(\cdot)^*$ is the complex conjugate. This is a correlation-type metric increment, so the objective of the VA is to *maximize* the metric. Besides the change to metric increment, the only other major difference between this assignment and the previous project is the fact that each output value in the sequence $\hat{\mathbf{m}} = \{\mathbf{m}(T_k(\hat{S}_k))\}_{k=0}^{K-1}$ represents a *pair* of bits, thus when it is "expanded" the final output vector will have $2K$ binary-valued elements.

2. **Generate a BER Plot for this TCM Example.** Your simulation should include the range of E_b/N_0 from 0 to 7 dB, using the same minimum run-time requirements as before. Compare the TCM BER curve with the uncoded QPSK BER curve and comment on your findings. Submit the file containing your simulation code, and a separate document with the BER plot and your comments.

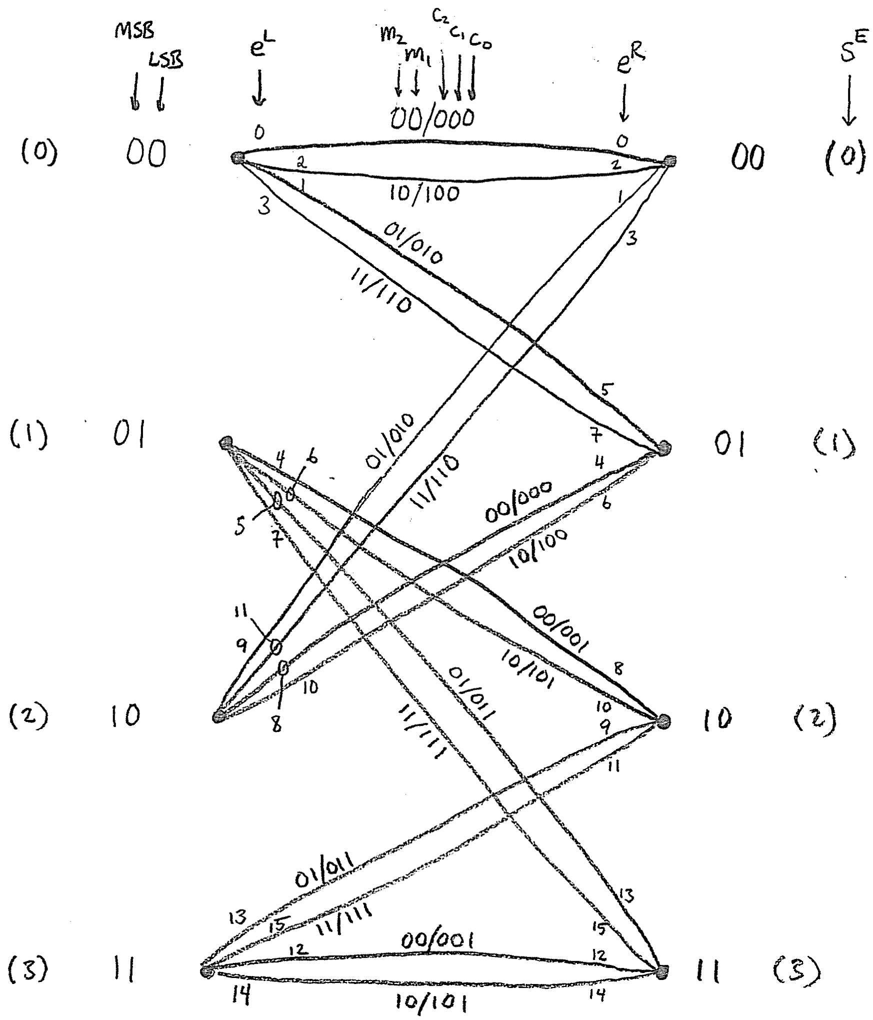

Figure 2: Trellis diagram for the example TCM encoder.