A Trellis Coded Modulation Scheme with A Convolutional Processor

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Abstract — **We propose a new trellis coded modulation (TCM) scheme. The proposed TCM is encoded by employing the encoder of a convolutional code C, which is followed by a convolutional processor and a signal mapper. Large free distances can be easily achieved for the proposed TCM. The decoding can be implemented by using the trellis for the convolutional code C with some feedback information.**

SUMMARY

For a proposed TCM, the encoding is shown as Fig. 1. Here

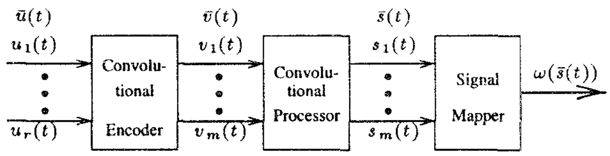

Fig. 1: Encoding structure of the proposed TCM.

C is a rate r/m convolutional code with generator matrix G_C. In each time unit of encoding, an r-bit message $\bar{u}(t)$ is fed into the encoder of C, followed by a convolutional processor and a signal mapper to generate a signal point $\omega(\bar{s}(t))$ in the signal space Ω, which may be an 8PSK signal set, for example. The convolutional processor is the encoder of a rate 1 convolutional code with transfer function matrix F [1].

In the following, we use an example to show how to properly design a convolutional processor to achieve a TCM with large free distance. Define $\Delta_i = \min\{||\omega(\bar{s}) - \omega(\bar{s}')||^2 \ : \ \bar{s} \neq \bar{s}', s_j = s'_j \text{ for } j \leq i-1\}$. We call Δ_i the level distance of the i-th level.

Let $r = 2$, $m = 3$ and Ω be an 8PSK signal set with level distance $\{\Delta_1, \Delta_2, \Delta_3\} = \{0.586, 2, 4\}$. Let

$$F = \begin{pmatrix} X^{4\lambda} & 0 & 0 \\ X^{3\lambda} & X^{\lambda} & 0 \\ 0 & 0 & 1 \end{pmatrix}, \qquad (1)$$

where λ is a positive constant. We have $s_1(t) = v_1(t-4\lambda) \oplus v_2(t-3\lambda)$, $s_2(t) = v_2(t-\lambda)$, and $s_3(t) = v_3(t)$. Let V denote the sequence $\{\bar{v}(0), \bar{v}(1), \cdots, \bar{v}(t), \cdots\}$ and d_i denote $\sum_t v_i(t)$ for $i = 1, 2, 3$. The squared free distance of the proposed TCM can be shown to be

$$D^2_{free} = \min_{V \in C, V \neq 0} \{d_1 \cdot \Delta_1 + d_2 \cdot (\Delta_2 + \Delta_1) + d_3 \cdot \Delta_3\}. \qquad (2)$$

If we choose $G_C = \left(\begin{smallmatrix} 4 & 4 & 4 \\ 5 & 7 & 0 \end{smallmatrix}\right)$, then $D^2_{free} = 7.17$. The asymptotic coding gain over uncoded QPSK is 5.54 dB.

The proposed TCM is equivalent to a conventional TCM [2] with a huge number of encoder memory. The trellis for optimum decoding of the proposed TCM will be formidable. However, because of special encoding structure, the proposed TCM can be decoded in a suboptimum way by using the trellis of C (4-state trellis in this examle). The key point of the suboptimum decoding is to determine the branch metric $M_{\bar{v}(t)}(t)$ for $\bar{v}(t)$. With the branch metrics, the Viterbi decoding for the trellis of C is applied, where the truncation length is set to be λ. The branch metric $M_{\bar{v}(t)}(t)$ is calculated to be the sum of the bit metrics $M_{v_i(t)}(t)$, $i = 1, 2, 3$, which can be obtained by using the related received symbols and previously recovered informations. Let $z(t)$ be the received symbol which is the noise-corrupted form of $\omega(s(t))$. In the proposed example, in addition to the recovered information, $M_{v_3(t)}$ can be calculated based on $z(t)$, $M_{v_2(t)}$ can be calculated based on $z(t+\lambda)$, $z(t+3\lambda)$, and $M_{v_1(t)}$ based on $z(t+4\lambda)$, $z(t+2\lambda)$. The overall decoding delay is $5\lambda - 1$ time units. Fig. 2 shows the simulation results. From Fig. 2, we can achieve a coding gain of about 3.5 dB over uncoded QPSK.

For the aforementioned example, the bit $v_2(t)$ is weighted by $\Delta_2 + \Delta_1$. The bit $v_1(t)$ and $v_3(t)$ is weighted by Δ_1 and Δ_3 respectively. In general, we may design a transfer function matrix such that the bit $v_i(t)$ is weighted by $\Delta_i + \ell\Delta_{i-1}$, where $\ell \leq \lfloor \Delta_i/\Delta_{i-1} \rfloor$. The proposed TCM scheme is a generalization of those in [3] and [4].

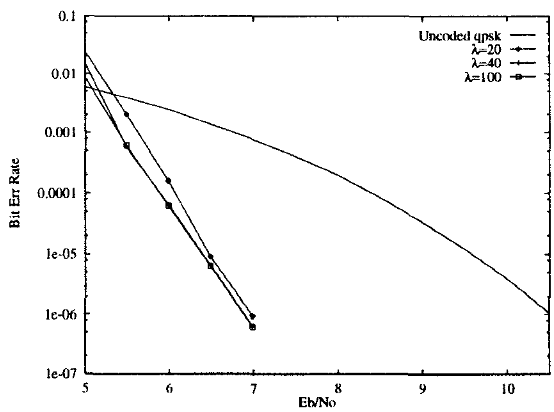

Fig. 2: Simulation results for the proposed example.

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