Optimal 4- and 8-State Across-the-subchannels TCM Encoders for DMT Systems

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Abstract — **We give the optimal 4- and 8-state trellises for across-the-subchannels TCM for DMT systems.**

I. Introduction

TCM can be performed for DMT systems in two ways : coding parallely and coding across the subchannels. The decoding delay in the latter case is M times less than that in the former case, where M is the number of subchannels [1]. We refer the latter as across-the-subchannels TCM for DMT systems.

At the receiever input, the SNR's in different subchannels are different due to the channel impulse response. Thus, the minimum weighted Euclidean distance becomes the decision criteria for ML decoding, and hence we use weighted Viterbi decoding. Due to this weighting, the best trellis known for single carrier systems need not be the best in our case.

II. Classification of Trellises

We classify all the S-state trellises into γ classes (where $\gamma = \log_2 S$) as $\{S^{(2^x;p)} : 1 \leq x \leq \gamma\}$, where $S^{(2^x;p)}$ denotes an S-state trellis with a node at a level connected to 2^x nodes in the next level and having 2^p parallel transitions. We label the top most node as s_0 and the last node as $s_{2^\gamma-1}$.

Definition 1 : A cyclic trellis is a trellis in which the branches diverging from a node s_n at any level connect to 2^{b-p} nodes of the next level, beginning from $s_{(n \cdot 2^{b-p}) \bmod 2^\gamma}$ and ending at $s_{((n+1) \cdot 2^{b-p}-1) \bmod 2^\gamma}$, where b is the number of input bits per symbol.

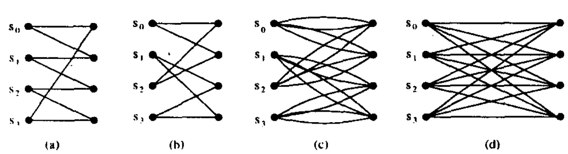

Figure 1: Some possible 4-state trellises : (a) $4^{(2;0)}$ non-cyclic (b) $4^{(2;0)}$ cyclic (c) $4^{(2;1)}$ cyclic (d) $4^{(4;0)}$ cyclic

Definition 2 : The Convergence length of a trellis is defined as the minimum of all lengths of pairs of paths that diverge from a node, excepting the parallel transitions, and converge at another node.

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The upper bound on the convergence length of a trellis is given by [2]

$$L_{max} = \lfloor \frac{\gamma}{b_1} \rfloor + 1$$

where b_1 refers to that part of the input bits which affects the state of encoder and $\lfloor x \rfloor$ denotes the largest integer less than or equal to x.

Theorem 1 : The convergence length of a cyclic trellis is equal to L_{max}, i.e., cyclic trellises achieve the upper bound on the convergence length.

III. Optimal 4- and 8-State Trellises

Let $b_{min} = \min_{i \in [0,M-1]}\{b_i\}$, where b_i is the number of input bits in i^{th} subchannel and $s_t w_t = \min_{i \in [0,M-1]}\{s_i w_i\}$, where s_i and w_i are the squared miniumum Euclidean distance of the i^{th} subchannel symbol constellation and weighting factor for that subchannel, respectively.

Theorem 2 : The best trellis for 4-state across-the-subchannels TCM is

(a) the $4^{(2;0)}$ cyclic trellis, for $b_{min} = 1$,

(b) the $4^{(4;b_{min}-2)}$ cyclic trellis if

$$\min_{i \in [0,M-1]} \{2 s_i w_i + s_{i \oplus 1} w_{i \oplus 1}\} > 4 s_t w_t$$

else the $4^{(2;b_{min}-1)}$ cyclic trellis, for $b_{min} \geq 2$.

Theorem 3 : The best trellis for 8-state across-the-subchannels TCM is

(a) the $8^{(2;0)}$ cyclic trellis, for $b_{min} = 1$,

(b) the $8^{(4;0)}$ cyclic trellis, for $b_{min} = 2$,

(c) the $8^{(8;b_{min}-3)}$ cyclic trellis if

$$\min_{i,k \in [0,M-1]} \{2 s_i w_i + s_k w_k\} > 8 s_t w_t$$

else the $8^{(4;b_{min}-2)}$ cyclic trellis, for $b_{min} \geq 3$.

Acknowledgments

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References

[1] J. A. C. Bingham, "Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come," *IEEE Communication Magazine*, pp.5-14, May 1990.

[2] S. Hamidreza Jamali and Tho Le-Ngoc, "Coded-modulation Techniques for Fading Channels," *Kluwer Academic Publishers*, 1994.