

GEL7114

Module 6 Trellis Coded Modulation(TCM)

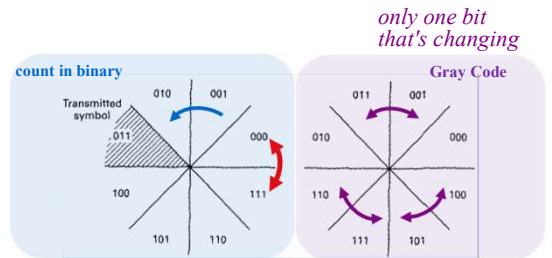
Section 9.10, pages 573-590

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1

Grey Code



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Correction code

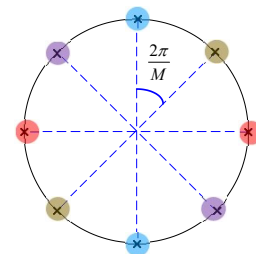
- Gray code: a first step...
- Temporal correlation can be introduced to symbols
- TCM
 - ❑ Combine modulation and correction code
 - ❑ No longer treat both independently

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Distance between symbols...



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TCM

- k message bits
- $n = k + p$ bits of code
- p parity bits
- Number of symbols without coding 2^k
- Number of symbols with coding 2^{k+p}
- Changing 2^k QAM to 2^{k+p} QAM
 - ❑ No bandwidth expansion
 - ❑ Closer symbols
 - ❑ Coding to improve performance despite closer symbols

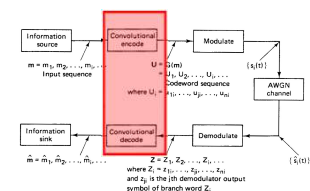
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TCM

- Contrast with
 - ❑ Coding of binary sequences



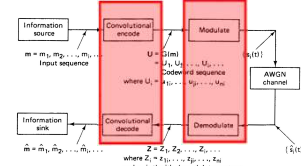
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TCM

- Contrast with
 - Coding of binary sequences
 - Modulation of bits into symbols

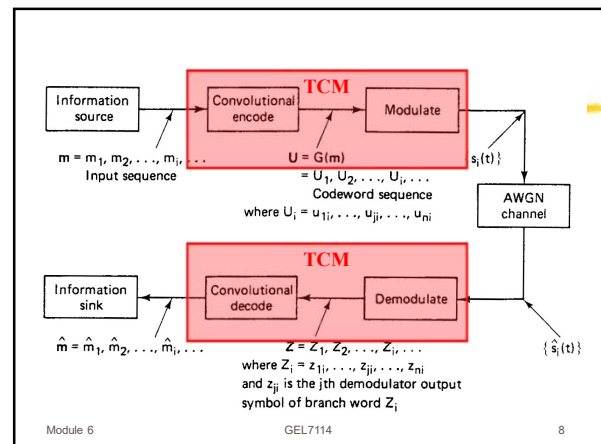


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TCM

- Contrast with
 - Coding of binary sequences
 - Modulation of bits into symbols
- Changing 2^k QAM to 2^{k+1} QAM
 - Best compromise of gain and complexity

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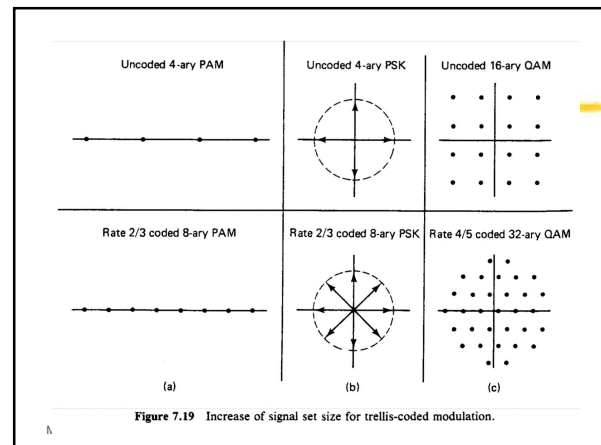
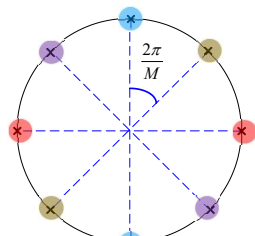


Figure 7.19 Increase of signal set size for trellis-coded modulation.

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Distance between symbols...



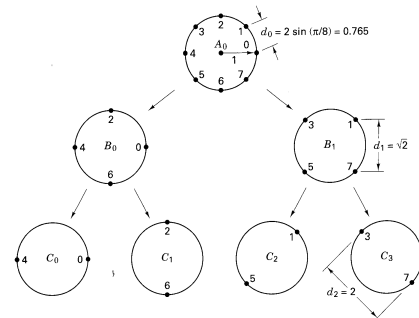
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Set partitioning Fig 9.22

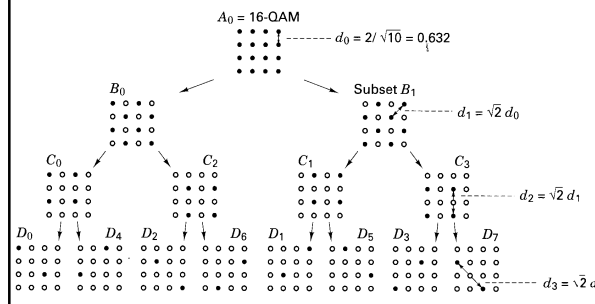


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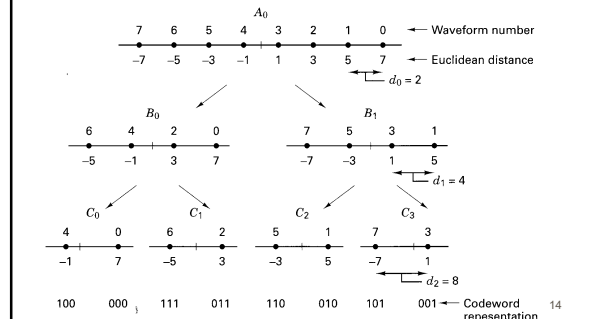
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Set partitioning 16QAM



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Set partitioning Fig. 9.32



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Grey vs. TCM 8PAM

- Grey code
 - 000 001 011 010 110 111 101 100
- TCM
 - 101 111 110 100 001 011 010 000

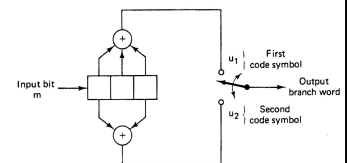
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Why "T"CM

- T = trellis
- Coding with convolutional code



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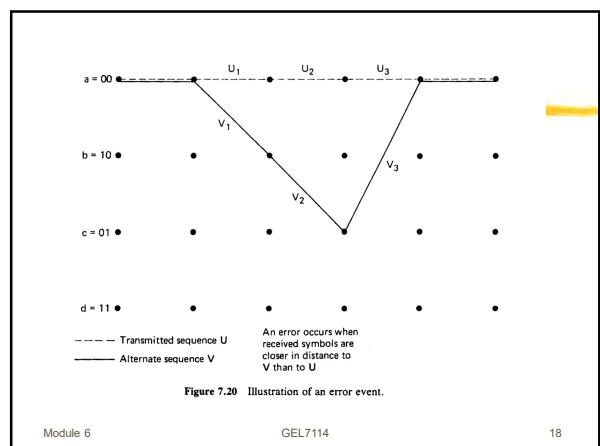
Two metrics $dist(z_i, u_i)$

- Hamming distance
 - For hard decisions
 - $dist(z_i, u_i) = \# \text{ different bits}$
- Euclidian distance
 - For soft decisions
 - $dist(z_i, u_i) = z_i^T \cdot u_i = \sqrt{(z_{i,1} - u_{i,1})^2 + \dots + (z_{i,n} - u_{i,n})^2}$

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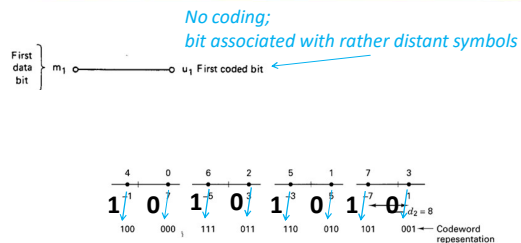


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TCM Coding



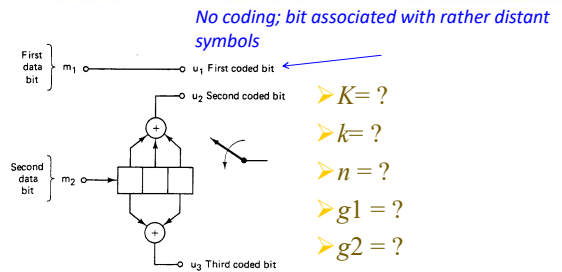
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TCM Coding



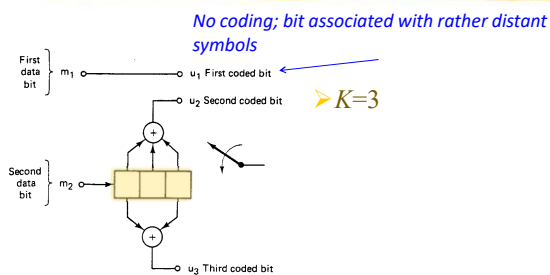
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TCM Coding



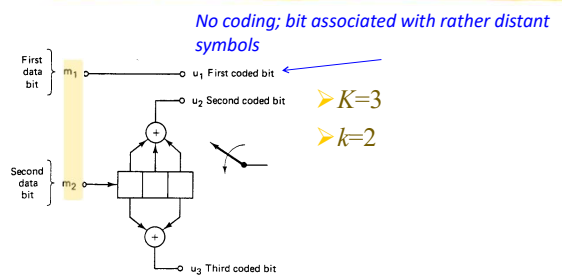
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TCM Coding



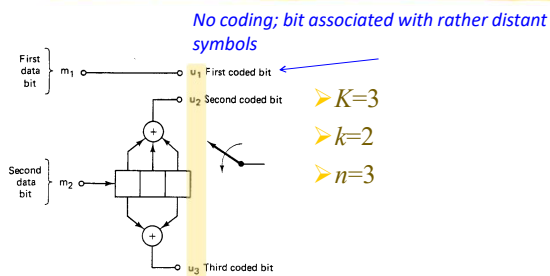
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TCM Coding



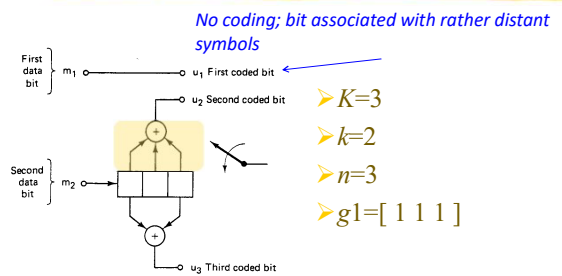
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TCM Coding



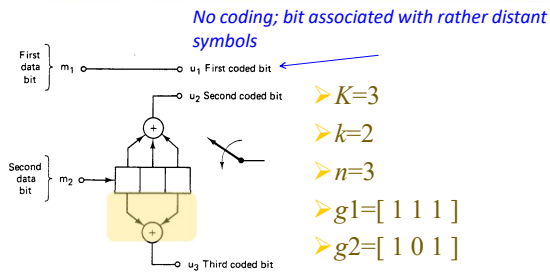
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TCM Coding



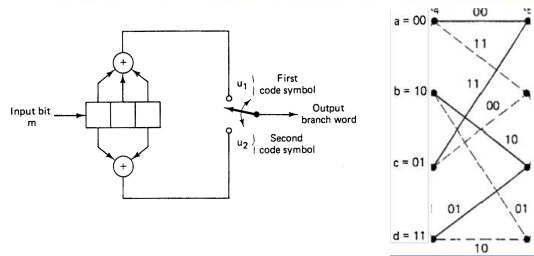
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Simple code & trellis



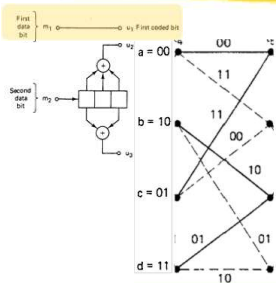
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Final trellis



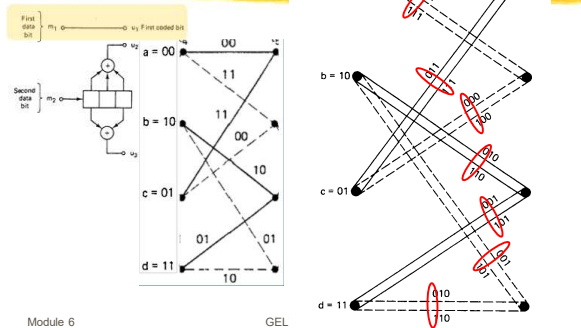
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Final trellis

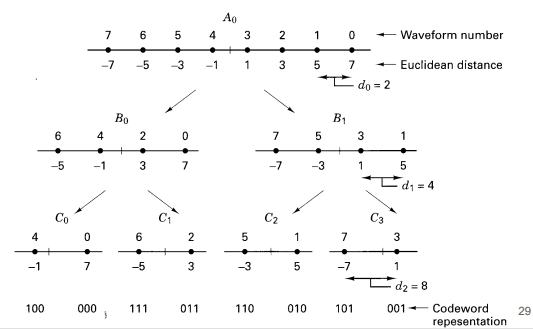


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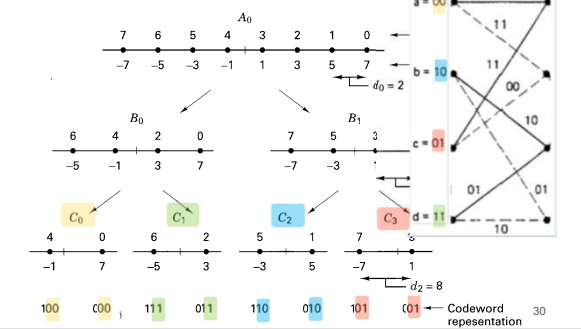
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Fig. 9.32

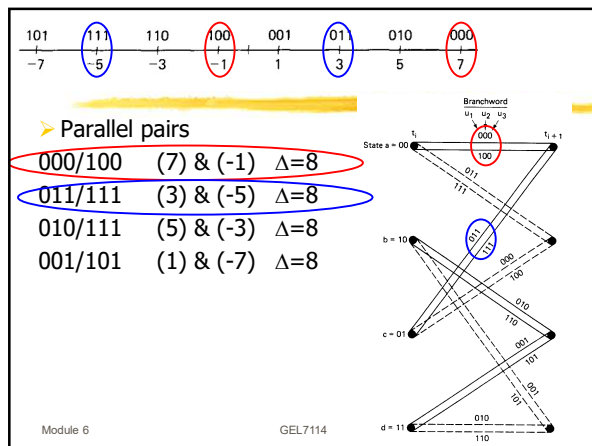


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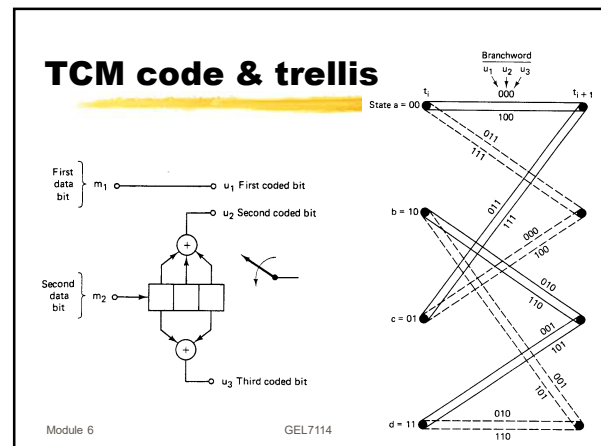
Fig. 9.32



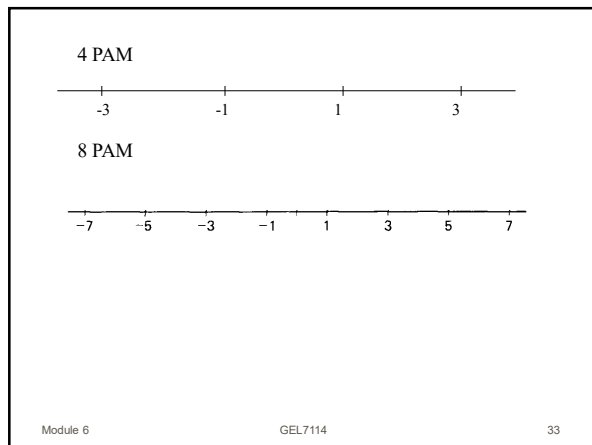
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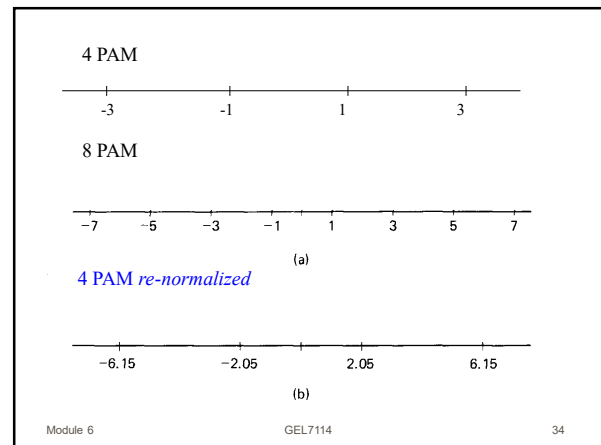
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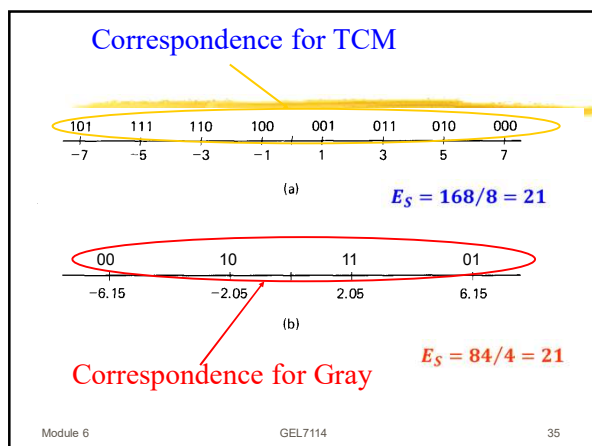
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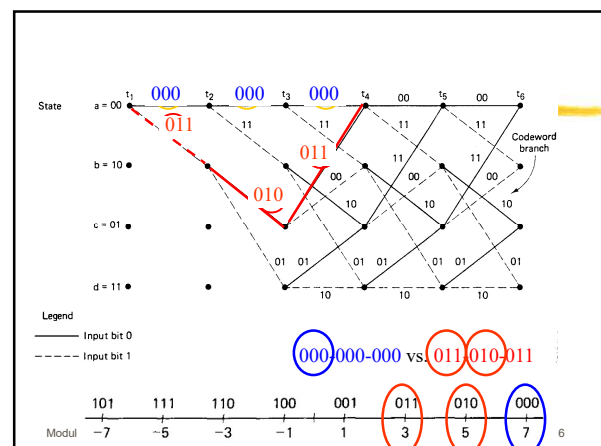
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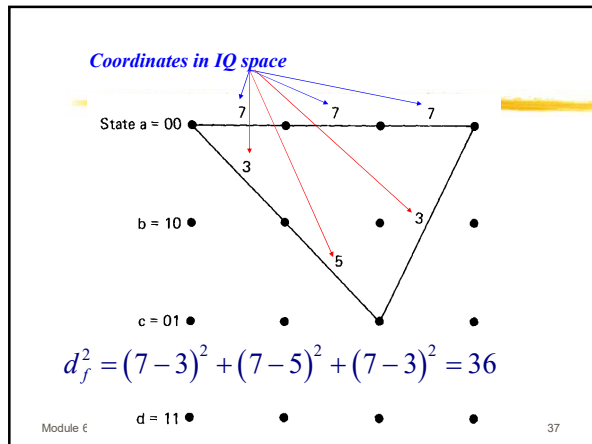
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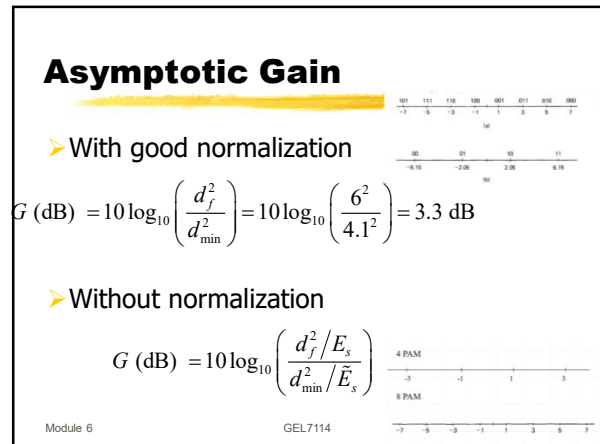
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TCM Gain

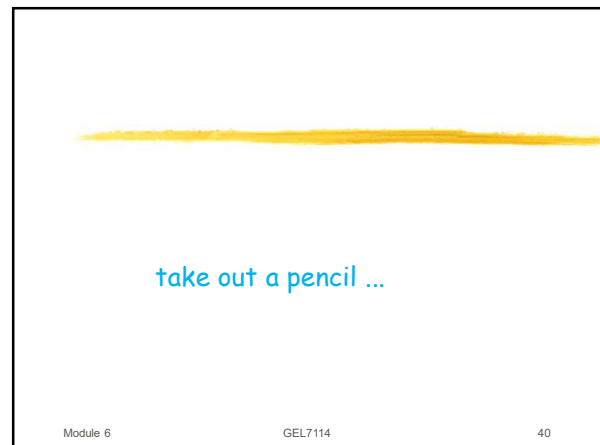
TABLE 7.5 Coding Gain Obtained for 8-ary PAM with Rate 2/3 Trellis Coding

Number of trellis states	Constraint length (K)	Average power gain (dB)
4	3	3.31
8	4	3.77
16	5	4.18
32	6	4.56
64	7	5.23
128	8	5.23
256	9	5.83

Source: G. C. Clark, Jr. and J. B. Cain, *Error Correction Coding for Digital Communications*, Plenum Press, New York, 1981, p. 388.

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Example

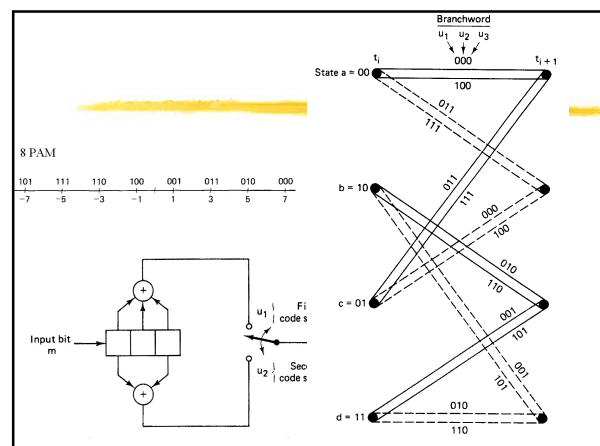
➤ Suppose the received signals (soft decisions) in a Gaussian channel are $(-5, 1, -7, 3)$. The transmitter uses 8PAM trellis coded modulation (TCM).

8 PAM

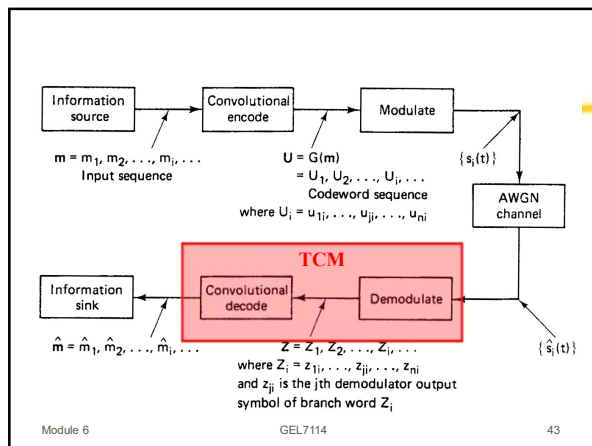
➤ Find the most probable path in the trellis diagram using **Euclidean distances**.

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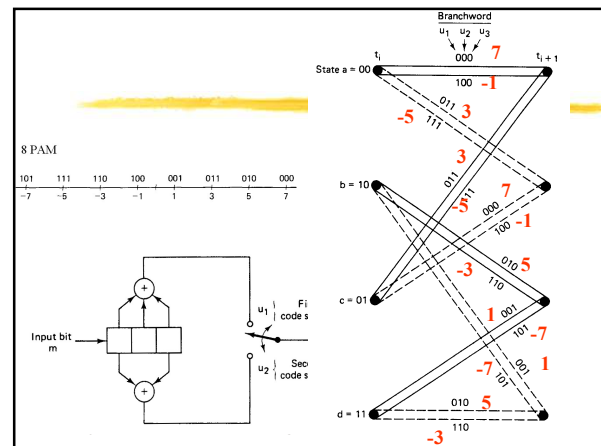
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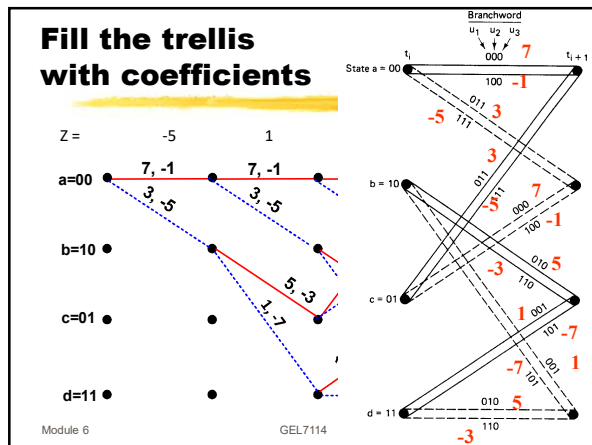
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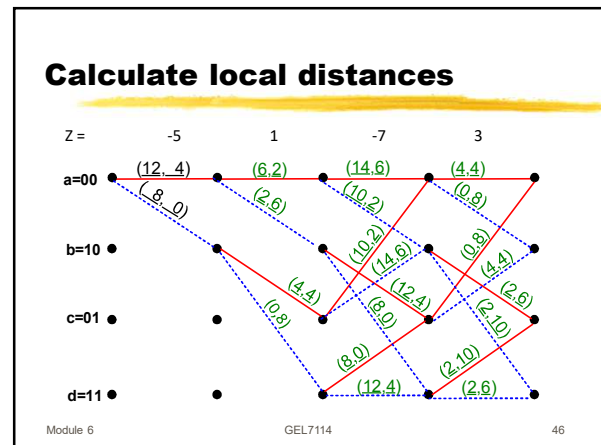
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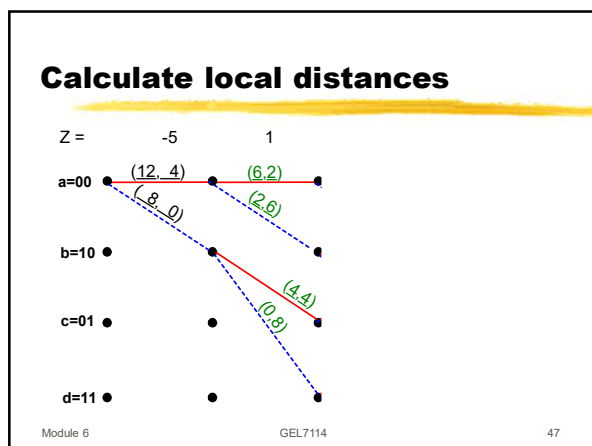
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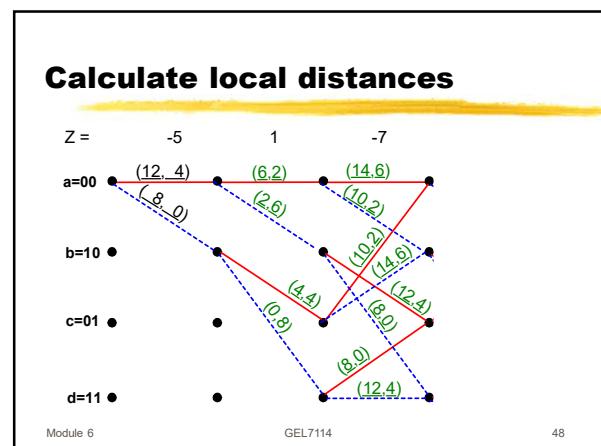
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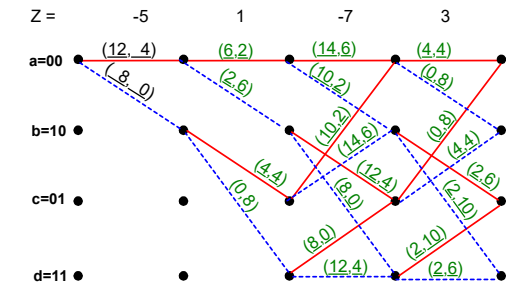


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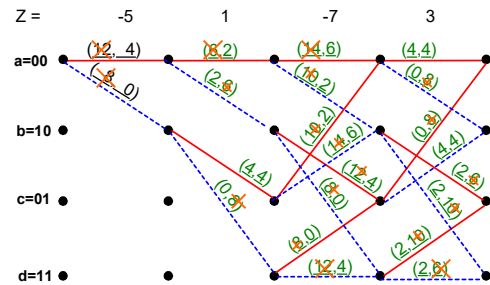
Calculate local distances



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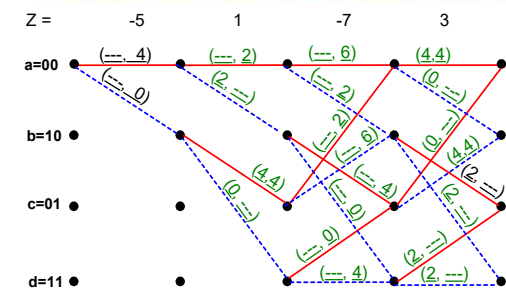
Calculate local distances



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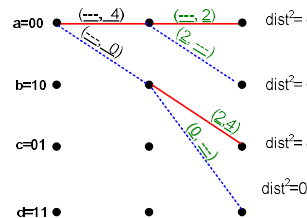
eliminate greater distances



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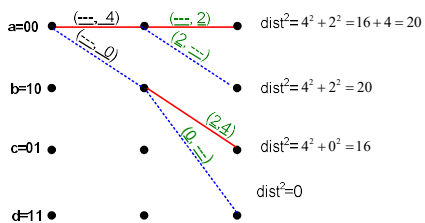
Calculate global distances



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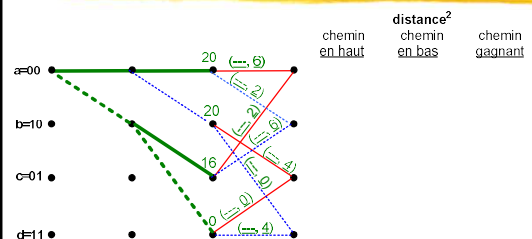
Calculate global distances



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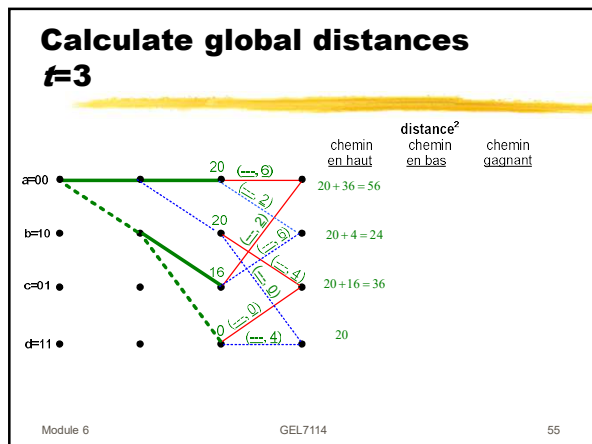
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Calculate global distances t=3

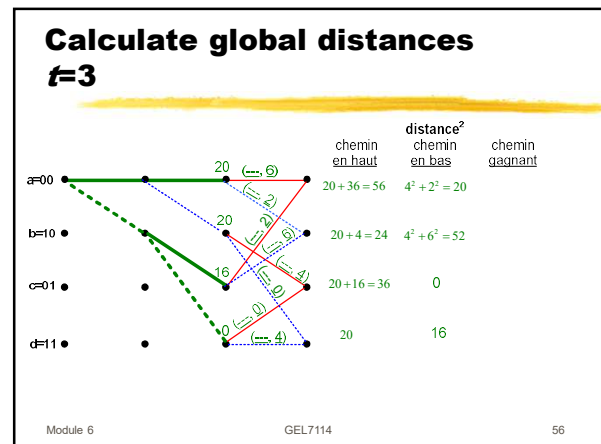


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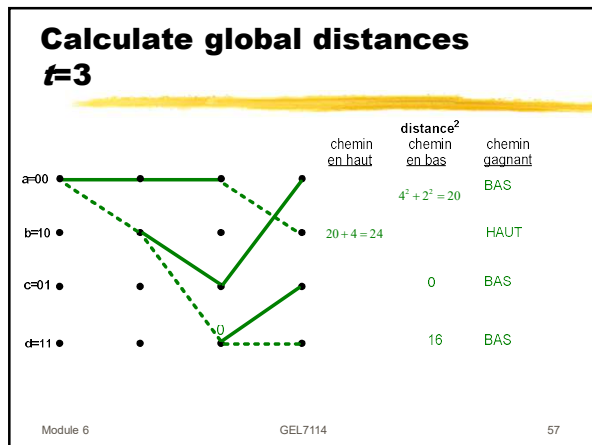
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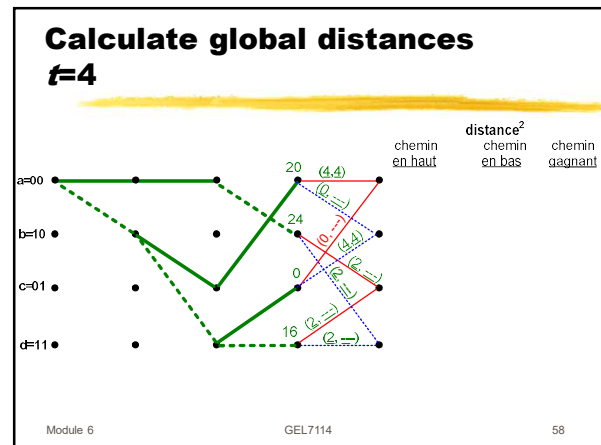
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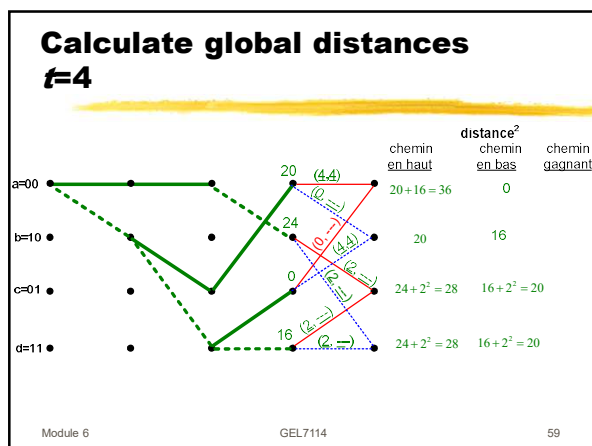
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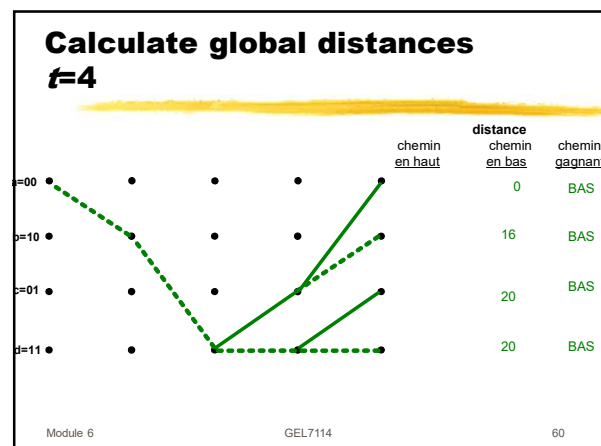
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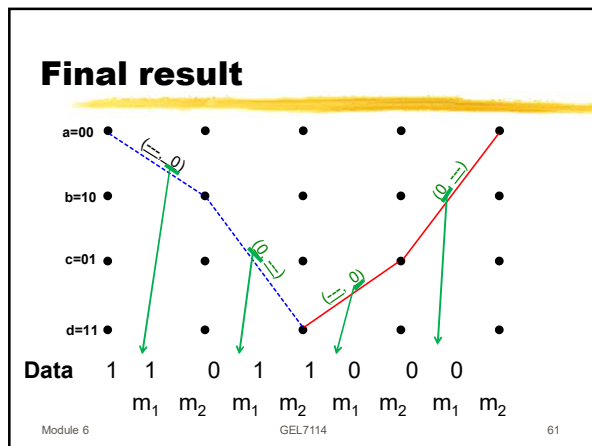
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